

# RELIABLE MAINTENANCE PLANNING, ESTIMATING, AND SCHEDULING



**RALPH W. PETERS** 





# RELIABLE MAINTENANCE PLANNING, ESTIMATING, AND SCHEDULING



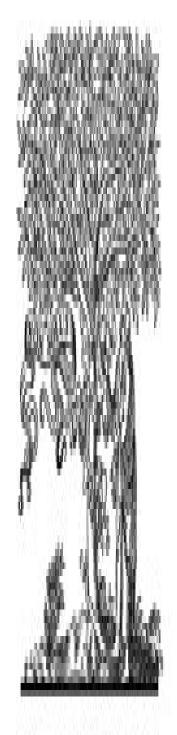
**RALPH W. PETERS** 



# Reliable Maintenance Planning, Estimating, and Scheduling

.

Ralph W. Peters



ELEVER

AMSTERDAM • BOSTON • HEDELBERG • LONDON

NEW YORK • OXFORD • PARIS • SAN DIEGO

SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Gulf Professional Publishing is an imprint of Elsevier

-
Table of Contents
-
Cover image
<u>Title page</u>
Copyright
About the Author
Introduction

1. Profit and Customer-Centered Benefits of Planning and Scheduling

Symptoms of Ineffective Planning

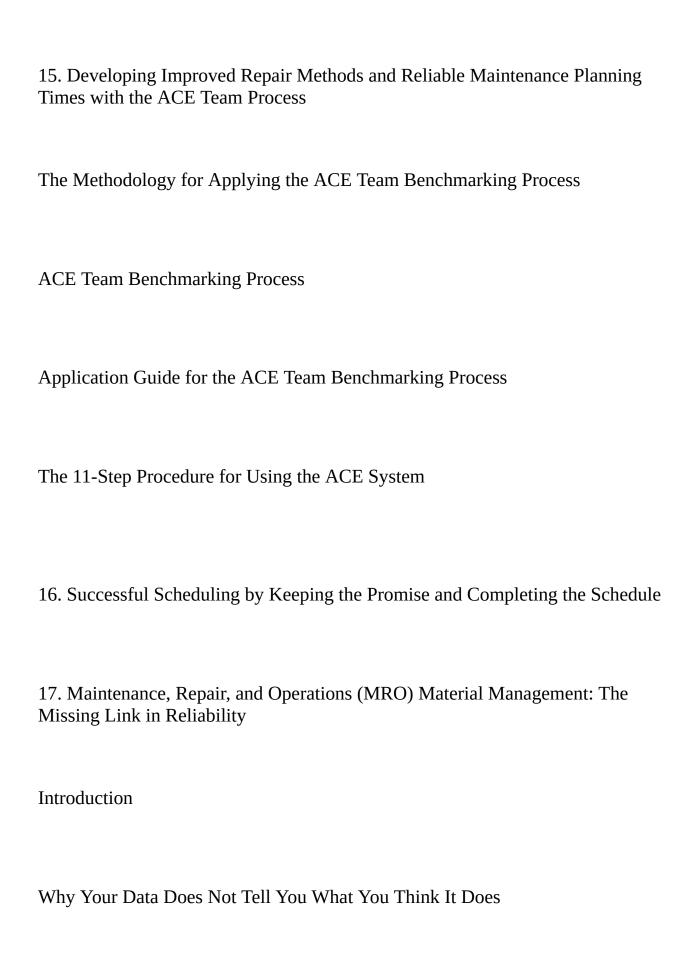
Benefits of Effective Planning
2. Defining Results to Top Leaders and Operations Leaders
Conclusion
3. Leadership: Creating Maintenance Leaders, Not Just Maintenance Managers
4. How to Create PRIDE in Maintenance within Craft Leaders and the Technical Workforce
PRIDE in Maintenance and Construction
5. Define Your Physical Asset Management Strategy with The Scoreboard for Maintenance Excellence and Go Beyond ISO 55000
Understanding the Types of Benchmarking

How Do You Get "There" If You Do Not Know Where There Is When You Start?
1. People Resources
2. Technical Skill Resources
3. Physical Assets and Equipment Resources
4. Information Resources
5. Parts and Material Resources
6. Hidden Resources—The Synergy of Team Efforts
Plant Operating Goals: Crescent-Xcelite Plant (A Division of Cooper Industries)
Pre Assessment Checklist for Baseline Information

Recommended Next Steps after the Scoreboard for Maintenance Excellence Assessment
6. Planners Must Understand Productivity and How Reliable Maintenance Planning, Estimating and Scheduling (RMPES) Enhances Total Operations Excellence
Overall Equipment Effectiveness
Craft Utilization
Craft Performance
Example C: What if We Increase Wrench Time from 30% to 50% and CP from 80% to 90%
Example C Details

7. What to Look for When Hiring a Reliable Planner/Scheduler
8. Planner Review of the Maintenance Business System—Your CMMS-EAM System
Conducting the CMMS Benchmark Evaluation?
Ranking Index of Maintenance Expenditures
9. Defining Maintenance Strategies for Critical Equipment With Reliability-Centered Maintenance (RCM)
10. Defining Total Maintenance Requirements and Backlog
11. Overview of a Reliable Planning-Estimating-Scheduling-Monitoring-Controlling Process
12. Why the Work Order Is a Prime Source for Reliability Information

13. Detailed Planning with a Reliable Scope of Work and a Complete Job Package
14. Understanding Risk-Based Maintenance by Using Risked-Based Planning with Risk-Based Inspections
Basic Overview
Evolution of Maintenance Strategies to Create Transition Between ReliaSoft
Introduction to the RBI Software from ReliaSoft Corporation
Case Study Example
Results
Category 22 on Risk Based Maintenance from The Scoreboard for Maintenance Excellence



How Proper Spares Storage Can Significantly Improve Your Reliability
The Real Function of Your Storeroom
Spare Parts Ownership Can Help Drive Reliability Outcomes
Establishing a Spares Maintenance Program
Conclusion
About the Authors
18. How to Measure Total Operations Success with the Reliable Maintenance Excellence Index
19. How This Book Can Apply to the Very Small Work Unit in Oil and Gas or to Any Type of Maintenance Operation

20. A Model for Success: Developing Your Next Steps for Sustainable and Reliable Maintenance Planning—Estimating and Scheduling
Planning
The Job Plan
Scheduling
Reasons why Maintenance and Planning Fail
Appendix A. The Scoreboard for Maintenance Excellence—Version 2015
Appendix B. Acronyms and Glossary of Maintenance, Maintenance Repair Operations Stores/Inventory, and Oil and Gas Terms
Appendix C. Maintenance Planner/Scheduler or Maintenance Coordinator: Position Description, Job Evaluation Form

Appendix D. Charter: Format for a Leadership Driven-Self-Managed Team at GRIDCo Ghana
Appendix E. Case Study–Process Mapping for a Refinery
Appendix F. The CMMS Benchmarking System
Appendix G. The ACE Team Benchmarking Process Team Charter Example
Appendix H. Shop Load Plan, Master Schedule and Shop Schedules: Example Forms and Steps on How to Use
Appendix L. Routine Planner Training Checklist
Index
Appendix I. Management of Change (MOC) Procedures Example

Appendix J. Risk Management

Appendix K. Measuring the True Value of Maintenance Activities

Appendix M. Planner Viewpoints on the Question; "Is it Required to Have a Trades Background to be a Planner?"

\_

# Copyright

-

Gulf Professional Publishing is an imprint of Elsevier

225 Wyman Street, Waltham, MA 02451, USA

The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK

Copyright © 2015 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangement with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

### **Notices**

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-0-12-397042-8

# **Library of Congress Cataloging-in-Publication Data**

A catalog record for this book is available from the Library of Congress

# **British Library Cataloguing in Publication Data**

A catalogue record for this book is available from the British Library

For information on all Gulf Professional Publishing visit our website at http://store.elsevier.com
Typeset by TNQ Books and Journals www.tnq.co.in
This book has been manufactured using Print On Demand technology.





# Working together to grow libraries in Book Aid developing countries International developing countries

www.elsevier.com • www.bookaid.org

-		

# **About the Author**



Ralph "Pete" Peters is a highly recognized author, trainer and leader around the world in the areas of implementing maintenance and manufacturing best practices, developing effective productivity measurement systems and initiating long-term sustainable operational improvement processes. He has also supported both the public and private sectors during his career. His value as a consultant has been enhanced through his direct leadership and profit and loss responsibilities within large maintenance and manufacturing plant operations prior to focusing upon consulting. He is the author of two major books; Maintenance Benchmarking and Best Practices from McGraw-Hill and now Reliable Maintenance Planning, Estimating and Scheduling from Elsevier. He has written a number of e-books and five major handbook chapters plus over 200 articles and publications. And as a frequent speaker, he has delivered speeches and TrueWorkShops<sup>TM</sup> on maintenance and manufacturing excellence related topics worldwide in over 40 countries to over 5000 people.

Worldwide Maintenance Consulting and Training Services: He founded The Maintenance Excellence Institute International in 2001 and has helped such diverse operations such as British Petroleum, EcoPetrol (Columbia), Marathon Oil, Total, SIDERAR Steel (Argentina), Atomic Energy Canada Ltd, Boeing Commercial Airplane Group, Caterpillar, Campbell Soup, UNC-Chapel Hill, Ford, Honda (America), Anderson Packaging Inc., Polaroid, Lucent Technologies, Heinz, General Foods, BigLots Stores, Sheetz Inc., Sanifi Pasteur, Great River Energy, Wyeth-Ayerst (US & IR), Cooper Industries, National Gypsum, Sarasota County Government-Operations and Maintenance Division, Carolinas Medical Center, NC Department of Transportation, NC Department of Health and Human Services, the US Department of Health and Human Health Services' Indian Healthcare Services, Air Combat Command and the US Army Corps of Engineers.

Education: He received both his BS Industrial Engineering and Masters of Industrial Engineering focused upon management information systems from

North Carolina State University. He is also a graduate of the US Army Command and General Staff Course, the Engineer Officers Advanced and Basic Courses, the Military Police Officers Course and the Civil Affairs Officer Course. He is certified as a Total Quality Management Facilitator for the National Guard Bureau and the North Carolina Army National Guard.

# Introduction

\_

Operations within the oil, gas, and petro chemical sectors provide the most operational, safety, and maintenance challenges available. Also planning, estimating, and scheduling in these areas must achieve a higher level of accuracy and reliability. Thus we have used the title Reliable Maintenance Planning, Estimating and Scheduling (RMPES) along with estimating. However, this book has universal applications for all type operations because if you can do it within oil, gas, and petro chemical sectors you can do it most anywhere. This book will be much different than most others you have used, read, or researched. Of course, it will cover material and ground that has been plowed and still being cultivated before by some great author/trainers like Joel Levitt and Don Nyman in their book; Maintenance Planning, Scheduling and Coordination and also other great books on planning and scheduling by Tim Kister and Bruce Hawkins, Doc Palmer, and Michael Brown.

Thanks especially to Ricky Smith and Jerry Wilson who have provided the case study, Alcoa-Mt. Holly from 1997 to 2012. I have used this as the closing Chapter 20—A Model for Success: Developing Your Next Steps for Sustainable and Reliable Maintenance Planning, Estimating, and Scheduling. Thanks to Phillip Slater and Art Posey for Chapter 17—MRO Material Management: The Missing Link in Reliability.

And last but not least, thanks to a real maintenance planner, Gary Royer, who came from a giant corporation and made many things work well as a "one man band" so to speak within a small undisciplined operation. He never gave up on improving, and has made excellent progress. His story is Chapter 19—How This Book Can Apply to the Very Small Work Unit in Oil and Gas or to Any Type of Maintenance Operation.

This book will be about reliable maintenance planning, estimating, and scheduling (RMPES) within organizations having very critical and complex equipment, extreme HSSE challenges, and located in environmentally sensitive locations in most cases. For today's oil, gas, and petrochemical operations it will cover the complete scope of planning, estimating, and scheduling of work in these critical continuous process operations. It will also include in detail an added focus a planner/scheduler can have on reliability and continuous reliability improvement (CRI).

Appendix A-The Scoreboard for Maintenance Excellence Version 2015 is a major body of work within this book. The Scoreboard for Maintenance Excellence provides an extensive and prescriptive self-assessment guide to 38 best practice areas with 600 evaluation items. It was updated from the previous version to include many areas specific to oil, gas and petro chemical operations. It also goes well beyond the descriptive and often vague terms of ISO 55000 requirements with prescriptive action items. It is available from The Maintenance Excellence Institute International in easy to use Excel format. Go to www.pride-in-maintenance.com for details to receive your own Excel copy.

Planners and schedulers (P/S) play a key role within good maintenance and reliability improvement processes. This book will further define how their roles can support CRI and how these positions when properly trained can become an important new dimension to their key position within in large and small operations.

I will refer to all leaders in this book; Top Leaders, Maintenance Leaders, and Craft Leaders. I will also refer infrequently to "managers of the status quo," which I have seen in many cases at all levels. Leaders at these three levels will all gain a better understanding of the professionals that perform RMPES. My underlying goal is that this book will expand the P/S role and the appreciation of this profession to another level of professional recognition.

During my career back in 1972 I was lucky enough to be on a team that interviewed, selected, personally trained, and implemented over 70 planners across the State of North Carolina for the NC Department of Transportation's Fleet Equipment Maintenance Management Division. Later I will share with you the true story of the outstanding career progressions by these mechanics that reluctantly left their tool boxes behind for a new role as planners/service managers within in a governmental agency, the NC Department of Transportation.

Our stated focus is on oil and natural gas operations and large petro chemical organizations with large complex equipment, continuous processing units, and integrated systems that present some of the greatest challenges to performing effective maintenance. Asset integrity management, process safety management, risk management, HSSE, and change management all add to a need for a fully integrated process for capital planning, day-to-day maintenance and shutdown/turnaround activities. This book will primarily cover day-to-day RMPES and how integration to shutdown, turnaround, and outage (STO) should occur.

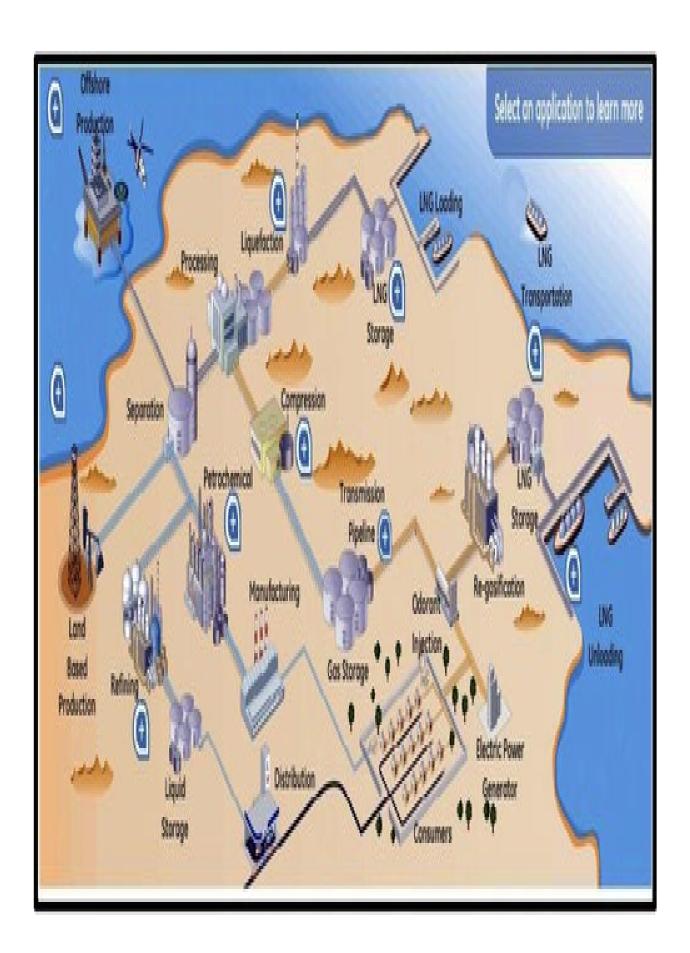
A profit-centered maintenance strategy requires effective and reliable maintenance planning, estimating, and scheduling (RMPES) and many other best practices. RMPES is considered by me and many others as one of the most important maintenance best practices because it is a very important enabler of profit, gained value customer service, craft labor productivity, and physical asset productivity. Effective and reliable maintenance planning, estimating, and scheduling enables:

- 1. craft labor productivity-Improved OCE (Overall Craft Effectiveness)
- 2. asset productivity-Improved OEE (Overall Equipment Effectiveness)
- 3. reliable and safe repair methods

- 4. reliable planned time for knowing your TMR (Total Maintenance Requirements)
- 5. increased operations labor productivity
- 6. validated direct savings and gained value that contributes directly to the bottom line.

We will first of all define the benefits of successful RMPES to three key groups:

- 1. Top leaders: C-positions, especially the chief financial officer, VP-operations, managing directors, and also engineering and maintenance managers
- 2. Maintenance leaders: Maintenance managers, supervisors, foremen, maintenance engineers and reliability engineers



### Figure I.1 Surface facilities operations. Courtesy of General Electric.

3. Craft leaders: Subject matter experts, crew leaders, and other technician specialists. I like to think of a craft leader in sports term; "It's your Go to Guy when a real problem occurs."

We will define for each of these three groups the foundation on why RMPES is important. From the 500 plus plant visits and assessments, I have personally performed, less that 20% really applied RMPES effectively. Many had planners physically in the wrong place doing ineffective RMPES for the customer. That leaves 80% in both large and small operations that need help. From that real-life sample of shop level personal experience there were some obvious needs.

- a. A clear and comprehensive maintenance strategy was not defined by the maintenance leader up to their top leaders and down to craft leaders
- b. Maintenance leaders did not know "where they were in terms of best practices" and therefore did not have a clear path forward that could achieve validated and measured benefits from their existing RMPES
- c. Top leaders did not truly understand maintenance and certainly had no idea of their "total maintenance requirements."
- d. Top leaders and maintenance leaders set lower performance goals for total backlog, when in fact "total maintenance requirements" often exceeded current craft capacity.
- e. Craft leaders and craft technician were still operating in a reactive, fire fighting mode and did not really have effective planning/scheduling or did not clearly see the true benefits when planning/scheduling was in place. Figure I.1 illustrates the scope of surface facility operations within the oil, gas, and petro chemical sectors.

Our goal is that this book will benefit both large oil and gas operations as well as smaller discrete manufacturing operations. Ninety percent of this book will apply to all type operations, because the best practice for RMPES basic processes apply to every operation. Again, leaders at all three levels will gain a better understanding of the professionals that perform RMPES. My underlying goal is that this book will expand the P/S role as it is related to maintenance and reliability excellence and will increase the appreciation of this profession to an even higher level of professional recognition in the future.

1

# **Profit and Customer-Centered Benefits of Planning and Scheduling**

\_

### **Abstract**

This chapter sounds the alarm for top leaders to understand the importance of maintenance as key to total operations success. If your current maintenance strategy, leadership philosophies, and planning and scheduling processes do not allow you to manage maintenance like a profitable internal business, you could be in trouble or heading toward serious trouble. Top leaders that still view maintenance as a "traditional cost center" and then continuously "squeeze blood from the maintenance turnip" are on the road to major problems with physical asset management. This chapter summarizes that investments in reliable maintenance planning, estimating, and scheduling along with other best practices can have many measurable benefits.

# **Keywords**

Chief maintenance officer, CMO; Contract maintenance; Cost center; Customer-centered; Maintenance; Maintenance leader; Maintenance manager; P–F interval; Physical asset management; Planner/scheduler; Profit ability; Profit optimization;

# **Profit-centered; Value-adding investments**

Effective and reliable maintenance planning and scheduling that we will discuss later is an essential element for physical asset management operation. But does your view of maintenance and physical asset management process see it as a profitable in-house business within your organization? Would your current maintenance operation sustain itself as a contract maintenance organization and make a profit? These might seem to be two strange questions. But, if your current maintenance strategy, leadership philosophy, and planning and scheduling processes do not allow you to manage maintenance like a profitable internal business, you could be in trouble or heading toward serious trouble.

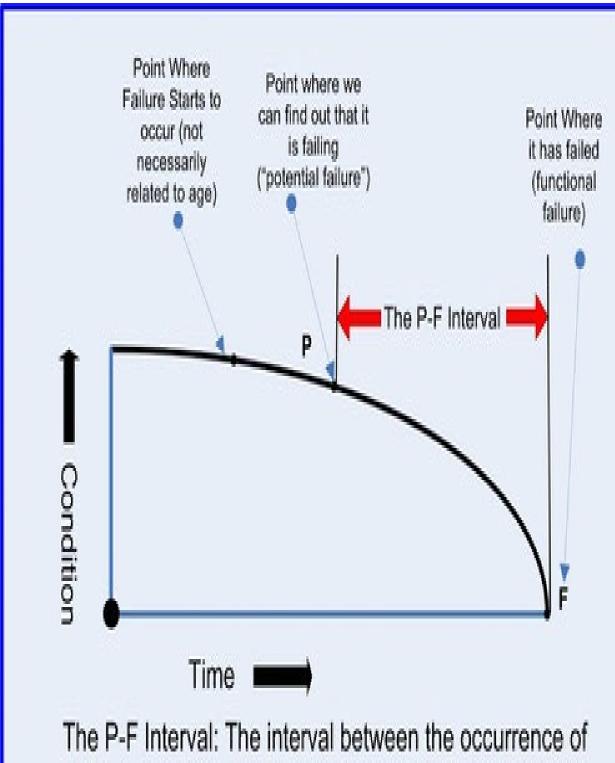
Top leaders that still view maintenance as a "traditional cost center" and then continuously "squeeze blood from the maintenance turnip" are on the road to major problems with physical asset management. This attitude has resulted in catastrophic failures within airlines, refineries, ships at sea, and many other operations. Maintenance requirements are everywhere and the need for effective maintenance is continuous because... Maintenance is forever! Maintenance of our body, soul, mind, spirit, house, car, physical assets, and infrastructures all around us will be with us forever.

Are top leaders gambling with maintenance? There can be a very high cost of gambling with maintenance, and most operations lose when they gamble with their maintenance chips. There is an extremely high cost to bad maintenance within oil and gas operations, on the plant shop floor, in combat, and everywhere the maintenance process fails in the proper care of physical assets. Look at Figure 1.1 below to gain an understanding of the P–F interval. What chances are you willing to take when you know that a failure is occurring"?

Point P above is like the saying, "You can't be a little bit pregnant." Point P can be confirmed by numerous possible means, but the P–F Interval is basically the unknown time between seeing a certain failure start and at what time the failure actually occurs. If you have not invested wisely in predictive maintenance or continuous monitoring, you may be at the point where you can manage and lead forward as a profitable internal business.

You may also be a potential takeover target for contract maintenance. Many operations have lost heavily by gambling with indiscriminate cuts to a core

requirement: the resources necessary for effective physical asset management and maintenance. Quantum leaps backward will occur for the top leader that fails to view maintenance as a core business requirement. I feel strongly that indiscriminate downsizing and "dumb sizing" of maintenance is finally being recognized as a failed business practice. Where are your maintenance chips being stacked? Do not view maintenance as a cost center and not worthy of effective planning and scheduling. View it with a profit and customer-centered mentality and with an attitude that promotes initiative, customer service, profit optimization, and ownership. Invest in reliable maintenance planning, estimating, and scheduling, and the other best practices we will discuss later to ensure success.



a potential failure and its decay into a functional failure

#### Figure 1.1 The P–F interval.

Profit and customer-centered contract maintenance. You might say that profit and customer-centered maintenance is not possible for an in-house maintenance operation. But a profit-centered strategy does exist in the thousands of successful businesses that provide contract maintenance services everywhere we look, especially within many oil and gas operations. Maybe we invest our maintenance chips (or even real U.S. dollars) heavily in profit-centered contract maintenance providers who are truly in the maintenance for profit as business to truly serve their customers. They will expand even further if organizations continue to give up on in-house maintenance operations.

Third-party maintenance will continue to be a common practice in organizations that have continually gambled with maintenance costs and have lost. For some of the maintenance operations that I have seen as a result of hundreds of maintenance benchmarking assessments, the best answer for survival is a partnership with a contract maintenance provider. It is often a hard choice, especially when it is tempered with all the relentless pressure from unions. For some operations, quality service from qualified maintenance service providers is unfortunately the best choice available. However, we should not give up on inhouse maintenance when contract maintenance could be just as bad if they operate within our current organization without effective planning and scheduling.

This is not a scare tactic that advocates third-party maintenance in total for an organization. It positively and unequivocally does not support the dumb-sizing of in-house maintenance to provide lean maintenance, which in turn fails to meet the total maintenance requirement needs. Dumb-sizing of maintenance and reengineering without true engineering has failed. Third-party maintenance in specialty areas or areas where current maintenance skills or competencies are lacking will be needed and be a growing practice. It provides real profit to the maintenance provider and savings to the customer.

Greater third-party maintenance of all types is occurring around the world, especially in the Middle East, and will continue to occur in United States'

operations where maintenance is not treated as an internal business opportunity. It will obviously occur where the maintenance operations have deteriorated to the point that a third-party service is more effective and less costly than in-house maintenance staff.

Where is your chief maintenance officer? We now have more "C-positions" than we know the terms for: CEO (Chief Executive Officer), COO (Chief Operating Officer), CFO (Chief Financial Officer), CIO (Chief Information Officer), CPO (Chief Purchasing Officer). An important position that is missing is the chief maintenance officer (CMO). The evolution of the CMO position must occur to provide leadership to physical asset management within large manufacturing operations. I sincerely believe that the real maintenance leaders will begin to emerge as CMOs in the business world. This new staff addition of a CMO is desperately needed, and smart organizations will have someone near the top that is officially designated to ensure that physical assets are properly cared for. I believe that the CMO will join the ranks of the CEO, COO, CFO, and CIO in large multisite manufacturing operations to manage physical assets. This can be a real technical asset for large oil companies, for example, using the same business system and associated computerized maintenance management system such as SAP. These CMOs will manage and most importantly lead maintenance forward as a "profit center." A good CMO with "profit ability" will be in place to lead maintenance forward to profitability. A good CMO will help the CFO take the "right" fork in road as it relates to physical asset management and profitability providing consistent application of let's say SAP. Regardless of the size of the operation, every manufacturing operation needs a CMO. For smaller operations, it might be a CMO equivalent, a true maintenance leader or a maintenance leader supervisor that can really manage maintenance as a business and as an internal profit center.

Profit ability. Leadership ability is an important personal attribute, but being in the "maintenance-for-profit business" also requires an important new type of ability that we call "profit ability." To lead maintenance forward, we must learn from the leaders within the third-party maintenance business. There are many good ones out there, but one that I personally know about is a company in Oman that manages their pipeline maintenance like they own the contractor. Of course not literally, but this was a great example of true "profit ability" on both sides. This attendee who was responsible for all of Oman's pipeline maintenance was at my

"Maximizing the Value of Contracted Services" course in Dubai. He could have taught the course. One of the key things that stood out was that the contractor was required to employ a planner/scheduler that worked closely with the pipeline company planner/scheduler. Direct measurement of contractor work, schedule compliance, plus other key metrics were at the heart of their profit-centered relationship.

Having a good CMO adds the missing link to achieving total operations success and profit = optimization. Maintenance has rapidly evolved into an internal business opportunity and can almost now stated financially correct as a true "profit center." The change from a "run-to-failure" strategy into a proactive, planned process for asset management requires a CMO with demonstrated technical and personal leadership. Plan on becoming the CMO in your operation regardless of your organization's size or current level in your organization. Ensure that an effective planning and scheduling process is in place.

No matter how bad something is, it can always be used as an illustrative bad example. We all learn lessons either the hard way or the easy way. Therefore, bad examples are not wasted. I think we can learn important good lessons about maintenance the easy way by having an effective CMO. I think that a new breed of corporate officer will evolve. An effective CMO will be a firm requirement for organizational success. CMOs will take their place near the top with the CEO, COO, CFO, CIO, and the corporate quality gurus. I think we will start to listen closely to the maintenance messenger, our CMOs. We will not and should not shoot the maintenance messenger. Many have been seriously wounded when they have tried to state the "true state of maintenance" within an organization. Manufacturing plant managers, CFOs, COOs, and VPs of manufacturing operations who do not understand the true value of maintenance will continue to be the bad examples. The CMOs of successful organizations will have an important and unprecedented role in the success of their total operation.

The successful manufacturing company, whether discrete or continuous processing, will have true maintenance leaders, not managers of the status quo. The true maintenance leaders and CMOs of these successful companies will know the contribution to profit that their maintenance operations provide. They will view maintenance improvements and practices such as planning estimating and scheduling as value-adding investments that provide a measurable return on

investment. The return on investment for RMPES plus supporting practices such as effective preventive and predictive maintenance with good parts inventory and procurement can be unbelievable. CMOs will measure the results of the maintenance process whether it is internal or outsourced maintenance. They will validate the investments they have made just as they try to validate other return on investments. The CMO will be the maintenance messenger!

The true CMO will also be the maintenance leader that understands how to operate the total maintenance process as an internal business within a business. They will be able to turn in-house maintenance into a profit center comparable to contract service providers. All true corporate top leaders must strive to understand current and future trends, take action, and proactively plan for the maintenance strategy within their total operation.

There must be a maintenance champion to manage all of a company's physical assets. The real maintenance leader readily accepts the role as champion for maintenance excellence. Likewise, integrity of purpose and the integrity of the maintenance champions must set an example for others in the organization to follow. Ralph Waldo Emerson said it very well when he remarked, "What you are thunder so loudly, I cannot hear a word you say to the contrary." Leadership by example and "walking your talk" is essential for the maintenance champion and all company leaders.

The maintenance champion as CMO understands and can communicate the true cost of deferred maintenance as well as the cost of inadequate preventive/predictive maintenance. The CMO is prepared to provide proactive leadership and support to the company's compliance to regulatory issues. The real CMO must be prepared to take bad news about the true "state of maintenance" to company leaders with courage, confidence, and most importantly with credibility. The maintenance messenger does not always bring good news to top leaders and must possess the skills and traits to be candid, honest, and credible, backed up with facts.

The effective CMO utilizes a true teaming process to bring maintenance, operations, and operators together to detect, solve, and prevent maintenance problems. This book also will show how a planner/scheduler can be another key resource for improving reliability. The effective CMO will take the lead for implementing best practices such as an effective CMMS. They will work closely with information services staff and CMMS vendors over the long term to make it

work to enhance the business of maintenance.

The CMO and pride in ownership. The true CMO also encourages pride in ownership with equipment operators and maintenance as they do their part to fix and prevent maintenance problems through a cooperative team effort of operation-based maintenance. The CMO has the integrity and inspires individual integrity to the point that all employees do their jobs as if they too owned the company. Individual integrity includes pride in one's work no matter what the task. An effective CMO can help your operation go beyond the bottom line to ensure long-term total operations success of the company and the maintenance process.

Take action on this question. As a maintenance leader, you must act on this key question: "If I owned my maintenance operation, what would I do differently to make a profit?" Another question could be, "How high is your return on maintenance management?" If you begin to think like the chief maintenance officer, you will get others to think this way too. Planner/schedulers are maintenance leaders too...so you should also think this way because you will make so much it actually happens! You will get more people thinking "profit and customer centered." As each crafts person feels they own part of the business, you will experience a groundswell of profit ability. One key part of this answer will be to get maximum value received from your information technology tools, your CMMS, which for 95% of every Scoreboard benchmark assessment I have done over the past 40 years needed some type of improvement to gain maximum value.

Effective in-house maintenance plus high quality maintenance contractors. Profit and customer-centered in-house maintenance in combination with the wise use of high quality contract maintenance services will be the key to the final evolution that occurs. There will be a revolution within organizations that do not fully recognize maintenance as a core business requirement and establish core competencies for it. The bill will come due for those operations that have subscribed to the "pay-me-later syndrome" for deferred maintenance. There will also be a revolution within those operations that have gambled with maintenance and have lost, with no time left before profit and customer-centered contract maintenance provides the best financial option for a real solution. Whereby maintenance was once considered to be a necessary evil, it is now being viewed as a key contributor to profit in a manufacturing or service-providing operation. My goal is for

this book to build your case clearly within your organization for reliable planning, estimating, and scheduling.

Where is the profit in maintenance, really? You might ask yourself after reading this far, "Where is the profit in maintenance really for an in-house operation trying to keep its head above water?" Later we will cover areas where planning and scheduling provides other profit and productivity improvement opportunities. For example, what if the net profit ratio of an operation is 4%? What does a 4% net profit ratio mean in terms of the amount of equivalent sales needed to generate profits? A net profit ratio of 4% requires \$25 of equivalent sales for each \$1 of net profit generated.

Therefore, when we view maintenance in these terms, we can readily see that a small savings in maintenance can mean a great deal to the bottom line and equivalent pure sales revenue as shown in Figure 1.2. Maintenance as a profit center is illustrated below showing that only a \$40,000 savings is required to translate into the equivalent of \$1,000,000 in sales revenue. As we will discuss in later chapters, there are many more areas such as the value of increased asset uptime, increased net capacity, and just-in-time throughput, increased product quality, and increased customer service that all contribute to the bottom line and subsequently to profit.

Maintenance as a Profit Center	
Maintenance Savings that Impact Net Profit	Equivalent Sales Required for Generating Net Profit
\$1	\$25
\$1,000	\$25,000
\$10,000	\$250,000
\$20,000	\$500,000
\$30,000	\$750,000
\$40,000	\$1,000,000
\$80,000	\$2,000,000
\$120,000	\$3,000,000
\$200,000	\$5,000,000

#### Figure 1.2 Maintenance as a profit center.

Investments in reliable maintenance, estimating and scheduling and other best practices can achieve results comparable to the following:

- 15–25% increase in critical capacity constraining equipment uptime
- 20–30% increase in maintenance productivity of the craft workforce
- 25–30% increase in planned maintenance work
- 10–25% reduction in emergency repairs
- 20–30% reduction in excess and obsolete inventory
- 10–20% reduction in maintenance repair costs

Other improvements can include:

- Improved product quality
- Improved utilization of equipment operators
- Improved equipment productivity (OEE (Overall Equipment Effectiveness)) and production throughput capacity
- Improved equipment life lower life cycle cost
- Improved productivity of the total operation and pure profit

The results listed above can be achieved by maintenance organizations who have committed to continuous maintenance improvement or other terms such as maintenance benchmarking and best practices implementation. Your organization must realize that there are no easy answers and no "quick fixes." Organizations that have invested in maintenance over the long term have realized a tangible return on that investment.

Consider what would happen if your numbers were used in the following very

basic examples:

• Maintenance craft productivity increase of 20%

20% net improvement in craft productivity (craft utilization, craft performance, and craft service quality) would be 20 × 40 craftsmen × \$35,000/year = \$280,000/year.

• Increased equipment uptime of 25%

25% downtime reduced from 8% to 6%—value of increased uptime would  $0.25 \times baseline \$800,000$  value of downtime = \$200,000/year.

• Inventory reduction in maintenance storeroom of 25%

25% reduction from \$1,000,000 to \$800,000 would be \$200,000 × 0.30 inventory carrying costs = \$60,000/year.

• Improved pricing from suppliers of 1%

1% direct price savings (not high cost of low bid buying) would be  $0.01 \times 1,000,000$  purchase volume/year = 10,000/year.

• Reduction in net maintenance repair costs of 10%

10% would be 0.10 × \$750,000 annual repair cost = \$75,000/year if all required maintenance requirements were being met.

• Improved product quality of 1%

1% reduction through equipment-related scrap, rework returns, waste, and better yields would be  $0.01 \times \$2,000,000$  value of production standard cost = \$20,000/year.

• Improved equipment life of one-half year

1/2 year longer productive asset life would be 0.5 year  $\times$  \$10 million capital investment  $\times$  0.10 expected capital ROI = \$500,000 minus additional \$200,000 additional maintenance cost = \$300,000/year.

These examples all contribute to the bottom line either directly or indirectly.

They illustrate briefly that tangible ROI can be significant, depending on the size of the maintenance operation and the type of organization being supported. Maintenance leaders must be able to gain support for continuous maintenance improvement by developing valid economic justifications. Take the time to evaluate the potential savings and benefits that are possible within your own organization. Gain valuable support and develop a partnership for profit with operations. Include all other key departments that will receive benefits from improved maintenance. The application of today's best maintenance practices will provide the opportunity for maintenance to contribute directly to the bottom line. However, the pursuit of maintenance excellence requires leadership.

Core requirement versus core competencies for maintenance. The core requirement for good maintenance never goes away because "maintenance is forever"! There will always be a need to maintain. Maintenance of our physical bodies, minds, souls, cars, computers, and all physical assets providing products or services will always be required. Maintenance, gravity, extinction, and change are truly forever. Yet some organizations today have neglected maintaining their core competencies in maintenance to the point that they have lost complete control. The core requirement for good maintenance will always remain (forever) but the core competency to do good maintenance can be missing. In some cases, we know that the best and often only solution is value-added outsourcing. Maintenance is a core requirement for profitable survival and total operations success. If the internal core competency for maintenance is not present, it must be regained with internal leadership of top leaders and maintenance leaders. Neglect of the past can either be overcome internally or externally. The core requirement for maintenance can be reduced, but it can never go away.

## **Symptoms of Ineffective Planning**

Top leaders must know the true state of maintenance in their organization and understand the symptoms of ineffective planning, which one of today's most important best practices. Lack of effective planning will include the following:

- 1. Delays encountered by our most valuable resources, the craft workforce
- a. Gaining information about the job
- b. Obtaining permits
- c. Identifying and obtaining parts and materials
- d. Identifying blueprints, tools, and skills needed
- e. Getting all of above to the job site
- f. Waiting for required parts not in stock
- 2. Crafts waiting at job site for supervisor or operations to clarify work to be done
- 3. Delays or drop in productivity when operations request work without sufficient planning
- 4. Equipment is not ready, even if on a schedule
- 5. Number of crafts does not match scope of work
- 6. Coordination of support crafts; not the right skill, come too late or early and stand around watching
- 7. Crafts have no prior knowledge of job tasks or parts
- 8. Crafts leave job site for parts, go to storeroom, or wait for delivery

- 9. If parts to be ordered, job is left disassembled and crafts go to next job
- 10. Many jobs in process awaiting parts
- 11. Crafts cannot develop work rhythms due to start/stops and going from crisis to crisis
- 12. Supervisors become dispatcher for emergencies

## **Benefits of Effective Planning**

With effective planning and scheduling, top leaders can begin to see the benefits, which include:

- 1. Provides central source of equipment condition, workload, and resources available to perform it
- 2. Improves employee safety and regulatory compliance
- 3. Helps achieve optimal level of maintenance in support of long- and short-term operational needs
- 4. Challenges work request of questionable value
- 5. Provides forecast of labor and material needs
- 6. Permits recognition of labor shortages and allows for leveling of peak workloads
- 7. Establishes expectations for what is to be accomplished each week, and variations from the schedule are visible
- 8. Improves productivity by anticipating needs and avoiding delays
- 9. Increases productivity of both operations and maintenance
- 10. Provides factual data: performance measurements, cost variations
- 11. Provides info to identify problems that need focused attention
- 12. Reduces the total cost of maintenance while improving customer service
- 13. Increases useful life of physical assets
- 14. Improves preparation, management, and control of minor and major projects

- a. Outages
- b. Turnarounds
- c. Renovations

Later we will discuss The Scoreboard for Maintenance Excellence, which can define the overall state of maintenance and give top leaders a road map for their overall maintenance strategy with reliable planning, estimating, and scheduling as one major cornerstone to success.

What happens when you get scared half to death.

-

2

# **Defining Results to Top Leaders and Operations Leaders**

\_

#### **Abstract**

This chapter strives to ensure that maintenance leaders provide top leaders accurate results so they will realize the potential increases in profits from the best practice of reliable maintenance planning, estimating, and scheduling. We can be very efficient at firefighting and performing reactive maintenance repair but not be truly productive. To break this cycle we must develop a new, disciplined approach to identifying, prioritizing, and completing properly planned maintenance work. The total operation must understand that an effective maintenance planning and scheduling program will produce greater productivity of the craft workforce by increasing uptime, minimizing costs, and increasing overall production throughput and capacity.

### **Keywords**

ACE Team Process; Cost center; Efficiency; Estimating; Maintenance; Maintenance leader; Physical asset management; Planner/scheduler; Planning; Productivity; Profit ability; Scheduling; Top leader; Total maintenance requirements; Total

### operations success

"Show me the money!" The true goals in business are results in the form of profits, along with total operation success and sustainability in the marketplace. In turn, top leaders and operations leaders must see clearly defined results. A reliable maintenance planning, estimating, and scheduling process allows the maintenance business to perform as a profit center. First, consider the Harvard Business Review's (HBR) definition of asset management, which is all about managing money. So, what about their discussions of physical asset management? There are basically no articles on physical asset management, even though physical assets provide the means to make money and profits to share dividends with stakeholders. To me, that is a definite case for improving physical asset management. However, when one searches for "physical asset management" within HBR articles, contributed by hundreds of management gurus, the results contain only articles on asset management as related to money management. That is incredibly unbelievable to me.

However, things are changing. Remember that change and gravity are constant. New circumstances now require maximum uptime, throughput, and quality. With many low-cost producers competing around the world, the previously dominant and status quo organizations are fighting for survival. During these challenging and economically difficult times, all operations are looking for improvement opportunities.

Top leaders must recognize that an important area for improvement is the maintaining of facilities and other physical assets. In the past, the maintenance department may have been viewed as a "necessary evil"—costly "wrench turners," often viewed unjustly as those who sat in the shop and waited for equipment to fail. That outlook is now history for smart companies that are finding ways to detect and prevent catastrophic failures before they occur. Predictive maintenance technologies such as vibration analysis, infrared imaging, acoustic testing, and preventive maintenance help companies to maximize profits by minimizing downtime. For example, the information from the P–F interval, as illustrated in Chapter 1, can be analyzed when deciding whether to shut down a piece of equipment for planned maintenance. Planned maintenance is up to three times more productive than purely reactive, "firefighting" maintenance strategies.

We must show top leaders accurate results so that they will realize the potential

increases in profits resulting from the best practice of reliable maintenance planning, estimating, and scheduling. This is especially necessary in large and small oil and gas surface maintenance facilities. In addition to identifying potential failures, we must also focus our resources on correcting potential problems before a catastrophic failure occurs. With decreasing work forces and increasing responsibilities, this can easily become a second priority. However, as less work is completed, more failures occur and our time is spent repairing failures, not on preventing failures from happening.

It is very important to understand the differences between productivity and efficiency. We can be very efficient at firefighting and performing reactive maintenance repair, but are we truly being productive? In other words, like the government at times, we can be very efficient at doing the wrong things. Later, in Chapter 6, we will discuss productivity in greater detail, reviewing plant labor productivity (standard labor variances), physical asset productivity, and craft labor productivity, which The Maintenance Excellence Institute International (TMEII) has coined as overall craft effectiveness (OCE). The way to break this cycle is to approach maintenance planning, estimating, and scheduling as a part of a new external profit center. To do this, we must develop a new, disciplined approach to identifying, prioritizing, and completing properly planned maintenance work. The total operation must understand that an effective maintenance planning and scheduling program will result in greater productivity of the craft workforce by increasing uptime, minimizing costs, and increasing overall production throughput and capacity. Survival is a keyword, and this best equates to the highest possible profit margins for all for-profit operations.

Here again, the increased productivity of people and physical assets is a direct result of planning and scheduling. It is basically a disciplined approach for utilizing existing maintenance resources to increase craft productivity and asset productivity by increasing uptime and minimizing the overall production costs. This is accomplished in many ways, such as the following:

- Prioritization of work
- Developing the physical steps to complete the job
- Procuring the necessary tools and materials
- Scheduling the work to be done

- Completing the work with reasonable performance levels
- Identifying any additional work to be completed on the equipment
- Filing written documentation for equipment history

From my past experience as a plant manager of two large manufacturing plants, I see the primary and true goal as being "total operations success." Maintenance must be very customer centered, with operations and production being the internal customers. When we view maintenance as an internal business, the strategy and philosophy become more apparent to all. For top leaders, maintenance leaders, and craft leaders, what are the underlying results from maintenance and reliability excellence? Your obvious answer might be to improve the long-term viability of your facility due to the reduced costs associated with maintenance and equipment downtime. That translates into total operations success. But for some craftspeople and technicians in the trenches, that can often mean very little. Later chapters address how change can be viewed in a more positive light. Nonetheless, how many times have you been called out in the middle of the night to deal with an equipment failure? Or had a vacation cancelled due to issues with critical equipment? Or had a technician cover work when he or she had an important event to attend? Better planning and scheduling practices will reduce the frequency of these catastrophic failures. Later in this book, I will explore the philosophy of pride in maintenance for maintenance technicians and pride in ownership for operators.

One can very easily sit back and play the victim by claiming there are too few staff members to keep the area running or complete the total backlog of work. You can manage the status quo for just so long, then you must decide to lead. If you do not lead and have a disciplined system in place, then you do not know how many people it truly takes to maintain your equipment. Planners are there to help you determine one very important number: the total maintenance requirements or your total backlog of work, which includes completing 100% of your preventative maintenance (PM) tasks, deferred maintenance, and maybe minor projects. With reliable information from the planner, the maintenance leader can then take facts to the top leaders. Reliable estimating methods add greatly to the accuracy of your backlog photos. All of this may or may not lead to more staffing, but facts on total maintenance requirements can support the various best practices necessary to improve the productivity of existing resources; people assets, and physical assets.

During my 40+ years in manufacturing and maintenance, I have seen in detail more than 400 different types of plants. Many were in the oil-gas-petrochemical sector or were discrete manufacturing facilities, including pharmaceuticals, universities, hospitals, and fleet operations. One was Boeing Commercial Airplanes, which at that time was improving its maintenance processes significantly during the 1990's. Their approach then was to have what they called "the plan of the day." It was a relatively simple system that worked. They were also moving rapidly into predictive maintenance and condition monitoring —an important first step in establishing an effective planning and scheduling program.

First, we must identify the current planning and scheduling practices. From my experience in performing on-site scoreboards for maintenance excellence audits, I have seen very few sites with true world-class planning, estimating, and scheduling. Improving your process requires getting out in the operating areas and speaking with supervisors, planners, and maintenance and hourly employees. Process mapping of work initiation through work completion and work order closeout are excellent tools to visually see the entire current process. From this graphical representation, you can quickly see areas for improvement, especially by applying key principles from this book.

It is very likely that you will run into a lot of frustrations around what is currently in place. In this case, a third-party audit can be extremely beneficial and cost-effective. Just like a third-party maintenance consultant, you will get an opportunity to hear a multitude of excuses for why it cannot work. You must keep digging for information to help build a successful system. Here is a very important recommendation for newly hired maintenance leader: have a third-party conduct a due-diligence audit to determine the current state of maintenance that you will be inheriting. This can be related to the new ISO 5001 or it can be an audit based upon the 2015 version of The Scoreboard for Maintenance Excellence, included as Appendix A in this book. PAS 55: 2008, which recently led to the ISO 55000 standards, is a very descriptive narrative that is often unclear. The Scoreboard for Maintenance Excellence has X best practices areas rating of the y evaluation criteria and is very prescriptive as to what is required for world-class maintenance. For planning, estimating, and scheduling, here are some things are some things to look for:

• Is your backlog of maintenance work extremely large?

- Are reliable estimates and estimating techniques being used?
- Do you seem to accomplish very little with the people you have?
- Do you have repetitive failures on critical equipment?
- Are all jobs estimated and scheduled based upon the Noah's Ark method (e.g.,  $2 \times 2$  with two employees, 2 h;  $2 \times 4$  with two employees, 4 h)?
- Are parts on the job before it is started?
- Do employees understand what is expected of them?

These are just some of the symptoms of a planning and scheduling system that is not functioning well. For example, I have seen planners who went to the storeroom and retrieved parts for jobs, while others labored over data entry and struggled with scope of work, poor storeroom support, and gaining cooperation with production to schedule PMs and other work.

When we look at planning, estimating, and scheduling closely, we see that it is not rocket science. Other best practices complement planning and scheduling, such as effective PM and predictive maintenance (PDM), plus a responsive and customer-driven maintenance storeroom. For planning and scheduling, the goal is to get the most critical jobs completed in the most productive way. If you have attempted a planning and scheduling project and it failed or did not achieve its full potential, then learn from those mistakes and drive down a different path next time.

Problems with well-defined roles, responsibilities, and written guidelines often have been encountered in past attempts to fully implement planning, estimating, and scheduling. Someone once said, "As soon as the man with the briefcase left, we quickly reverted to the comfort of how it was done in the past." You must make sure the newest variation of a planning and scheduling program becomes a way of natural operation, where you get serious about creating clear roles and responsibilities for everyone in the organization. This includes everyone from the mechanics to craft leaders, maintenance leaders, and most importantly, top leaders.

To lead maintenance forward as a business, a key challenge is to make sure that the new roles and responsibilities of your planners/schedulers (Chapter 7)

become a part of the way you do business. You must take a realistic approach to what can be sustained and implemented for long-term benefits. I love the term of being "rigidly flexible," which personally I am. Your system also has to be flexible enough to accommodate the skill set and resources of each area. Your planners will have a key role with very well-defined responsibilities. As stated in the introduction, planners can be a viable resource to support maintenance and reliability improvement, but they cannot neglect their primary roles and responsibilities; rather, they must integrate the areas related to reliability improvement into their daily routines. Much of the work they should be doing relates to reliability.

It has been said that, in general, planning consumes approximately 10% of project time versus implementation, which consumes 90% of the time. Creating a planning and scheduling process on paper is easy using this book and many other books like it. All are excellent guidelines for planning based upon your unique site requirements and your computerized maintenance management system. However, how many times does a program of the month fail when it runs into the "not this again" mentality of the workforce? We have "cried wolf" so many times when implementing new types of systems or programs that the majority of the workforce has quit listening. Before you roll the system out, make sure you have documented lessons learned (as to why you failed in the past, if that is the case) and what you will do differently to succeed now. Again, I recommend that you conduct a thorough assessment of the total physical asset management process. Do not form a committee but rather use a leadershipdriven, self-managed team that is chartered for a specific reason, such as how planning and scheduling should be conducted at your site. This is a crossfunctional team from across the entire operation, including technicians and craft leaders. Also, this team should have a clear charter sponsored by top leaders. A sample charter for a leadership-driven, self-managed team is included in Appendix D. You can began with just some informal polling, shop floor observations, and even develop a process map of the vision of your future system. Selected sections of an actual process map for the British Petroleum (BP) refinery in Texas City, Texas are included in Appendix E. Find out what the perception is of the current or previous planning and scheduling systems. Make notes of previous weaknesses and address them specifically in your implementation plan. Also, please do not think your operation is the only one having problems with this best practice. Approximately 75% of the plant sites that I have audited with the Scoreboard for Maintenance Excellence have had serious challenges with planning and scheduling.

I have seen and facilitated a number of cross-functional teams made up of middle managers, front-line supervisors, and even some hourly employees and current planners, plus key support staff, for CMMS. Remember that an existing planner should be classified as a super-user of your system. The employees selected should be some of the most influential and respected members of their respective work areas. The team should be sponsored by a top leader to develop the system and a define timeline for rollout. The rollout should include defined team member roles and responsibilities (especially the planner/scheduler), as defined in Chapter 7.

You must decide on appropriate metrics, meeting frequencies and agendas, and sustainability plans. Off-site time of a week or so can useful for team training and solution discussions with a third-party facilitator to help train and work through the entire system. This can be a very good investment, especially if there are other best practices that must be implemented to complement the planning and scheduling process. In this case, a detailed process map of the current system should be developed as a team deliverable, providing a graphic representation of the document flow and actions required by all involved. A process map of the recommended solution also serves as an important project deliverable.

There may be some very heated discussion on what will or will not work, but in the end the goal is to develop a plan that can be implemented and sustained over time as a normal business practice. It is recommended that this same team be part of the implementation solution, as either resource persons or active participants in the operation of the planning and scheduling system. Normally, a consensus can be achieved on the system without creating unsolvable issues within operations or within the maintenance department. Also, a strong team leader should be named by the team sponsor or nominated by the actual team members. During the team's activities, every effort should be taken to define and quantify benefits from planning and scheduling, as well as other best practices that may be needed to complement planning and scheduling. These values may be in direct savings, cost avoidances, or gained value as shown as increases in craft labor productivity (i.e., OCE). A dollar range of benefits can be used. For example, one client manufacturing a wide range of cosmetics had an annual potential savings/gained value of \$3,000,000. If our estimate of benefits was only 50% accurate, then savings and gained value would be \$1,500,000, which is not a bad return on investment for a short amount of consulting and training time. Also, the team can look back and say, "Wow, we did it ourselves!"

The logical next step is to present the team's findings and plans to the team sponsor for final approval. This is a very crucial step because without support of top leaders and operational/production leaders, the system will never be sustainable. Sustainability is one important evaluation category that was included our 2015 Scoreboard for Maintenance Excellence. It is also highly recommended that the proposal be signed off by key top leaders, including the vice president (VP) of operations. When the management team signs the cover page to indicate their approval, support, and commitment, this covers new ground by doing something may never have been done before for maintenance. This signoff can help set the expectations that the system will be implemented across the total operation this time by committed top leaders. Remember, there is a big difference between involvement and commitment: It is like an egg and bacon breakfast—the chicken was involved, but the pig was committed.

Now the real work of implementation begins, which I stated earlier was 90% of the work. At this point, we have an agreed-upon document for how the operation will plan and schedule maintenance. Dedicated resources may be needed to successfully roll out the system. This should be defined in the report to top leaders. The developmental team becomes responsible for the individual area rollouts. This was one of the key reasons that we selected some of the most influential and well-respected members from each operational area. Because they helped to develop the system, they have built-in ownership, so they then become the drivers at the lowest level in their periods. Communication to the shop floor is a very important element for success, up and down and all across the organization.

In some cases, area team members can hold short meetings with their areas to review the system, including a line-by-line review of the system, allowing for a question-and-answer session. It is recommended that assigned planners and the third-party facilitator also attend these meetings. Questions can be brought back to the team as a whole to get a consensus decision, but most should have been having addressed in the document as it stands. In the end, a complete and comprehensive description of the system is a very effective way to communicate details as well as to maintain the integrity of the system into operations.

Sustainability is important to our nation's infrastructure as well as an ongoing business. So our new scoreboard includes a new evaluation category Number 34 for Sustainability. Once the system is rolled out, the main focus must be on sustainability. The first 6 months is the crucial timeframe for establishing a

foothold in the organizational culture. Each work area must feel a constant presence to ensure that using the new or improved planning and scheduling system becomes second nature. Customers must also see value-added results. The implementation team members should be encouraged to attend area meetings at least weekly. As planning progresses into scheduling, with weekly and daily schedules, the team can also attend some of these meetings, along with the planner and employees who are having work schedules for their respective areas. The team should also conduct monthly meetings to allow team members to discuss issues and advancement of the process. By openly and regularly sharing, you will be able to make decisions on the progress and status of the system. In turn, you can keep top leaders well informed of the shop-level results. This also helps the team members to stay aware of how the system is progressing, and maybe even inspiring some competition between areas to try to be the best.

To ensure sustainability, you may use The Scoreboard for Maintenance Excellence<sup>TM</sup> as a system audits tool. This tool can very easily be completed as a team-based self-assessment performed at, for example, 6-month intervals to show progress. This is another way to document results to top leaders as well at the grassroots level and to your most important maintenance asset—your craftspeople. Basically, our scoreboard is a checklist of 38 benchmark/best practice areas. Each best practice has number of evaluation criteria that are rated on a scale of 5–10, with 5 = poor, 6 = below average, 7 = average, 8 = good, 9 = very good, and 10 = so-called world class. The scoreboard is very easy to use, with each criterion defined in clear prescriptive terms.

Ratings are not absolute values, but the scoreboard results can be a total overall score of 38 best practices or just scores for the two work management and control categories and the two planning and scheduling categories. The score for each best practice category is a category progress score, and it provides valuable benefits information to all involved. There can also be specific checklists for areas, such as conducting scheduling meetings with operations, completeness of work scope of major job packages, or a checklist to help identify well-planned jobs in the backlog. This becomes a real tool when you see an area start to backslide a little. One good practice is for the planner to get periodic feedback from supervisors and craft workforce surveys related to his or her work.

I was personally amazed one time when a VP of operations attended a kickoff meeting for a Scoreboard audit for the world's largest contract packaging

operation. It made the group snap to attention when the VP came into the audit kickoff meeting just to see how things were going. A few well-placed questions about some part of the system that is lacking always goes a long way to show the team that the expectations are real and will be followed up on. When I returned 8 months later to train their prospective planners for just 3 days, he was plant manager/president of this single plant operation. I heard him tell all of the second-shift employees about their new crafts skill training program and the great opportunities ahead to move from packaging into maintenance.

Later, I will discuss how to measure the effectiveness of your planning and scheduling process, as well as your crafts skills training program. It will also be an important part of the overall measurement tool—the reliable maintenance excellence index (RMEI), which is detailed in Chapter 25. Here, we develop metrics to measure the impact of the planning and scheduling system, plus a range of 10–15 other key metrics, including financial, physical assets, maintenance storeroom, quality, and craft productivity items. During our own scoreboard audits, the RMEI is developed and reviewed with the client. In general, the current client selects from metrics that we propose and determines what levels of achievement that they are driving toward for each metric. Using a one-page Microsoft Excel document, the client reports and monitors on a monthly basis. The implementation team's planner representative, as a superuser of the CMMS, would normally maintain the RMEI. Based on the agreedupon metrics to measure planning and scheduling system utilization, the RMEI also integrates metrics from operations and financial areas. This goes a long way in helping everyone to understand the total scope of planning and scheduling, as well as the scope of other improvement activities that may be ongoing. Just like the broad-based scoreboard audits, the RMEI goes down to both shop and plant levels. It is a way to keep everyone actively monitoring the overall goals within the RMEI.

Here I note that there has been much discussion about the balanced scorecard. I have both books by the originators of the concept, and neither book mentions the words "maintenance" or "physical asset management" anywhere. Also, as I discussed before, HBR does not include articles related to physical asset management. If physical asset management is not part of a "balanced scorecard," there a great imbalance for sure.

There is a good saying within the industrial engineering community (as well as others) that states: "What gets measured gets done" Once your system has been

rolled out and people understand that it is not going away, you will see amazing things start to happen. People adapt to a system that helps them find ways to make it easier to use in their areas. You will see a crossover stage by operations, with their roles and responsibilities being accepted, and team members will enhance the system to make their jobs easier.

For example, planners and schedulers provide a vital service to support a plant shutdown, turnaround, or outage, especially in oil and gas operations that have both planners and schedulers. As planners scope out work for shutdowns for the equipment, they could very easily tag each job during the scoping process. It could also identify the mechanic assigned, the trade crews involved, and even contractor support personnel. This tag also may include where the parts are located, such as in a job box, a controlled laydown area, staged in the storeroom, or (best of all) delivered to the jobsite. This can help reduce the "morning rush" of a shutdown when supervisors are running to get mechanics on their respective jobs and to answer any questions when contractors' are clocking into the refinery (or any site for that matter). With the use of radiofrequency identification (RFID) tags that contain chips for significant data, the sky is almost the limit as to what you can do with RFID tags on a wireless basis. Your hourly mechanics should give very positive feedback on the system, and they may even leave more notes than usual on what they found and the necessary follow-up work. Nonetheless, all work completed during a shutdown turnaround or outage should be documented on a formal work order and captured in the equipment history file. Examples like this can often be seen across the total operation once each area takes ownership of the system and it becomes part of the everyday culture and way of supporting the business of maintenance.

Once you start to see people taking the system to the next level, you will have succeeded with your initial implementation. Now, it is time to take another look in the mirror for continuous improvement, find your weaknesses, and focus on ways to continue to improve them. Those who do not continue to improve will be left behind. Also, do not forget to celebrate the successes that you have achieved along the way. These will be readily denoted on your RMEI on a monthly basis, where direct savings and gained value can be calculated on improvements from your baseline timepoint.

#### **Conclusion**

Planning and scheduling can be exciting when applied properly. The concepts of an effective planning and scheduling system have been around for years. Your charter today may be to successfully develop and implement a new system or to revive a system that has to achieve its maximum value. You may very well become a part of the way your site does business for years to come. If you are currently a planner/scheduler, do not just sit back and watch what happens—be motivated to make good things happen.

In a world where only the strong survive, it is imperative to focus on the costs that are within your control. We all must change the perception that maintenance is a business and that planning and scheduling are essential to success. This book includes a number of chapters that appear to be outside the scope of reliable maintenance planning and scheduling, but there is a purpose for including them; they will cover some areas that other books have neglected to cover. As stated in the introduction, by the inclusion of "reliable" in the book's title, I wanted to emphasize my belief that a planner/scheduler is a next step for a greater leadership role within a maintenance department. Therefore, these additional topics support professional development of a planner or scheduler (or a combined planner/scheduler position).

Five key things to for you to consider and remember are as follows:

- 1. Always know your total maintenance requirements in terms of job types, job status, man hours required, and specifically the high cost of deferred maintenance throughout the organization.
- 2. Use a reliable method of estimating that is based on improving repair methods and providing estimated job times for scheduling by using a system such as the ACE Team Process developed by TMEII (discussed in detail in Chapter 17).
- 3. Remember, "What gets measured get done."
- 4. P.T. Barnum of circus fame said, "Without publicity, a terrible thing happens

—nothing." Therefore, publicize and communicate your success across and up and down your organization.

5. It has been said that, "Nothing happens until someone sells something." This is a true statement for those managing the status quo, never selling the top leaders on the benefits of planning and scheduling.

\_

3

## Leadership

\_

# Creating Maintenance Leaders, Not Just Maintenance Managers

#### **Abstract**

This chapter is to help the planner/scheduler understand leadership and to realize that each planner/scheduler is a leader within their respective maintenance operations. It also looks at the key differences between managers and leaders and provides a number of important topics on leadership. Maintenance planners must be leaders or develop into true leaders for their future success. We need still managers, but more maintenance leaders are needed within the physical asset management arena. Leadership is rarely an innate quality. It is a combination of hard work, conviction, and instinctive strategy, which need to be developed and nurtured.

# **Keywords**

Communicate; Empower; Lead by example; Leaders vs managers; Leadership; Motivate; Patience;

# Perseverance; Personal goals; Power of optimism; Professional goals; Publicize; Take responsibility; Vision

Maintenance planners must be leaders or develop into true leadership for their future success. We still need managers, but more maintenance leaders are needed within the physical asset management arena. Figure 3.1 summarizes some of the basic differences between maintenance managers and maintenance leaders.

Leadership is rarely an innate quality. Rather, it is a combination of hard work, conviction, and instinctive strategy, which needs to be developed and nurtured. When you see someone who is naturally charismatic and inspiring, you are likely disregarding an immense amount of work that has occurred behind the scenes. This is precisely the reason why we are witnessing an increasing demand for cultivating this talent at the earliest possible age. Whether in sports, business, or entrepreneurship, today's youth are striving to sow the seeds of leadership in hopes of future success.

In my case, I served 26 years within the US Army Corps of Engineers, as a trained civil affairs officer and last as a military police officer. I can say without question that my formal education did nothing to expand my leadership capabilities. The US Army offered some of the best opportunities for teamwork and to build leadership skills. Below are some key points for leadership in the business of maintenance:

1. It all starts with a well-defined and measurable vision

People buy into the leader before they buy into the vision.

John Maxwell

The true essence of leadership begins with envisioning a set of personal or

professional goals. Do not just have a vague image in your mind; rather, define the target with focused clarity. Think through the final result over and over to make sure you will be committed until the end. As discussed in Chapter 2, a team process brings together a synergy of cross-functional members of an organization.

However, stating objectives is not enough. Enforcing the purpose and mission are equally important. Provide a clear and realistic path forward to your team. Believe in yourself and be persistent when things look difficult. Without John F. Kennedy's ambitious vision, Neil Armstrong would not be the first man on the moon. No dream is too big until you have realized it.

# Maintenance Leader Maintenance Manager Versus Reactive Proactive Makes Things Happen Wonders What Happened Has Vision May Wear Blinders Promotes Growth Maintains Control Promotes Continuous Improvement Maintains Status Quo

# Figure 3.1 Basic differences between maintenance leaders and maintenance managers.

2. Communicate often and clearly. Publicize your goals when it is appropriate. Report periodic reviews of your personal goals and the positive status of ongoing improvement goals

Great leaders are almost always great simplifiers, who can cut through argument, debate, and doubt, to offer a solution everybody can understand.

General Colin Powell

Communication is the fundamental link between vision and reality. Deliver the message concisely and with conviction so that it permeates through all levels of the organization. Your people need to understand why they are working on a task, what they should be doing, and where it will lead them. This entails having good presentation skills, being a good listener, and facilitating problem-solving on the leadership-driven self-managed teams established to improve the planning and scheduling process. Effective communication skills make a standout leader.

3. Do not underestimate the power of optimism. Become a member of an Optimist Club International and do not be nominated to join a local pessimist club.

If opportunity doesn't knock, build a door.

A great story in this regard is Walt Disney's remarkable story. It was 1928 in New York when Walt learned that his distributor hired most of Disney's animators to start a new studio. He practically lost everything, including his staff, the contract, his income, and the hit character Oswald the Rabbit. He immediately sent a telegram to his brother Roy saying, "Don't worry. Everything okay. Will give details when I arrive." On his 3-day journey back to Hollywood, Walt took out his sketchbook and created the character of Mickey Mouse. Within a year, Mickey was the most popular cartoon in the world.

Optimism helps channel the negative energy of fear and uncertainty towards driving innovation. As a leader, you will be surrounded by skeptics. Reject pessimism and turn the volume up on positivity.

#### 4. Motivate and empower

If your actions inspire others to dream more, learn more, do more and become more, you are a leader.

John Quincy Adams

Without the right kind of stimulus, people produce mediocre work and drain out quickly. Some get inspired by power, some by incentives, some by appreciation, and some by interesting work. It is your responsibility to identify specific motivation factors in your employees and empower them. There are three main types of motivation: fear motivation, incentive motivation, and attitude motivation. All three at times may play a part within our professional lives and careers. As I have said many times before, a successful planner is on a career path to becoming a supervisor or a maintenance leader at a higher level. As a leader, your efforts to nourish and empower your team will also indicate that you care for them, which in turn is a great fuel to boost productivity and loyalty.

5. Accept feedback generously.

Leadership and learning are indispensable to each other.

John F. Kennedy

One of the best ways to grow and improve is by graciously accepting constructive feedback. Planners may receive feedback from their services through surveys conducted or direct/indirect communication with supervisors and operations staff. Each planner must be able to take constructive criticism and not let it be a negative factor. Many managers, especially chief executive officers (CEOs), by way of their power, find it demeaning to be advised by their juniors. However, your people hold the key to invaluable information that can make you more successful. Therefore, leave your ego behind, and ask what you can do better. You may choose to do that in an informal setting or through a defined 360-degree feedback model.

6. Lead by example.

You don't lead by pointing and telling people some place to go. You lead by going to that place and making a case.

Ken Kasey

Planners and schedulers in essence are leading their organization on a path forward to productive and cost-effective execution of the maintenance mission. Teaching by force and directive orders is passé. This is the generation of producing future leaders by walking the talk. Do not waste hours trying to

convince people. Instead, demonstrate the benefits of a particular decision by your own actions. You cannot expect others to do what you would not do. Besides garnering respect and trust, you will be able to set higher standards and achieve better results. The easiest way to begin is by thinking of your role model. Who would you want to emulate? What kind of traits does that person have?

7. Take responsibility and own up!

A good leader is a person who takes a little more than his share of the blame and a little less than his share of the credit.

John Maxwell.

As the top maintenance leader, you may have to come clean on the declining state of maintenance, if it does exist. While serving as a major within the 30th Infantry brigade, I worked for a brigadier general with a full staff of lieutenant colonels commanding armor, infantry, artillery, and direct support maintenance battalions. My unit was a larger-than-normal company responsible for combat engineering support to the brigade, which included ribbon bridge construction. During the final assault, which crossed our ribbon bridge to the objective, one commander of an armor battalion failed to make the final river assault crossing due to bad maintenance. At the general's staff meeting for an after-action review, this commander was relieved and fired right on the spot.

When things go wrong with critical equipment and the plan was not completed as scheduled due to many factors, there will be finger-pointing. In your role as planner, you must realize things will go wrong, and it is not for you to assess who is to blame. Say no to passing blame onto others—that is the most diminishing quality any leader can possess. Being at the top implies taking ownership of your vision and your team's actions. In spite of having a robust set of internal controls, any organization will have its share of slip-ups and errors. You will need a whole lot of courage to apologize for mistakes and take

measures to improve upon them. I have also said this many times: Maintenance leaders must have courage. You must have courage to be the messenger to top leaders about total maintenance requirements not been accomplished and a declining state of maintenance (if it is present).

8. Use your power to drive change

Anyone can hold the helm when the sea is calm.

**Publilius Syrus** 

A planner can drive change and in essence create a sense of so-called power within the maintenance organization. By having a finger on all the factors related to a specific job, the planner can answer many questions. Having the right answers as to when repair jobs can be completed builds a base of knowledge. As the craftspeople complete schedules regularly on time, the credibility of maintenance plus planning, scheduling, and execution of work builds the so-called power to provide greater customer service.

In the book Onward: How Starbucks Fought for Its Life Without Losing its Soul, Starbucks CEO Howard Schultz shared his remarkable story, giving us many leadership lessons. Eight years after stepping down from the daily oversight of Starbucks, Schultz returned as CEO in 2008. His aim was to bring back the core values that Starbucks was originally known for. He made some drastic decisions, including closing 900 stores and shutting the remaining 11,000 US stores for a day to retrain 115,000 people. The media questioned the relevance of these changes, but Schultz explained, "It was honest, it was authentic and it was necessary."

Maintenance leaders and planners are often faced with challenges that require bold and unconventional decisions. Trust your instincts and use your authority to your advantage, but always bring the facts related to the situation. Change is necessary to establish an environment for continuous growth. And, just like gravity, change is constant.

9. Cultivate patience

Patience and perseverance have a magical effect before which difficulties disappear and obstacles vanish.

John Quincy Adams

Have you ever heard the saying to have the patience of Job? During Job's return to a righteous way of life, his three friends came to give him their thoughts and advice as to why he had lost everything in life. They sat with Job for seven days and seven nights without saying a word. Maybe this standoff led to the slogan, "He has the patience of Job."

Successful leaders are proactive yet patient. They understand that a lifespan consists of periods of sprint followed by periods of recovery time. Many of us are prone to making snap decisions under deadlines and pressure. Be careful when you are influenced by excitement and wishes to see quick results. This especially holds true for small businesses and start-up phases of projects, where patience can make or kill. The Dutch often say that a handful of patience is worth a bushel of brains.

10. There is no one leadership style.

*In matters of style, swim with the current; in matters of principle, stand like a rock.* 

Thomas Jefferson

When there are no two people in this world exactly alike, how can there be a single way to lead? Daniel Goleman studied around 3000 mid-level managers, uncovering six different leadership styles:

- a. Commanding
- b. Visionary
- c. Affiliative
- d. Democratic
- e. Pacesetting
- f. Coaching

Leadership style depends on underlying emotional intelligence competencies, when the style works best, and the overall impact on climate or culture.

Emotional intelligence is the driver for each of these techniques, and it can have a deep impact on your organizational climate and culture. Effective leaders have all of these cards up their sleeve and address the demands of the particular situation. They are flexible and keep switching from one style to the other.

## 11. Opportunity never knocks

Opportunity never calls, and it never stays the night. If you want a seat at the table, you have to hunt down every opportunity yourself. You are not entitled to anything. For maintenance planners, it is very important that they possess the initiative and the desire to create their own opportunities for job improvement and service to their customers. Maintenance staff who are nominated and recruited to become planner schedulers are beginning a key new role for their future within the maintenance organization.

#### 12. It is better to be best than to be first

If you watch the Hollywood version of success, you can easily get duped into thinking you have to be the first to hit the market in order to win. That is true if

you are a reporter and want credit for breaking a story. Otherwise, keep in mind that Myspace predated Facebook.

The first person out the gate may get the competitive advantage and land early. However, when the honeymoon phase is over, people want quality. As long as you focus on creating quality, you will always have something to offer. Maintenance must be focused on quality repairs and not create unrealistic planning times, in which case craftspeople are forced to take shortcuts that result in callbacks to a job that was initially done incorrectly.

## 13. Leaders believe in serving others over themselves

Maintenance is a vital service for total operation success. The planner's service to both maintenance and operations puts this position in a very important service role. In turn, planners must believe that their service is making a difference within the organization and is creating value that can be measured.

### 14. Quality is important

One of the three elements of overall craft effectiveness is what I call craft service quality (CSQ), which will provide a good measure of the quality of repairs within maintenance. A truly successful person is not successful because of their position in life. It does not matter if you are a janitor or a CEO—success is defined by how content you are with where you are. Kevin O'Leary (a self-made millionaire and TV personality) will tell you that success means being rich, while Gandhi successfully led a revolution and freed both India and Pakistan while living poor.

Quality of life is not defined by what you own or how high up the ladder you have climbed. It is defined by your satisfaction with what you have. No matter where you are in your life, strive to create quality experiences for those around you. Planners create expectations with the development and publishing of a weekly or daily schedule. Craftspeople who truly exhibit a pride in maintenance attitude normally can meet expectations.

## 15. Execution trumps ideas

Everyone has great ideas. Some executed idea have brought great success. For example, someone thought there should be a Website where people can socialize online, so Facebook was invented. Someone said it would be cool if you could

shop online; now Amazon exists for fast service from online shopping. John Lennon's and Paul McCartney's best songs used only a handful of basic chords. Those names rose to prominence because they thought of something no one else did. They took action and accomplished something no one else did, and most of them continue doing so to this day.

Ideas are important, but anyone can come up with ideas. Backing those thoughts with action is how you create success. The idea of planning and scheduling along with good estimating is not rocket science and is a very good idea, but execution and implementation are the key.

## 16. Respect is something you earn

Planners may or may not begin their work with respect from all within maintenance or operations. The advice I have heard the most in my life—at home, in school, in the military, in corporate America—is that respect is something that is earned. You are not entitled to respect. You are entitled to common courtesy and politeness, but you have to prove yourself worthy of peoples' respect. It does not come from a title; it comes from your daily actions and attitude. Respect everyone, act ethically, and always follow through. People will respect such traits in a planner or scheduler.

## 17. Leaders believe in their place in history

A successful person knows his or her place within the work environment and is comfortable with it. Whether or not you have made a blip in the history books, you have your own history, a work history, family history, and a history in your community. With time comes memory. People remember your actions in the past, and they judge you in the present based on them. If you understand your place in your organization, you will be prepared for successful results.

## 18. Quitting is the only failure

Some people talk about treading water or keeping your head above water, but that is only enough to remain in the same spot. To actually reach your goal, you cannot tread water—you have to keep swimming.

You can only see by looking back and forward, but that gives the confidence to keep swimming.

## 19. Success is about more than money

Money does have its uses. While it may be the root of all evil, it is also a resource that can be used to enact good change. If you define your worth by how much money you have, you have a long way to go before you are as valuable as anyone on the Forbes billionaire list. You will also likely never reach that billionaire list, because it takes a belief in your own value to reach that level. This brings me to the final point.

## 20. Believe in yourself

Successful people think that they are successful—it is what makes them successful. Perspective is everything in life, and the only way to reach success is to move with a successful perspective. You become what you think. If you do not believe in yourself, no one else will.

\_

4

## How to Create PRIDE in Maintenance within Craft Leaders and the Technical Workforce

\_

## **Abstract**

This chapter strives to understand the importance of planners readily soliciting and accepting ideas from the crafts workforce. Planners who have luckily moved from being a good craftsperson into one as a planner at the next level will have an important advantage. We will also see why planners not only support reliability improvement but also help create pride in maintenance within craft leaders and the technical workforce. One of the key points included: "Do every job as if you owned the plant, the department, or the piece of equipment you operate or maintain. Every employee in a plant is a manager of a small piece of the business."

## **Keywords**

# Craft leader; Golden rule; PRIDE in Excellence; PRIDE in Maintenance; PRIDE in Work; Reliability improvement

This chapter strives to understand the importance of planners readily soliciting and accepting ideas from the crafts workforce. Planners who have moved from being a good craftsperson into one as a planner at the next level will have an important advantage compared with a brand-new mechanical engineer being assigned as a planner. This chapter also examines why planners not only support reliability improvement but help to create People Really Interested In Developing Excellence (PRIDE) in maintenance within craft leaders and the technical workforce.

I begin this chapter with something I wrote while serving as plant manager of manufacturing operations for the Crescent Xcelite tool plant in Sumter, South Carolina. PRIDE in maintenance is something that every maintenance leader must practice and believe in. Planners are in the category of maintenance leaders as well. This introduction talks about PRIDE in excellence, which parallels all we will talk about for achieving PRIDE in maintenance in this chapter. Late in 1983 when this was written to our plant employees, little did we know that more than 100 of the 500 employees from the total plant direct labor workforce would face layoffs (in late 1984 and 1985) due to the dumping of foreign hand tools into US markets. Because South Carolina is a right-to-work state, the layoff was based upon employee seniority. The good news was that we were able to call back almost everyone by early 1986. We began the layoff process with positive expectations that the business would return, which it did. So, what about PRIDE in excellence?

PRIDE in Excellence: The very famous German sports car manufacturer, Porsche, had a slogan that said, "Excellence is expected." To me, this is what customers, distributors, and group sales/marketing people expect. Excellence is expected from the world-famous Crescent and Xcelite trade name brands.

In our employee communication meetings, the topic of foreign competition and the real threat that it presented to the American hand tool industry at that time was an issue that all employees had to keep in mind. Crescent/Xcelite was continually addressing both foreign and domestic competition through an aggressive capital investment effort to upgrade old equipment, secure new equipment, and improve manufacturing methods, implementing a closed-loop MRP (Materials Requirements Planning) system (pilot plant in Cooper Industries) and improving processes by whatever means available. We were also scheduling a vibration analysis service across this large plant with a large portfolio of rotating equipment. At that time, we did not have planners; the two supervisors did a good job reporting at weekly operations meetings on upcoming PM's (preventive maintenance) and critical jobs.

However, although money buys the new equipment and raw materials, people are the most important assets for developing continued excellence in a company's products. Personalized human skills, ranging from die making to final inspection, were the assets that determined the outcome of the "big game" with foreign and domestic competitors. To win the "big game," each employee at Crescent/Xcelite was encouraged to consider taking "PRIDE in excellence" as a renewed effort for the 1984–1986 period, which was very challenging.

Below, I listed a few of the thoughts that I used with the production and maintenance employees at Crescent/Xcelite in 1984. They will still apply to every job at your plant as well as to your personal family life. Add one or two to your list of resolutions.

- 1. Do every job as if you owned the plant, the department, or the piece of equipment you operate or maintain. Every employee in the plant is, in a real sense, a manager of a small business, regardless of the operation. Crescent/Xcelite as a plant is made up of many small plants or teams. Be a proud competitor on your team.
- 2. Develop a commitment to excellence in everything you do. Have fun and seek justice against poor quality where it is due. If work is thought of as a hobby, such as golf or fishing, imagine how much fun it would be to meet that 7:00 a.m. starting time at the plant.
- 3. Develop PRIDE in your work, regardless of the task. Give 105% to your performance whenever possible to make up for the times you were at only 95%.
- 4. Maintain a sincere belief in your capabilities, as well as the potential of those you meet each day. Practice positive reinforcement on yourself and others.
- 5. Practice the golden rule. If it does not work the first time, then Practice!, Practice!
- 6. Practice good maintenance in all areas: physical, spiritual, family, equipment, mental, financial, etc. Plan to wear out rather than rust out. I have a saying that "maintenance is forever."
- 7. Particularly for planner/schedulers, it is your job to "make things happen" rather than "watch things happen." Try not to be in the group of people that wonders what happened. Reduce work-in-process and stamp out rework-in-

process.

- 8. Develop PRIDE in yourself, your company, and your country.
- 9. Establish written and specific written personal goals in all areas of your life.
- 10. If none of the above items works for you, just keep smiling. People will really wonder what you are up to!

PRIDE in excellence is a very personal matter that we as individual Americans must address. The late Congressman Larry McDonald (who died in a Korean Air Lines accident when the plane was shot down by Soviet interceptors in 1983) made a closing statement in the documentary film No Place to Hide with these words: "Freedom is not free." Excellence, quality, and success likewise are not free; all take hard work and commitment from people.

PRIDE, on the other hand, is free when the work is done. When the game is over, you can look back and say, "I did the very best I could do." A departmental team can say, "We did the best we could do!" Our goal should be to look back a year later and be able to honestly say, "We did our best!" If a planner can do this, he or she can and will be successful.

Think about leading your maintenance operation with the above as part of your personal philosophy for achieving PRIDE in maintenance. Planning for excellence will help create positive expectations for every planner/scheduler (P/S) serving their customers all around the world.

PRIDE in Maintenance: The term "PRIDE in Maintenance" was first used in 1981 while I was on the Cooper Tools Group staff as group manager of industrial engineering, striving to improve maintenance processes across seven plant sites. The first step, along with creating the original Scoreboard for Maintenance Excellence, was to sponsor a groupwide training session on maintenance best practices. This was a weeklong session held in Greenville, Mississippi, on the Mississippi River, way down south at two of the Nicholson saw plants. We had plant managers attend for one day and then engineering managers, maintenance supervisors/foreman, planners and storeroom managers for the rest of the week. We also had two predictive maintenance equipment vendors come in to discuss this new technology and to demonstrate the benefits of vibration analysis and other technologies. To our good fortune during an in-plant demo, one vendor actually found a bad

bearing on a major piece of equipment. This was in the mill for rolling specialty steel for hacksaw and band saw blades. The training event was a success at creating a better understanding about the importance of maintenance for top leaders and maintenance leaders. It also helped to avoid a catastrophic bearing failure at the Nicholson steel mill.

However, we neglected to include any craftspeople in this weeklong event. The consultant that I used for the training was Mr. George Smith from Orange, New Jersey, who had just recently purchased Marshall Institute from the founders. George discussed many topics related to the crafts workforce throughout his presentations. Therefore, I said to George, "We forgot a very important group. We did not get your message down to the crafts level. I will talk to the plant manager here at the Greenville plant. We will see if we can get the crafts together for at least a 1 h session and you can talk to them too before you leave." The plant manager agreed, and George talked to 20 or more craft people on the topic that I called "PRIDE in Maintenance." George was a Navy pilot in World War II, and he had some real maintenance stories to tell about why PRIDE in maintenance was important .For example, he always told the aircraft mechanic working on his plane to be ready for a test to "see how she's running." We videotaped George's presentation, and his words apply today just as much as they did back in the 1980s.

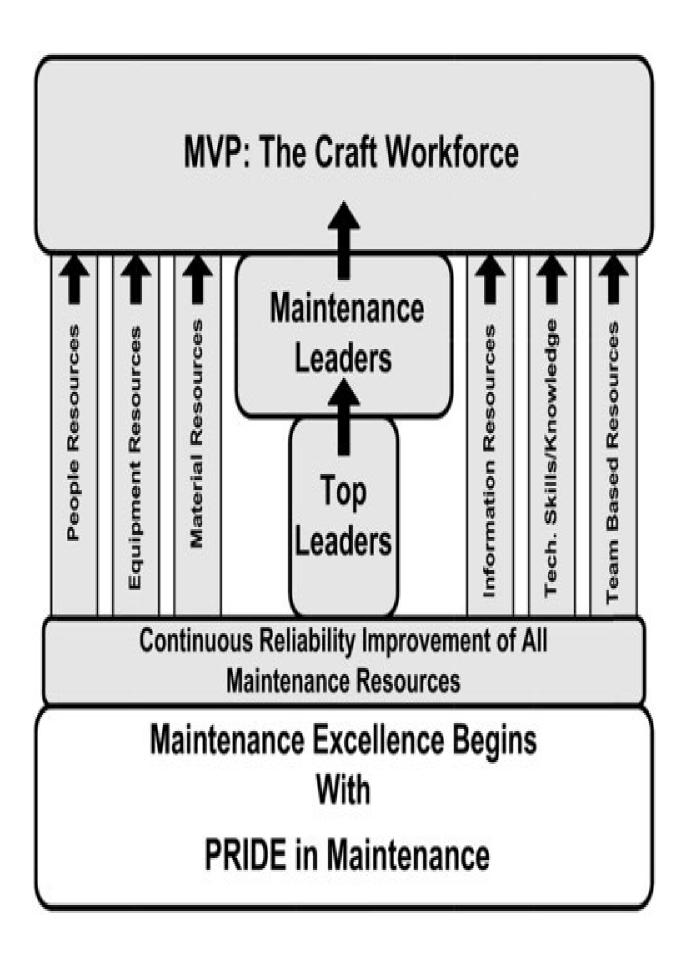
Planners must not forget the crafts people either. The craft workforce must not be forgotten in today's world of fancy new terms and technological advances. Your crafts workforce will be really interested in developing excellence in maintenance when they feel that they are a true member of the team. Our domain name, www.Pride-in-Maintenance.com, reflects our belief about the important of maintenance, the value of maintenance people and the work they do, and how we must change attitudes about the profession of maintenance.

I now would like to reinforce some key points made in previous chapters that have been leading toward our main subjects: reliable maintenance planning, estimating, and scheduling. Your improvement strategy must include all maintenance resources, equipment, and facility assets, as well as the craftspeople and equipment operators. It must also include MRO parts and material assets, maintenance informational assets, and the added value resource of synergistic team-based processes. Maintenance leaders and top leaders must support their most important maintenance resource of all, the crafts workforce, which should be considered as your most valuable people. Figure 4.1 illustrates the support

role, which must start with top leaders realizing that the foundation for maintenance excellence begins with PRIDE in maintenance.

Our vision is to help achieve PRIDE in Maintenance from within the craft workforce and their maintenance leaders. In addition, top leaders should realize the true value of their total maintenance operation (Chapter 1) and then take positive actions to support the maintenance leaders, craft leaders, and the craft workforce. The Maintenance Excellence Institute International provides a wide range of consulting with our maintenance excellence services, temporary operational services and customized and public training for maintenance excellence offerings we call TrueWorkShops<sup>TM</sup>. We support all types of maintenance operations. However, the bottom line is that PRIDE in maintenance within your craft workforce is the foundation for your success for building long-term maintenance and reliability excellence and sustainability. Your craft workforce can be a valuable source of new ideas and positive reinforcement during your journey toward maintenance and reliability excellence.

During each Scoreboard for Maintenance Excellence assessment, we always interview a number of craftspeople. We get very candid input and many comments that support the improvement needs of the overall maintenance operation. However, we lacked a focused method that could bring out more ideas and concerns from the craft workforce. Following an assessment, one client requested that we conduct a session with the craft workforce and support staff to get ideas directly from this group. They did not want any supervisors or managers present, which might hinder open discussion of ideas and concerns. As a result, the first PRIDE in Maintenance sessions for the craft workforce and support staff were developed. This client wanted to make sure that their craft and support employees (approximately 350 in total) had the opportunity to express both their concerns and ideas. It is important to:



## Figure 4.1 Build your foundation upon PRIDE in maintenance. Most valuable player (MVP).

- 1. Understand the client's goals for maintenance improvement per assessment results, which should include a new P/S, for example.
- 2. Provide ideas that the crafts people thought were important and needed by the operation.

From the results of this first session, more than 300 good ideas were generated. Therefore, we feel that it is well worth the time to bring crafts and support staff together for a session devoted to sharing ideas and concerns. We firmly believe that maintenance excellence begins with PRIDE in maintenance. It is important to have people at all levels with PRIDE in maintenance—People Really Interested in Developing Excellence in Maintenance. These sessions can help you gain people with greater PRIDE in maintenance. They will be your own craftspeople who can add greater value to your maintenance operation by sharing their ideas and being a vital part of helping you implement today's proven best practices for maintenance excellence.

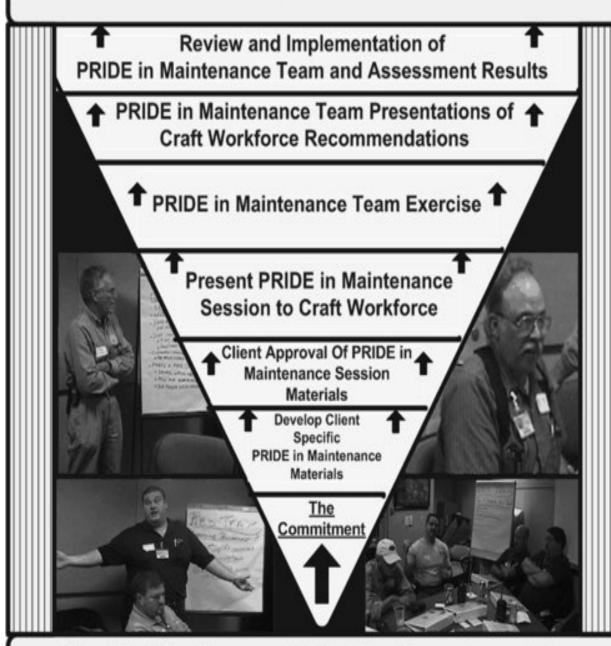
A Positive and Proven Approach: PRIDE in Maintenance sessions with your craft workforce should begin only after the consultant has a clear understanding of the client's current improvement goals, current challenges, and past successes. To do this, a Scoreboard for Maintenance Excellence assessment is recommended. The following key steps (illustrated in Figure 4.2) should be taken to help your craft workforce become a valuable source of new ideas and attitudes.

- 1. Develop your results from the Scoreboard for Maintenance Excellence Assessment.
- 2. Develop your PRIDE in Maintenance session materials. Gain your approval of materials and your commitment to begin.
- 3. Conduct PRIDE in Maintenance sessions for the craft workforce and support staff to share goals and key challenges (1 h).

- 4. Conduct PRIDE in Maintenance team exercises with the craft workforce focused on your key challenges (1 h).
- 5. Have the teams present their recommendations. Presentations from each team should be videotaped and a summary of all team recommendations prepared.
- 6. Have the client review the assessment results and crafts team recommendations, then determine their strategic, tactical, operation, and "do it now" commitments.
- 7. Provide implementation support from The Maintenance Excellence Institute as needed.
- 8. Continue with continuous reliability improvement and chartered crossfunctional teams as a possible next step.
- 9. Measure and validate results.

Gaining Support from the Craft Workforce: Without support from the craft workforce, achieving maintenance excellence can be extremely difficult. Planners especially must have the craft workforce on their side and gain respect from them. In Chapter 13, we will define some of the traits to look for when hiring a P/S. PRIDE in Maintenance sessions developed specifically for the crafts workforce and other maintenance support staff can add much to your maintenance improvement efforts. They can serve as one way to introduce the concepts of your P/S. They can serve as a means to gain craft level support for the P/S, to achieve better understanding and greater cooperation for current and future maintenance improvements. It is important that maintenance leaders provide very positive reinforcement to the crafts workers that their job is important and that their ideas are needed and are welcomed. Because they perform such a mission-essential role to success, the need for their positive input, ideas, and active participation is critical.

## **PRIDE** in Maintenance



Identify Challenges With The Scoreboard for Maintenance Excellence Assessment

Figure 4.2 Your craft workforce is a valuable source of ideas.

PRIDE in Maintenance sessions also help instill a philosophy of profit-centered maintenance into the thinking and attitudes of each participant. For public service as well as oil and gas operations, it is about maximizing customer service. PRIDE in Maintenance sessions help to support internal teamwork as well as to eliminate the fear of changing the status quo. It is important for your craftspeople to understand their contribution to greater profit and service and how they fit into your P/S process. You must challenge and support them to do each job as if they owned the company. PRIDE in Maintenance materials should be customized to the operation, whether the goal is to maximize profit, service, or both. The client should be able to review and approve all client-specific materials that are developed for the presentation. Session materials, including participant handouts, case studies, and additional maintenance excellence references, are provided to each attendee. Each session can include up to a maximum of 25 participants, allowing for three teams of eight craftspeople across typical craft functions. We like to videotape all team presentations and give each client reproduction rights for future use of their PRIDE in Maintenance video and all custom materials prepared for their session. Determining the true value of training often seems difficult. However, when you can incorporate ideas from your crafts workforce into various plans of action, the value of this type of training can be readily demonstrated. Scarce craft resources are a terrible thing to waste. So, take action now to consider investing in your most valuable maintenance resources to get their ideas.



## Figure 4.3 Maintenance leadership team at UNC-Chapel Hill.

The following is a case study example from the Facilities Services Division for the University of North Carolina (UNC) at Chapel Hill. It shows a section from their newsletter, which is one of the communications tools they used to spread the word about their workforce's involvement in maintenance improvement. Each of the more than 300 recommendations from their initial PRIDE in Maintenance sessions were reviewed by the Maintenance Leadership Team, who are shown in Figure 4.3. This team looked at each recommendation, and their goal while reviewing each employee's idea was to answer one of these three questions:

- 1. What can I (we) do now to put this idea into action?
- 2. How can this idea be put into action based upon additional internal review and help?
- 3. How can this idea be put into action with support and cooperation from departments outside the UNC-Chapel Hill (UNC-CH)'s Facilities Services Division and additional external review?

Based on question 3, some recommendations needed support and cooperation from other departments. The following is an excerpt from UNC-CH newsletter, describing how they created a cross-functional team to address a major improvement opportunity. This newsletter column started out as PRIDE in Maintenance, but was quickly changed to PRIDE in Maintenance and Construction because minor construction and renovation work was an important part of the division's direct responsibility.

## **PRIDE** in Maintenance and Construction

## **Excerpt from the Resource Newsletter of UNC-CH Facilities Services Division**

PRIDE in Maintenance and Construction has continued with follow up on each of the over 300 recommendations received from employees during the initial PRIDE in Maintenance sessions. The Team headed by Steve Copeland with Stanley Young, Bob Woods, Bob Humphreys, Mark McIntyre and Joe Emory completed the review of each and every recommendation received back in November 2003.

Systems Performance Team Chartered: The review of all employee recommendations led to a number of recommendations where support and cooperation from departments outside the Facilities Services Division was necessary. Therefore, the Systems Performance Team was chartered. Its job was to provide additional external review and recommendations for a top priority issue that was common across all PRIDE in Maintenance sessions.

The objective of this team is to recommend methods to improve overall building systems performance. The scope includes design and construction phases and the commissioning process of new facilities. The team started in January 2004 and has been meeting biweekly. It has looking at ways that Building Services can be more closely involved with design and construction processes and how to eliminate additional work that typically must be performed on new facilities constructed by contractors. This team addressed specific quality control improvement opportunities during the design/construction phases to improve contractor accountability. It considered how to better support the construction administration process and how to support the final user's requirement for the facility during commissioning.

Team leader Joe Wall from Construction was supported by Ricky Robinson

—Maintenance/Plumbing, Rodney Davis—Life Safety and Access, Robbie Everhart—HVAC, Terry Bowers—Housing Support, Eddie Short—Construction Administrator, Joel Carlin—Engineering Information Services, Ed Willis, PE—Manager of Construction Management, Cindy Shea—Sustainability Coordinator, Julie Thurston, PE—A/E Services, Pete Peters—The Maintenance Excellence Institute, and Carole Questa and Keith Snead—Facilities Planning/Design.

The Systems Performance Team prepared its final recommendations and a presentation by team members was planned during April 2004. Their work has had very positive actions on important employee recommendations from our PRIDE in Maintenance session held last year.

Results from the Systems Performance Team helped to ensure that maintenance was involved during the design, preconstruction, construction, final inspection, and commissioning phases of new facilities on the UNC-CH campus. Facilities maintenance staff from each craft area became an important part of the total team. Significant costs were tried to be eliminated by ensuring contractors did the job right the first time and by not having to call maintenance in to correct contractor mistakes after commissioning. Tracking of warranted items was also improved with vendors and contractors being held more accountable.

Summary: Achieving PRIDE in Maintenance requires many things within an organization. It requires a top leader who understands the value of maintenance and its challenges. It requires maintenance managers, supervisors, and foreman that are true maintenance leaders within the important profession of maintenance. It requires crafts leaders and a craft workforce trained and dedicated to profit and customer-centered service. Effective storeroom and support staff all combine to perform the business of maintenance. Across all these people resources there must be dedication to the maintenance profession and PRIDE in Maintenance that comes from teamwork, personal motivation, good leadership, and good maintenance practices. Your maintenance operation will continue to improve its progress on the journey toward maintenance excellence. Maintenance excellence is truly not a final destination but rather a continuous journey.

\_

# Define Your Physical Asset Management Strategy with The Scoreboard for Maintenance Excellence and Go Beyond ISO 55000

## Abstract

This chapter is to help the planner understand how their current operation compares with others in regard to best practices that support the planning scheduling process such as the maintenance storeroom, the parts supply chain, preventive and predictive maintenance, reliability process improvements, and many others that we that will detail in Appendix A— the Scoreboard for Maintenance Excellence™ version 2015. Here are many new best practice categories specific to oil, gas, and petrochemical operations and any complex operation with extreme health, safety, security, and environmental challenges (HSSE). This chapter defines how we can get down to the detailed level of "determining where we are" with actually applying today's best practices.

## **Keywords**

Benchmarking; External benchmarking; Functional benchmarking; Hidden resources; Information resources; Internal benchmarking; ISO 55000; Maintenance excellence strategy team; Maintenance

repair operations (MRO) parts and material resources; PAS 55: 2008; People resources; Performance benchmarking; Physical asset resources; Process benchmarking; Process map; Scoreboard for Maintenance Excellence; Self-assessment; Soloman auditing; Strategic benchmarking; Team-based; Technical skill resources

Previous chapters have provided a prelude of important topics that the planner and others in maintenance should understand especially the practice of true leadership true leadership. The planner should also understand how his or her current operation compares with others in regards to best practices that support the planning scheduling process, such as the maintenance storeroom, their parts supply chain, preventive and predictive maintenance (PdM), reliability process improvements, and many others we will detail in Appendix A—The Scoreboard for Maintenance Excellence version 2015. Here are many new best-practice categories specific to oil, gas, and petrochemical operations and any complex operation with extreme health, safety, security, and environmental (HSSE) challenges. It is also important for top leaders to understand their HSSE challenges as well as to know the scope of the Scoreboard practices as well as the return on investment that can be achieved with an effective planning and scheduling process. Before beginning or renewing our material specific to developing or improving a planning, estimating, and scheduling process, we must get down to the detailed level of "determining where we are" with actually applying today's best practices.

You may have developed a viable physical asset management strategy defined in PASS 55: 2008 Part 1 and 2, now morphed into the ISO 55000 standards. However, you will need to take these open-ended descriptive requirements down to the shop level with prescriptive actions to be taken and measured. Your planners, storeroom, preventive maintenance (PM)/PdM, and all programs for reliability improvement must be fully integrated for gaining maximum value from your planning/scheduling process. This chapter introduces the 2015 version of The Scoreboard for Maintenance Excellence, focused on oil, gas, and petrochemical plant maintenance as your global benchmark or guideline for maintenance best practices. The 2015 version has 38 best-practice categories and

600 specific evaluation items. It has evolved since 1981 (then with 10 benchmark categories and 100 benchmark criteria) into today's most complete benchmarking tool to define where you are on your journey toward maintenance and reliability excellence. Combined with the other three benchmarking tools of The Maintenance Excellence Institute International (TMEII), we feel sure that this book provides today's best process, starting from global, external benchmarking and going down to the craft workforce level. We will discuss in detail how reliable benchmarks for craft repair times are with the ACE (a consensus of experts) Team Benchmarking Process. This is included later in Chapter 15, "Developing Improved Repair Methods and Reliable Maintenance Planning Times with the ACE Team Process." The four levels of maintenance benchmarking are illustrated in Figure 5.1.

# THE SCOREBOARD for MAINTENANCE EXCELLENCE: Benchmarking Current Operation Against Global Best Practices THE CMMS BENCHMARKING SYSTEM: Benchmarks Your Current CMMS to Achieve Maximum Utilization of Your IT Investment The RELIABLE MAINTENANCE **EXCELLENCE INDEX:** Defines Internal Benchmarks and KPI's to Measure and Validate Results of Maintenance and Reliability Excellence Actions The ACE TEAM PROCESS: Provides a Means for Improved Repair Methods and Benchmark Jobs for **Establishing Reliable Planning Times** for Scheduled Work

FOUR LEVELS OF MAINTENANCE BENCHMARKING

Figure 5.1 Maintenance benchmarking from four important levels.

## **Understanding the Types of Benchmarking**

A benchmark is a point of reference for a measurement. The term presumably originates from the practice of making dimensional height measurements of an object on a workbench using a graduated scale or similar tool and using the surface of the workbench as the origin for the measurements. In surveying, benchmarks are landmarks of reliable, precisely known altitude and location and are often manmade objects, such as features of permanent structures that are unlikely to change or special-purpose "monuments," which are typically small concrete obelisks set permanently into the earth. Does your current operation have a current benchmark or assessment as to "where you are" with your physical asset management process? Also, how do you compare to implementing a physical asset management strategy? If you desire to be committed to continuous reliability improvement and progressing toward a profit- and customer-centered operation, here is where we begin to help you get started, especially with the key elements required for successful planning, estimating, and scheduling.

As a planner is beginning their new position, they can then see "where their organization stands" and what may be missing from within their own operation. During my visits to many, many plants, I have seen serious gaps existing that caused the maintenance planning and scheduling process not to achieve its expected results. Therefore, I encourage every planner or maintenance leader to use this document or review any type of other audits, such as one resulting from an ISO 55000 audit, and like Nike, Inc., says, "Just do it." Now that is obviously easier said in a book than doing it in the often hectic maintenance environment no matter how well planned. We will now review parts of the 2015 version of The Scoreboard for Maintenance Excellence contained within Appendix A and enhanced for use within the oil, gas, and petrochemical sectors of business. This new Scoreboard for Maintenance Excellence addresses 38 major benchmark categories with 600 total benchmarking evaluation criteria. The benchmark categories are recognized maintenance best practices from around the world. Some are easier than others and basically can be "do it now" items. Many are strategic, tactical, or even operational tasks and improvement opportunities that

may require added internal and external resources to implement. The Scoreboard for Maintenance Excellence provides the first of four benchmarking tools introduced in this book that the planner can use. First is the global one that "benchmarks where you are with applying external best practices that other successful operations recognize and use or regulatory agencies require. Results from a Scoreboard assessment will identify the gaps and allow development of complete strategic, tactical, operational, or "do it now" plans for physical asset management.

Benchmarking is a very versatile tool that can be applied in various ways to meet a range of requirements for improvement. The following is a summary of different terms used to distinguish the various ways of applying benchmarking and how benchmarking tools from TMEII fit these summary definitions.

1. Strategic benchmarking: Improving an organization's overall performance by examining the long-term strategies and general approaches that have enabled high-performers to succeed. It involves high-level aspects such as core competencies, developing new products and services, changing the balance of activities, and improving capabilities for dealing with changes in the culture of the organizational environment. This type of benchmarking may be difficult to implement, and the benefits are likely to take a long time to see results. I consider an ISO 55000 audit to be in this category as well as best practices from the total scope of the Scoreboard.

The Scoreboard for Maintenance Excellence is strategic benchmarking and what we term global benchmarking because it applies to the total maintenance process and overall best practices for the "business of maintenance." Results from using The Scoreboard for Maintenance Excellence will include a strategic, tactical, and operational level of difficulty in improvement opportunities. There will almost always be "do it now" opportunities that can be immediately implemented.

2. Performance benchmarking or competitive benchmarking: A total organization considers their positions in relation to the performance characteristics of key products and services compared with benchmarking partners (or competitors such as contract maintenance providers) from the same sector. In our scope, this is physical asset management. In the commercial world, companies tend to undertake this type of benchmarking through trade associations or third parties to protect confidentiality. Very seldom will you see

an in-house maintenance operation openly benchmark with a contract maintenance provider. Conversely, contract maintenance providers base their entire business case upon comparing/benchmarking what they can do for your organization compared with what you are now doing or not doing. The planner should also strive to plan and schedule contractors' work and especially make use of the estimated repair times and performance measurement just as we will talk about measuring our own maintenance workforce. As stated several places in this book, you may always takeover a target for contract maintenance providers in one form or another. With the Scoreboard, it can serve performance/competitive benchmarking as it did within the Boeing Commercial Airplane Group, in which all manufacturing units all across the United States were assessed using the same Boeing Scoreboard for Maintenance we developed with specific Boeing criteria added to the 1993 Scoreboard. And because this audit had a 5% impact on maintenance in the top leader's annual performance reviews, this was very competitive benchmarking.

3. Process benchmarking: Focuses on improving specific critical processes and operations. Benchmarking partners are sought from best-practice organizations that perform similar work or deliver similar services. Process benchmarking invariably involves producing process maps to facilitate comparison and analysis. This type of benchmarking can result in short- and long-term benefits. Solomon Associates for refinery studies provide standardized peer groupings for performance comparisons within major geographic areas, operating regions, size/complexity groups, and those of similar configuration within the operating region. Customized peer group selection lets you request more narrowly defined peer groups for each of their refineries. Therefore, as in the military when you know that a command maintenance management inspection (CMMI) is coming or that a Solomon Associates audit is planned, this always brings maintenance to attention as well as operational concerns for each Solomon audit.

We feel very, very strongly that process benchmarking must go beyond analysis paralysis and lead directly to successful implementation and measured results. This gets down to the focused implementation of tactical and operational plans of actions that are based on priorities defined from The Scoreboard for Maintenance Excellence benchmarking or assessment results. It may involve vendors of predictive technology equipment, integrated suppliers, or external consultant resources to help recruit, train, and install a planning function; to help install a CMMS; or to help modernize an MRO (maintenance repair operations) storeroom. Process benchmarking is the complete business case analysis. Results

of process benchmarking plus implementation must be nailed down with a valid measurement process that your financial folks can readily understand and agree upon. Here is where The Reliable Maintenance Excellence Index (RMEI) comes into play as a key benchmarking tool at the shop level as the example shown in Figure 5.2. How to develop your own RMEI will be in discussed in Chapter 25, "How to Measure Total Operations Success with The Reliable Maintenance Excellence Index."

4. Functional benchmarking or generic benchmarking: This is benchmarking with partners drawn from different business sectors, public/private operations, military organizations, and different maintenance environments to find ways of improving similar functions or work processes. This sort of benchmarking related to planning and scheduling can lead to innovation and dramatic improvements. Although this book focuses on the oil, gas, and petrochemical sectors, it can be easily applied universally across all types of operations. Because planning and scheduling within these areas is so critical, there are special best practices necessary for total operations success.

A. Performance Measures	1. Actual Maintenance Cost Per Unit of Production	2. % Major Work Completed within 5% of Cost Estimate	3. % Overal Maintenance Budget Compliance	4. Overall Schedule Compliance	5, % Overall PM Compliance	6. % Planned Work	7.% Craft Time For Customer Charge Back	8. % Work Orders With Reliable Planned Time	9. % Critical Asset Availability	10. % Whench Time (Craft Utilization)	11, % Craft Performance	12, % Inventory Accuracy	13. Number of Stock Outs of Inventoried Stock Berns	F. Perfermance Level Scores
B. Current Month	1.30	90	94	90	94	68	75	50	90	34	90	90	15	Perf Level
C. Performance Goal	1.00	95	98	95	100	80	85	60	95	50	95	98	10	10
D. Baseline Performance Levels	1.05	94	96	94	98	78	83	83	94	48	94	97	11	9
	1.10	93	94	93	96	76	81	56	93	46	93	96	12	8
	1.15	92	92	92	94	74	79	54	92	44	92	95	13	7
	1.20	91	90	91	92	72	77	52	91	42	91	94	14	6
	1.25	90	88	90	90	70	75	50	90	40	90	93	15	- 5
	1.30	89	86	89	88	68	73	48	89	38	89	92	16	4
	1.35	88	84	88	86	66	71	46	88	36	88	91	17	3
	1.40	87	82	87	84	64	69	44	87	34	87	90	18	2
	1.45	86	80	86	82	62	67	42	86	32	86	89	19	1
	1.50	85	78	85	80	60	65	40	85	30	85	88	20	0
E. Performance Level Score	4	5	8	5	7	4	5	5	5	2	5	2	5	I. Total
G. Weighted Value of Metric	10	6	6	1	11	7	6	7	13	8	8	6	5	RMEI Score
H. Performance Level Score (E) x Weight (G)	40	30	48	35	17	28	30	35	65	16	40	12	25	481
J. Total MEI Value Over Time	Date	7.08	8.08	9.08	10.08	11.08	12/08	1.09	2.09	309	4.09	5.09	6.09	
	Score	481												

## Figure 5.2 The RMEI example.

The various Scoreboard versions available from TMEII include The Scoreboard for Maintenance Excellence (manufacturing plants), The Scoreboard for Facilities Management Excellence (pure facilities maintenance), The Healthcare Facilities Scoreboard for Maintenance Excellence (hospitals and other healthcare facilities), and The Scoreboard for Fleet Management Excellence (equipment fleet operations). These four represent unique maintenance processes requiring the art and science of maintenance but applications within different work environments. The sharing of practices and innovations across these maintenance practice areas often can have dramatic improvements or can enlighten one practitioner because exposure to other types of maintenance environments is made via benchmarking.

5. Internal benchmarking: This involves seeking partners from within the same organization (e.g., from business units located in different parts of the world). The main advantages of internal benchmarking are (1) access to sensitive data and information and standardized data are often readily available, (2) less time and fewer resources are usually needed, and (3) the same CMMS such as SAP may be in use. There may be fewer barriers to implementation because practices may be relatively easy to transfer across the same organization. However, real innovation may be lacking, and best-in-class performance is more likely to be found through external benchmarking.

The Scoreboard for Maintenance Excellence is ideal for this internal benchmarking by making comparisons between maintenance operations within a larger organization. A Strategy for Developing a Corporate-Wide Scoreboard in this chapter defines how multiple site operations can provide internal benchmarking with TMEII tools. A Scoreboard for Maintenance Excellence assessment will define "where you are" and helps you to then define a physical asset management strategy to cover the gaps in your current strategy.

We also consider the RMEI, as was shown in Figure 5.2, as an important internal benchmarking process, but this tool is at the grassroots level—the shop floor. It should also focus not just on maintenance but rather the success of the total operations, whether a plant, a pure facilities complex, a fleet operations, or

healthcare facility, as well as the equipment maintenance process. It is here from the RMEI that we will measure the success of our planning and scheduling process.

6. External benchmarking: Outside organizations that are known to be best in class are sought out to provide opportunities of learning from those who are at the leading edge. For example, the North American Maintenance Excellence award is given to nominees each year, and in 1999, the Marathon Ashland Petroleum refinery in Robinson, IL, received this prestigious award. During most of 1998, I was fortunate to work with Marathon to evaluate and select a CMMS system, which resulted in the selection of Meridian's solution, which included robust reliability-related data analysis. The Robinson refinery also had a world-class planning, estimating, and scheduling process at that time.

External benchmarking keeps in mind that not every best-practice solution can be transferred to others. This type of benchmarking may take up more time and resources to ensure the comparability of data and information, the credibility of the findings, and the development of sound recommendations. External learning is also often slower because of the "not invented here" syndrome.

The Scoreboard for Maintenance Excellence is also an external benchmarking tool, defining "where you are" with overall maintenance and physical asset management best practices at a single site or across multiple sites within the same organization. In fact, at Marathon we conducted Scoreboard assessments at each of their five refineries to help determine functional requirements for a future CMMS and other best-practice needs.

7. International benchmarking: This is used when partners are sought from other countries because best practitioners are located elsewhere in the world and/or there are too few benchmarking partners within the same country to produce valid results. The Toyota production system is a prime example. Globalization and advances in information technology (IT) are increasing opportunities for international projects. However, these can take more time and resources to set up and implement, and the results may require careful analysis because of national differences.

However, our work with many international maintenance operations has shown that we can learn or have our so-called best practices reconfirmed when we see maintenance in other countries. For example, my experience with Boeing, SIDERA Argentina, Ford Argentina, Coke Argentina, Avon Brazil, and AC Smith Mexico reconfirms that a very simple best practice—cleanliness in shops and plant areas—is an important contributor to maintenance excellence and pride in maintenance. I truly believe this and have seen it; therefore, planners get your maintenance leader to periodically have you schedule some shop clean-up time as needed.

Our Scoreboards all began originally as The Scoreboard for Excellence in Maintenance and Tooling services in 1981 while I was the industrial engineering manager for the Cooper Tool Group, the hand tool division of Cooper Industries. One of my many roles on a very small corporate staff was to improve maintenance processes at our seven plants: Crescent-Xcelite, Weller, Plumb, Nicholson File, Nicholson Saw, Wiss, and Lufkin. Ironically, after learning the manufacturing operations in each of these high-quality hand tool plants, I got the chance to be plant manager of the one making the "Knuckle Buster" Crescent Wrench. I was hired at the Cooper Tool Group corporate level, not only for my industrial engineering background but also for my previous maintenance experience installing a very extensive fleet maintenance management across 100 county shops from 1973 to 1975 for the North Carolina Division of Highway's Equipment Unit in the North Carolina Department of Transportation. We recruited, selected, trained, and installed over 66 planners across the 14 divisions within the North Carolina Department of Transportation.

## How Do You Get "There" If You Do Not Know Where There Is When You Start?

That question was my first concern as I tried to spread the maintenance gospel. A map is completely useless if you do not know your current location—"where you are right now on the ground." For the seven Cooper Tool Group plants, my first task was to determine "where we are" with regards to current maintenance practices. Therefore, research began to put together an assessment tool to benchmark where we were with best practices. Tooling services were included in this first Scoreboard because all plants had extensive tool rooms. For example, Nicholson File in Cullman, AL, made 80% of their repair parts for their custombuilt file-making machines. It was a parts manufacturing business and in the business of maintenance. We began with a self-assessment, which helped to get each plant to understand the basic best practices that were to come as we later got down to supporting each plant. The evolution of The Scoreboard for Maintenance Excellence is summarized in Figure 5.3.

The 1993 version of The Scoreboard for Maintenance Excellence, shown graphically in Figure 5.4, evolved and was used until 2003, when the next enhancement was made in 2010 using Excel and allowing up to five evaluators to be analyzed for level of consensus.

Over 30 Years of Application and Evolution: You can see how this external, global benchmarking process has evolved from over 30 years of successful application to many different types of public and private organizations. Its counterpart, the Scoreboard for Facilities Management Excellence<sup>TM</sup>, was also developed for pure facilities maintenance operations.

We will define now a recommended approach to develop your overall maintenance strategy and your own unique Scoreboard for Maintenance Excellence for continuously evaluating progress on your journey toward physical asset management excellence. Of course, the very first step is for the top leaders, maintenance leader, and the overall plant to have a firm commitment to improving the total maintenance operation. This is something we discussed in

Chapter 1 and is a main ingredient for ISO 55000 success. Supply and maintenance are high priorities across all five of the U.S. military services. Without a C-position (Chief Maintenance Officer) as a champion for maintenance, the total operation may not view and accept as core business requirement.

However, it is very important to avoid taking a piecemeal approach. A consistent piecemeal approach I and others can also confirm is that a new CMMS is not "the solution." Others within the organization must also understand this and share the commitment for best practices that are enhanced by a good CMMS. One key element of success is having a commitment from top-level leaders across the organization and craft leaders. Establishing a formal maintenance excellence strategy team is highly recommended, including having a current planner. This high- to mid-level, leadership-driven, cross-functional team can be made up from maintenance leaders, key operations leaders, shop-level maintenance staff, IT, engineering, procurement, operations/customer, and financial and human resources staff. Some may be designated as resources only when they are needed. At least one craft employee is always a recommended member of the maintenance excellence strategy team. Figure 5.5 illustrates continuous reliability improvement steps to improve the total operation.

Evolution of the Scoreboard	for Maintenance Excellence <sup>TM</sup>
-----------------------------	--

Date	Scoreboard Version	Benchmark Categories	Benchmark Criteria	Focus
1981	Scoreboard for Excellence	10	100	Plant Maintenance and Tooling Services
1993	Scoreboard for Maintenance Excellence	18	200	Plant Maintenance
2003	Scoreboard for Maintenance Excellence	27	300	Plant Maintenance
2003	Scoreboard for Facilities Management Excellence	27	300	Facilities Maintenance
2003	Scoreboard for Healthcare Maintenance Excellence	27	300	Healthcare Facilities Maintenance
2004	Scoreboard for Fleet Maintenance	27	300	Fleet Maintenance
2010	Scoreboard for Maintenance Excellence	27	300	Plant Maintenance-Updated Excel Design
2015	Scoreboard for Maintenance Excellence	38	600	Updated for Improved Oil & Gas Use and Many Categories Expanded

Figure 5.3 Evolution of the Scoreboard for Maintenance Excellence.

The Maintenance Excellence Strategy Team: The mission of this team is to develop, lead, and facilitate the overall maintenance improvement process and to ensure measurement of results. Top leader support and required resources must be provided. This team can also sponsor other teams within the organization (e.g., to support implementation operational plans for an individual site's planning and scheduling process). One of the very first things that this team should do is to sponsor a comprehensive evaluation of the total physical asset management and maintenance operation. Again, this is the first step to help determine "where you are." A sample charter for a maintenance excellence strategy team is included in Appendix D. This example was used for a multisite operation that was also undergoing the installation of a new CMMS, storeroom modernizations, and maintenance planner selection and training. Another case study charter for a new CMMS for Ghana's national power transmission company is also included in Appendix D.

#### 1993 Version of The Scoreboard for Maintenance Excellence

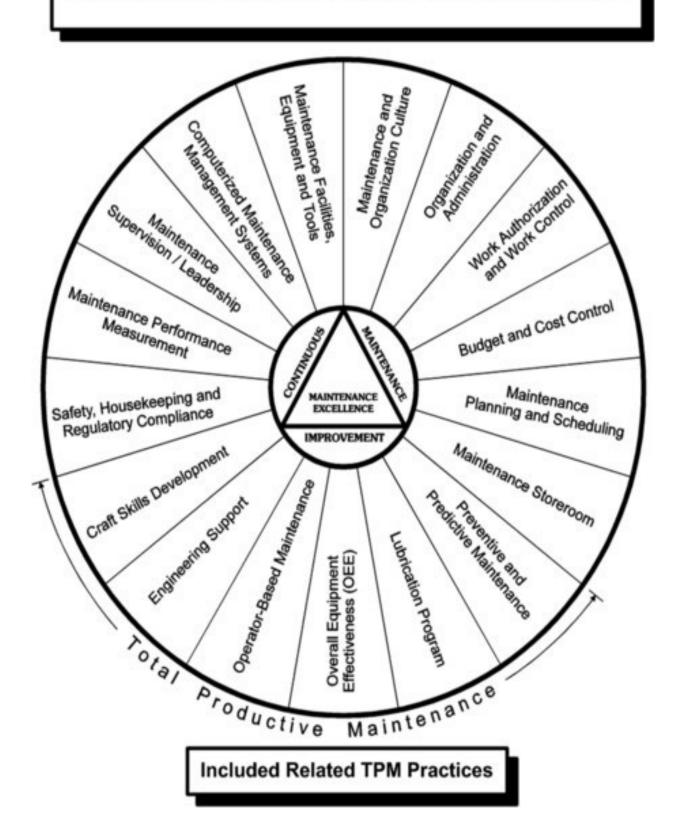


Figure 5.4 The 1993 Scoreboard for Maintenance Excellence.

How to Determine "Where You Are": The real goal is improvement of your total maintenance operation to better support profit- and customer-service of the total operation. Maintenance leaders must clearly understand and remember—your maintenance operation is not the tail wagging the dog, and you are working for your production customers as a total maintenance operation. Within plant maintenance operations, this is maintenance and repair of all production and facility assets; supporting infrastructure; overhaul and renovation activities; engineering support processes; and all material management and procurement of typical repair parts, supplies, and contracted services. You should benchmark your current operation against today's best practices for PM and PdM, especially planning and scheduling, effective spare parts control, work orders, work management, and the effective use of computerized systems for maintenance business management. The 2015 Scoreboard also includes 13 new categories, most of which apply to the oil and gas sectors as well as large, complex, continuous processing operations. This step is important because it gives you a baseline as to your starting point for making improvements and for validating results. It will help to ensure that you are taking the right steps for taking care of your mission-essential physical assets. They are included in Figures 5.6 and 5.7.

# CONTINUOUS RELIABILITY IMPROVEMENT IMPROVES THE TOTAL MAINTENANCE OPERATION

Continue With Continuous Reliability Improvement You Must Know Where You Are With Applying Today's Best Practices

Conduct a
Scoreboard
for
Maintenance
Excellence
AssessmenT

Establish Potential Benefits and Validate Results Improve Your Total Maintenance Operation

Know Where You Want to Go With a Plan of Action

Invest in Maintenance and Commit to Implementation

Figure 5.5 Continuous reliability improvement steps to improve the total operation.

In most cases, an independent evaluation helps to reinforce the local maintenance leader's desire to take positive action in the first place and to do something to improve the overall maintenance process. For multiple site operations, this provides a great opportunity for developing standard best practices that can be used across the corporation and for all sites.

The Scoreboard for Maintenance Excellence: You can also develop your own Scoreboard for Maintenance Excellence as Boeing did using the TMEII 1993 Scoreboard as the baseline. You then begin with a self-assessment, but we normally recommend getting help from a third-party consulting resource and beginning with at least a pilot plant site. For example, for Boeing, we tested the Boeing Scoreboard at the Portland plant before it was used on all five manufacturing regions (at that time with central leadership at corporate level). Therefore, if you plan a corporate-wide assessment/audit, define your own Scoreboard and test it on what you see as your best plant and especially the best planning and scheduling process. Personally, I will wager a significant sum of money that the best plant will have the best planning and scheduling process. Figure 5.8 illustrates how The Scoreboard for Maintenance Excellence includes these six key maintenance resources and how hidden resources can evolve from the synergy of team efforts.

#### THE SCOREBOARD FOR MAINTENANCE EXCELLENCE™ 2015 Part 1

#### MAINTENANCE BENCHMARK EVALUATION SUMMARY

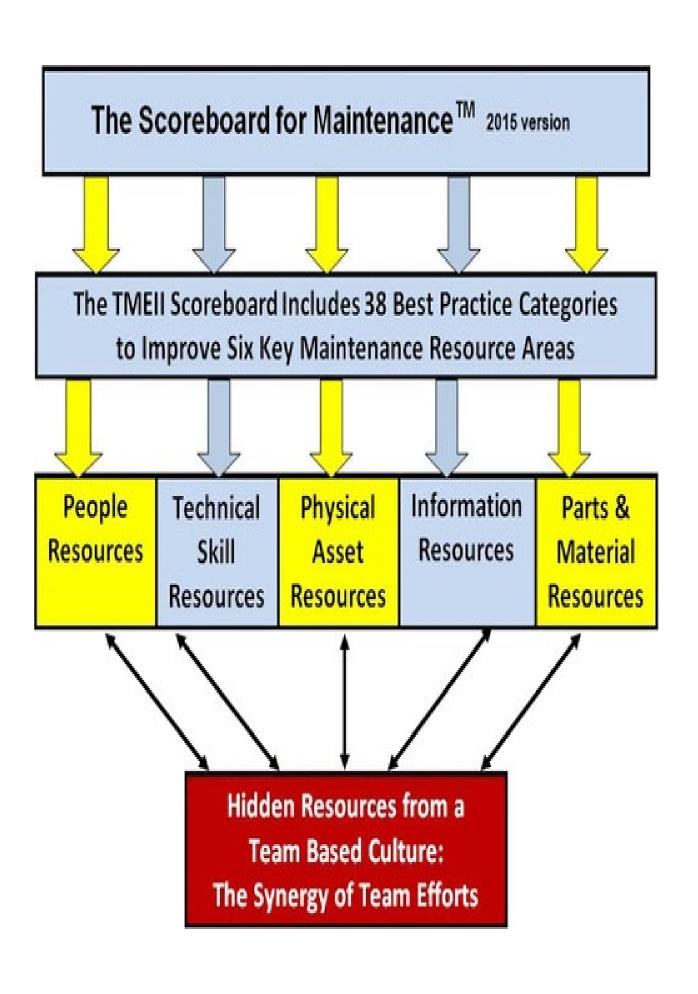
Category Number	Benchmark Category Descriptions & Rating Values for Each Evaluation Criteria 5=Poor, 6=Below Average, 7=Average, 8=Good, 9-Very Good & 10= Excellent  New Benchmark or Expanded Category	Number of Criteria	Total Assessment Points per Category
1,	Top Management Support to Maintenance and Physical Asset Management	10	100
2.	Maintenance Strategy, Policy and Total Cost of Ownership	30	300
3.	The Organizational Climate and Culture	9	90
4,	Maintenance Organization, Administration and Human Resources	18	180
5.	Craft Skills Development and Technical Skills	12	120
6.	Operator Based Maintenance and PRIDE in Ownership	10	80
7.	Maintenance Leadership, Management and Supervision	12	120
8.	Maintenance Business Operations, Budget and Cost Control	15	150
9.	Work Management and Control: Shop Level Maintenance Repair (M/R)	12	120
10.	Work Management and Control: Shutdowns, Turnarounds and Outages (STO)	26	260
11.	Shop Level Reliable Planning, Estimating and Scheduling M/R	30	300
12.	STO and Major Planning /Scheduling and Project Management	16	160
13.	Contractor Management	31	310
14.	Manufacturing Facilities Planning and Site Property Management	9	90
15.	Production Asset and Facilities Condition Evaluation Program	6	60
16.	Storeroom Operations and Internal MRO Customer Service	12	120
17.	MRO Materials Management and Procurement	12	120
18.	Preventive Maintenance and Lubrication	18	180
19,	Predictive Maintenance and Condition Monitoring Technology Applications	15	150
20.	Reliability Centered Maintenance (RCM)	34	340

**Figure 5.6 Part 1: Scoreboard for Maintenance Excellence.** 

#### THE SCOREBOARD FOR MAINTENANCE EXCELLENCE™ 2015 Part 2

Category	Benchmark Category Descriptions & Rating Values for Each Evaluation Criteria 5=Poor, 6=Below Average, 7=Average, 8=Good, 9-Very Good & 10= Excellent		Total Assessment Points Per
	New Benchmark Category or Expanded Category		Category
21.	Reliability Analysis Tools: Root Cause Analysis (RCA), Root Cause Corrective Action (RCCA Failure Modes Effects Analysis (FMEA), Root Cause Failure Analysis (RCFA) and Failure Reporting Analysis and Corrective Action System (FRACAS)	17	170
22.	Risk Based Maintenance (RBM)	24	240
23.	Process Control and Instrumentation Systems Technology		09
24.	Energy Management and Control		120
25.	Maintenance Engineering and Reliability Engineering Support		90
26.	Health, Safety, Security and Environmental (HSSE) Compliance		150
27.	Maintenance and Quality Control		90
28.	Maintenance Performance Measurement		120
29.	Computerized Maintenance Management System (CMMS) as a Business System		180
30.	Shop Facilities, Equipment, and Tools		90
31.	Continuous Reliability Improvement	15	150
32,	Critical Asset Facilitation and Overall Equipment Effectiveness (OEE)	15	150
33.	Overall Craft Effectiveness (OCE)	6	60
34.	Sustainability	[]	110
35.	Traceability	19	190
36.	Process Safety Management (PSM) and Management of Change (MOC)	26	260
37.	Risk Based Inspections (RBI) and Risk Mitigation	29	290
38.	PRIDE in Maintenance	8	80
	Total Evaluation Items:	600	2330
	Scoreboard Total Possible Points:		6000
	Actual Total Benchmark Value Score of All Ratings:		
	Assessment Performed By:	Date:	

Figure 5.7 Part 2: Scoreboard for Maintenance Excellence.



### Figure 5.8 Six maintenance resources to improve maintenance in total, not piecemeal.

The 2015 version of The Scoreboard for Maintenance Excellence was updated by adding or expanding these 15 important best-practice categories shown in Figure 5.9.

The Scoreboard for Maintenance Excellence provides a means to evaluate how we are managing our six key maintenance resources: people, technical skills, physical assets, information, parts and materials, and our hidden resources—the synergy of team efforts. The following shows how the 38 evaluation categories are broken down across the six key maintenance resource areas:

#### 1. People Resources

- Top management support to maintenance and physical asset management
- The maintenance organizational climate and culture
- Pride in maintenance
- Maintenance organization, administration, and human resources
- Contractor management
- Operator-based maintenance and pride in ownership
- HSSE compliance
- Shop facilities, equipment, and tools
- Risk-based inspections and risk mitigation
- Process safety management (and management of change)
- Risk-based maintenance

## SCOREBOARD FOR MAINTENANCE EXCELLENCE VERSION 2015

Scoreboard Category Number	New or Expanded Benchmark Categories for Scoreboard Version 2015	Number of Criteria	Total Assessment Points per Category
1.	Top Management Support to Maintenance and Physical Asset Management	10	100
2.	Maintenance Strategy, Policy and Total Cost of Ownership	30	300
10.	Work Management and Control: Shutdowns, Turnarounds and Outages (STO)	26	260
11.	Shop Level Reliable Planning, Estimating and Scheduling M/R	30	300
12.	STO and Major Planning /Scheduling and Project Management	16	160
26.	Health, Safety, Security and Environmental (HSSE) Compliance	15	150
13.	Contractor Management	3)	310
20	Reliability-Centered Maintenance (RCM)	34	340
21.	Reliability Analysis Tools: Root Cause Analysis (RCA), Root Cause Corrective Action (RCCA Failure Modes Effects Analysis (FMEA), Root Cause Failure Analysis (RCFA) and Failure Reporting Analysis and Corrective Action System (FRACAS)	17	170
22.	Risk Based Maintenance (RBM)	24	240
34.	Sustainability	11	110
35.	Traceability	19	190
36	Process Safety Management (PSM) and Management of Change (MOC)	26	260
37.	Risk Based Inspections (RBI) and Risk Mitigation	29	290
38.	PRIDE in Maintenance	8	80

Figure 5.9 Fifteen new or expanded Scoreboard for Maintenance Excellence benchmark categories in version 2015.

#### 2. Technical Skill Resources

- Craft skills development and technical skills
- Maintenance engineering and reliability engineering support
- Reliability centered maintenance (RCM)
- Overall craft effectiveness

#### 3. Physical Assets and Equipment Resources

- Production asset and facility condition evaluation program
- PM and lubrication
- Predictive maintenance and condition monitoring technology applications
- Process control and instrumentation system technology
- Energy management and control
- Maintenance and quality control
- Sustainability
- Critical asset facilitation and overall equipment effectiveness

#### 4. Information Resources

- Maintenance strategy, policy, and total cost of ownership
- Maintenance business operations, budget, and cost control
- Work management and control: maintenance and repair
- Work management and control: shutdowns, turnarounds, and outages (STOs)
- Shop-level maintenance planning and scheduling
- STO and major planning/scheduling and project management
- Manufacturing facilities planning and property management
- Maintenance performance measurement
- Traceability
- CMMS and business system

#### **5. Parts and Material Resources**

- Storeroom operations and internal MRO customer service
- MRO materials management and procurement

#### 6. Hidden Resources—The Synergy of Team Efforts

- Maintenance leadership, management, and supervision
- Reliability analysis tools: root cause analysis, root cause corrective action, failure modes effects analysis, root cause failure analysis, and failure reporting analysis and corrective action system
- Continuous reliability improvement

Your Global Benchmark: An assessment using The Scoreboard for Maintenance Excellence provides a "global, external" benchmark against today's best maintenance practices. It is very important to note that the overall total score for the assessment is not an absolute value. However, the assessment results and the overall total score do represent an important benchmark and a baseline value. Results will identify relative strengths within an operation and opportunities for improvement from among the 38 best-practice areas and 600 prescriptive evaluation items. The assignment of baseline values to each evaluation item is not an exact science. It should be based on an objective assessment of the best practice item when observed at a point in time.

Benchmarking Results: Overall assessment results fall into five possible overall rating levels as shown in Figure 4.6: excellent, very good, good, average, and below average. Each of the five overall ratings levels represents at least a nine percentage point spread.

A summary of baseline value assignment for each rating level is as follows (Figure 5.10):

Baseline Value 10: Excellent: The practices and principles for this evaluation item are clearly in place, and this rating provides an example of world-class application of the practice. There is evidence that this practice has received high-priority support in the past to achieve its current level.

For an overall baseline rating of excellent, the range of total baseline points is 5400-6000 points or 90-100% of the total possible baseline points of 6000.

TOTAL POINT  RANGE	SCOREBOARD FOR MAINTENANCE EXCELLENCE™: BENCHMARK RATING SUMMARY
90% to 100% of Total Points	EXCELLENT: 5400 to 6000 Points
80% to 89% of Total Points	VERY GOOD: 4800 to 5399 Points
70% to 79% of Total Points	GOOD: 4200 to 4899 Points
60% to 69% of Total Points	AVERAGE: 3600 to 4199 Points
50% 59% of Total Points	BELOW AVERAGE: 3000 to 3599 Points
49% and Less%	POOR: Less than 2999

#### Figure 5.10 Benchmark rating summaries by total point range.

Baseline Value 9: Very Good: This rating denotes that current practices are approaching world-class level as a result of high-priority focus on continuous improvement for this evaluation item. This practice continues to be a high priority for improvement within the organization.

For an overall very good baseline rating, the range of total baseline points is 4800–5399 points or 80–89% of the total possible baseline points of 6000.

Baseline Value 8: Good: This rating denotes that the practice is clearly above average and above what is typically seen in similar maintenance operations. There is a need for additional emphasis, to reassess priorities, and to reconfirm commitments to improvement for this evaluation item.

For an overall good baseline rating, the range of total baseline points is 4200–4899 points or 70–79% of the total possible baseline points of 6000.

Baseline Value 7: Average: This rating represents the typical application of the practice as seen within a maintenance operation that has had very little emphasis toward improvement. It reflects an operation that typically is just maintaining the status quo. The organization should conduct a complete assessment of maintenance operations and review this practice in detail for improvement or for implementation if it is not currently in place.

For an overall average baseline rating, the range of total baseline points is 3600–4199 points or 60–69% of the total possible baseline points of 6000.

Baseline Value 6: Below Average: This rating (a score of 6) denotes that the application of this practice is below what is typically seen in similar maintenance operations. This practice may not be currently in place and should be considered as part of the organization's continuous improvement process. Immediate attention may be needed in some areas to correct conditions having an adverse effect on customer service, safety, regulatory compliance, or maintenance costs.

For an overall baseline rating of below average, the total baseline points are

#### from 3000 to 3599 points of the total possible baseline points of 6000.

Baseline Value 5: Poor: This rating denotes that the application of this practice is below what is typically seen in similar maintenance operations. Similar to a below average rating, this practice may not be currently in place and should be considered as part of the organization's continuous improvement process. Immediate attention is to correct conditions having an adverse effect on customer service, safety, regulatory compliance, or maintenance costs.

For an overall baseline rating of poor, the total baseline points are less than 2999, or 49% or less of the total possible baseline points of 6000.

Figure 5.11 provides key comments for each of the Scoreboard for Maintenance Excellence benchmark rating levels.

Appendix A includes a complete Scoreboard for Maintenance Excellence formatted as shown in the following example in Figure 5.12.

Benchmark Criteria Number 1: This example also illustrates the very first benchmark evaluation criteria on the Scoreboard, which is related to whether or not maintenance is a considered a priority in your operation. Does your organization include maintenance within its plant goals as a key item?

TOTAL POINT RANGE	SCOREBOARD FOR MAINTENANCE EXCELLENCE™: RATING SUMMARY COMMENTS			
90% to 100% of Total Points	5400 to 6000 points Excellent: Practices and principles in place, for achieving maintenance excellence and World Class performance based on actual results.  Reconfirm overall maintenance performance measures. Maintain strategy of continuous improvement. Set higher standards for maintenance excellence and measure results.			
80% to 89% of Total Points	4800 to 5399 Points -Very Good: Fine-tune existing operation and current practices.  Reassess progress on planned or ongoing improvement activities. Redefine priorities and renew commitment to continuous improvement. Ensure Top Leaders see results and reinforce performance measurement process.			
70% to 79% of Total Points	4200 to 4799 Points-Good: Reassess priorities and reconfirm commitments at all levels of improvement. Evaluate maintenance practices, develop, and implement plans for priority improvements. Ensure that measures to evaluate performance and results are in place Initiate strategy of continuous reliability improvement.			
60% to 69% of Total Points	3600 to 4199 Points-Average: Conduct a complete assessment of maintenance operations and current practices. Determine total costs/benefits of potential improvements. Develop and initiate strategy of continuous reliability improvement. Define clearly to Top Leaders where deferred maintenance is increasing current costs and asset life cycle costs. Gain commitment from Top Leaders to go beyond maintenance of the status quo.			
50% to 59% of Total Points	3000 to 3599 Points-Below Average: Same as for Average, plus, depending on the level of the rating and major area that is Below Average, immediate attention may be needed to correct conditions having an adverse effect on life, health, safety, and regulatory compliance. Priority to key issues, major building systems and equipment where increasing costs and deferred maintenance are having a direct impact on the immediate survival of the business or the major physical asset. The capabilities for critical assets to perform intended function are being severely limited by current "state of maintenance". Consider possible leadership as required for business survival and for achieving the core requirements for maintenance services. Determine if the necessary investments for internal maintenance improvements is going to be made			
49% or Less	2999 or Less Points-Poor: Same as for Below Average, plus, depending on the level of the rating and major area that is Poor, immediate attention may be needed to correct conditions having an adverse effect on life, health, safety, and regulatory compliance. An overall Total Score indicates that contract maintenance should be considered Priority to key issues, major building systems and equipment where increasing costs and deferred maintenance are having a direct impact on the immediate survival of the business or the major physical asset. The capabilities for critical assets to perform intended function are being severely limited by current "state of maintenance". Consider immediate contract services as required for business survival and for achieving the core requirements for maintenance services. Determine if the necessary investments for internal maintenance improvements are going to be made. An overall poor rating requires a close look at the effectiveness of leadership at all levels.			

Figure 5.11 Rating summary comments for results from a Scoreboard for Maintenance Excellence assessment.

## 1. TOP LEADER'S SUPPORT TO MAINTENANCE & PHYSICAL ASSET MANAGEMENT

ITEM#	Rating: Excellent - 10, Very Good - 9, Good - 8, Average - 7, Below Average - 6, Poor - 5	RATING
	The organization has a strategic plan that is the starting point for development of the asset management and maintenance strategy, policy, objectives and plans	9

#### Figure 5.12 Example format of benchmark evaluation criteria.

Lesson Learned: As a plant manager of a high-quality hand tool manufacturing plant in the mid-1980s, I was fortunate to be a part of an operation that did have maintenance as a key written part of our plant goals, as listed below:

## Plant Operating Goals: Crescent-Xcelite Plant (A Division of Cooper Industries)

- 1. Aggressive investigation and follow-through of potential new products and markets. Maintain a close working relationship with sales and marketing functions to enable Crescent-Xcelite to react to customer and marketplace changes.
- 2. New manufacturing technology will be integrated into our manufacturing methods and process. This will allow Crescent-Xcelite to be competitive in the basic areas of quality, price, and service.
- 3. Maintain technical competence or workforce (internal and external training).
- 4. Clean, orderly, safe workplace.
- 5. Create an atmosphere of pride in workmanship (quality awareness and quality improvement programs).
- 6. Balanced line product flow through manufacturing phases using hard automation or robotics when economically feasible.
- 7. Control all inventory levels using automated reporting and Materials Requirement Planning (MRP) system and capacity planning.
- 8. PM to monitor and adjust equipment to eliminate production disruptions.
- 9. Simplified quick-change tooling to accommodate short runs and reduce Materials Requirement Planning (MRP).
- 10. Equipment and tooling monitored to achieve 100% first-run quality capability.
- 11. Create a no-crisis atmosphere for all employees.

In our case, effective PM and PdM was one of our key operating goals for the plant and was one of the factors contributing our quality and service level during a period of intense competition from foreign hand tool manufacturers. Our PM included not only heavy machining equipment, heat treat, plating, molding, and automated forging equipment, but it also included all of the tooling fixtures, cutters, and dies used in a high-quality machining operation. I vividly remember that our contracted vibration analysis service saved us from having a major catastrophic failure with a new automatic side polishing machine

Never, never, never give up: If you do not have a top leader that appreciates and values maintenance as a key contributor to profit and customer service, then do not give up. As Jim Valvano (the late coach of the 1983 North Carolina State National Champions) and Great Britain's World War II leader Winston Churchill both said, "Never, never, never give up!" Continue the good fight, get the facts for true return on maintenance investments, and continue to educate top leaders that pride in maintenance is a core requirement for total operations success. As a new or experienced planner, you play a key role in leading maintenance forward with proactive maintenance and greater productivity. Know what best practices you need or just the often very plain adjustments needed to make your planning, estimating, and scheduling a reliable process in your operation.

We strongly believe in basic maintenance best practices as the foundation for maintenance excellence. Our improvement process includes all maintenance resources, equipment, and facility assets as well as the craftspeople and equipment operators. It also includes MRO materials management assets, maintenance informational assets, and the added value resource of synergistic team-based processes. Continuous reliability improvement improves the total maintenance operation.

The Scoreboard for Maintenance Excellence concept and the various Scoreboard versions have been used to perform over 200 maintenance assessments/audits, and over 5000 organizations have requested and received copies for their internal use. For example, The Scoreboard for Maintenance Excellence was used by plant maintenance operations at Honda of America after making slight modifications and then using it extensively as a self-assessment to help direct their maintenance strategy. It was then translated into Japanese for presentation to key Japanese executives visiting Honda plants in the United States. Another excellent example as discussed previously is where the Boeing Commercial

Airplane group combined elements from this same Scoreboard with their company-wide maintenance goals to develop The Boeing Scoreboard for Maintenance Excellence. At Boeing, over 60 manufacturing maintenance work units at region, group, and team levels were then evaluated with structured onsite visits. The use of this comprehensive best-practice guideline, specifically tailored to the maintenance of aircraft manufacturing equipment (and the associated manufacturing and test facilities complexes) across the United States, is still one of the largest internal benchmarking efforts ever undertaken.

A Complete Scoreboard Self-Assessment is Recommended, So "Just do it!": For example, MRO materials management, storeroom operation, and procurement may be an area needing special attention. Shop-level planning and scheduling is often a typical need and can be a primary focus area. Regardless of the different areas creating the obvious concerns and "organizational pain," a short-term, piecemeal approach to an evaluation is not recommended. A complete benchmark evaluation of the total maintenance operation is highly recommended. There are 600 specific evaluation items that are evaluated through direct shop floor interviews, close observations, and review of information or procedures. Each one is important; some provide more value more than others. However, each of the 600 items on The Scoreboard for Maintenance Excellence is part of establishing a solid foundation for profit- and customer-centered maintenance. Long-term continuous reliability improvement is also a very important connecting link that ensures that we consider all maintenance resources in our improvement process. The journey is not to maintenance excellence but rather a journey that continuously moves toward maintenance excellence. Another key point is all about what this book encourages you to do with all topics in this book. That key point borrowed from the Nike commercial says to "Just do it."

Several organizations such as TMEII stand ready to support your mission-essential plant maintenance operation with an assessment performed by well-qualified staff. Although a self-assessment has many benefits, we believe an assessment conducted by an outside resource provides a greater sense of the "big picture" in terms of objectivity and completeness. Regardless of your situation, it is important that you do something to "determine where you are." Should you want to begin with an internal self-assessment of maintenance, here are some guidelines to consider when using The Scoreboard for Maintenance Excellence. You can do a self-assessment at any time by using Appendix A in this book. See

Figures 5.13 and 5.14 for key steps for your self-assessment.

#### **Obtain Leadership Buy-In**

- 1. Establish a firm commitment from the organization's top leadership for conducting a total maintenance operation assessment. Figure 5.2 illustrates this important key to your success. Not only must the commitment be from top leadership, it must also begin with the maintenance leader.
- 2. Establish a firm commitment from the organization's top leadership to take action based on your current needs. Every organization is different and may have a need to focus on one or more specific best-practice categories. For example, in this case, the self-assessment can focus on areas such as improving storeroom operations or planning and scheduling processes. However, the assessment must take a complete look at all Scoreboard categories and get a complete "where we are now" picture of the total maintenance process.

## THE SCOREBOARD for MAINTENANCE EXCELLENCE ASSESSMENT:

Key Steps to Continuous Reliability Improvement

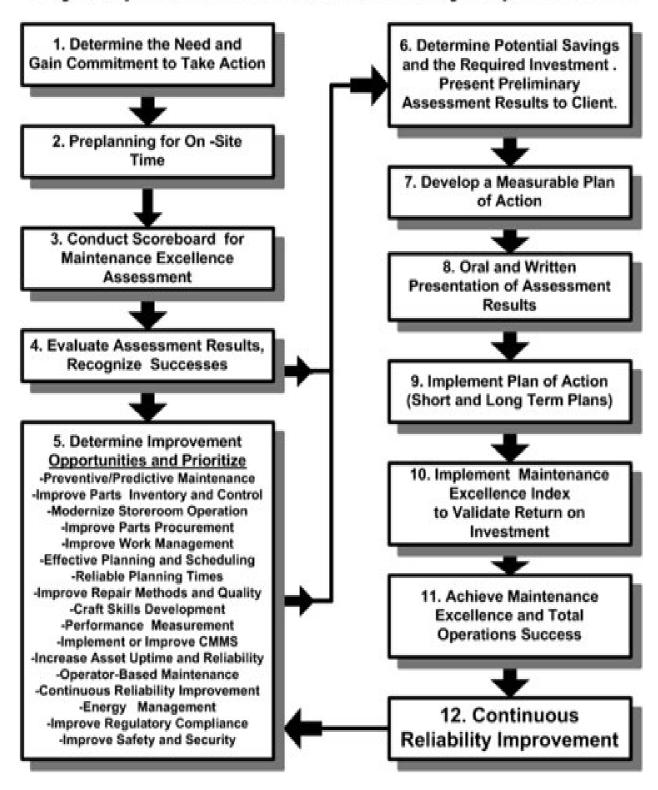
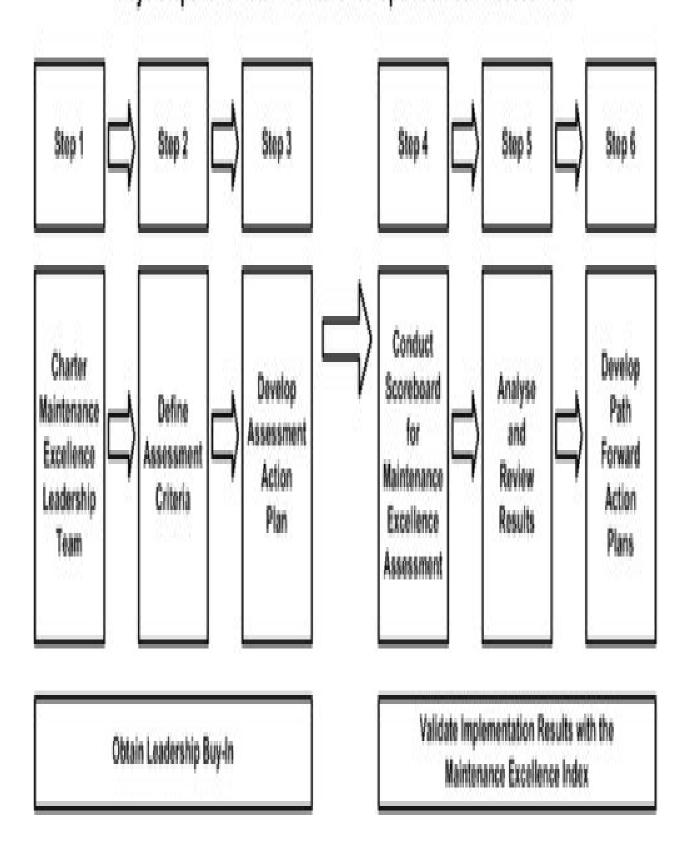


Figure 5.13 Key steps for the Scoreboard for Maintenance Excellence assessment.

## Keys Steps for a Total Maintenance Operation Self-Assessment



#### Figure 5.14 Key steps for your self-assessment.

3. Maintenance leaders must be brave enough and prepared to share good news and bad news on the basis of results of the evaluation to top leaders. When we perform an assessment, we strive to make it a very positive process for all involved. There will always be successes to highlight and really no bad news; rather, we focus on opportunities.

### **Step 1: Charter Maintenance Excellence Strategy Team**

- (a) Establish a maintenance excellence strategy team to guide and promote improved maintenance practices within your organization whether at single or multiple sites
- (b) Use a team-based approach with a cross-functional evaluation team specifically chartered for conducting and preparing the results of your evaluation
- (c) Have at least one team member (or designated resource person) with a solid background and knowledge in each of the 38 evaluation categories
- (d) Consider bringing on board third-party outside support to be a part of your team and the assessment process.

### Step 2: Understand the Evaluation Categories and Evaluation Criteria

- (a) Gain complete understanding of each of the 600 evaluation items
- (b) Modify existing evaluation criteria as required for your organization
- (c) Define the importance and weighted value of evaluation categories
- (d) Add or delete evaluation criteria as required for your unique operation
- (e) Ensure that all team members understand the scoring process for each evaluation item
- (f) Ensure that consistency in scoring each evaluation category is applied using standard guidelines

### **Step 3: Develop Assessment Action Plan**

(a) Determine baseline information requirements, persons to interview, and observations needed before the start of the evaluation. A pre-assessment checklist follows:

### **Pre Assessment Checklist for Baseline Information**

The following checklist is not all inclusive of the information required for an assessment. It does represent very important areas that we try to get before performing an assessment. All of the data/information listed in the following checklist may not be readily available. As much information as possible should be assembled and reviewed before the start date of the assessment. When we perform an assessment, this step allows us to gain a better understanding of the client's operation before the on-site visit and helps save a lot of time when on site.

### **Organization Charts/Job Descriptions**

- Mission statement/quality statement for your overall organization
- Mission statement for your maintenance operation
- Staff directory of personnel and contact information/e-mail, etc
- Organization chart for your plant/facility
- Maintenance organization charts by each craft area
- Head counts in each craft area
- Position descriptions of key maintenance leaders—managers, supervisors, foremen, maintenance engineers, planners, team leaders, storeroom supervisor, etc.
- Craft job descriptions—sample from each craft area

### **Craft Skills Development**

- Information on craft training completed in past several years (i.e., in-house programs, vendor)
- Seminars or ongoing apprenticeship programs, etc.
- Results of past craft skills assessments or employee surveys on training needs, etc.

### **Craft Labor Rates/Overtime History**

- Average hourly rate by craft area
- Average fringe benefit percentage factor for your organization
- Overtime rates
- Past 3 to 5-year history of overtime
- Overtime hours (by craft area, if available)
- Overtime payroll costs (by craft area, if available)

## **Maintenance Budget and Cost Accounting**

• Total maintenance budget (3 years)

- Total craft labor cost (3–5 years)
- Total parts/materials (3–5 years)
- Contract maintenance costs (3–5 years) (by type of service if available)
- Copy of current maintenance budget
- Copy of previous year's maintenance budget
- Procedures for charging craft labor and parts/materials to equipment history or to maintenance budget accounts
- Procedures for monitoring equipment/process uptime

# PM, PdM, RCM, and Total Productive Maintenance (TPM) Processes

- Sample lubrication services checklists or charts
- Sample PM checklist/instructions
- List of equipment having PdM services for vibration analysis, oil analysis, infrared or other technologies
- Any summary results of major success with PM/PdM and reliability improvement at the plant/facility site
- Summary of experiences with RCM-type processes
- Summary of experiences with TPM-type processes

### **Maintenance Storeroom and MRO Purchasing**

### **Operations**

- Total dollar value of current maintenance-related inventory (ABC classification if available)
- Inventory dollar value of critical spares/insurance-type items
- Inventory dollar value of all other items
- Estimated value of items not on inventory system
- Total number of stocked items (stock-keeping units)
- Total number of critical spares/insurance items
- Total stock items—all other parts not classified as critical spares
- Copy of storeroom procedures for
- Purchase requisitions/purchase orders
- Additions to stock/establishing stock levels
- Issuing/receiving
- Receiving requirements for incoming quality validation
- Obsolete parts
- Parts/material inventory classification
- Results of most recent physical inventory or cycle count results
- Accuracy level, write-offs, or adjustments
- Copy of storeroom catalog (if online will review on-site)
- Information on vendor stocking plans and vendor partnerships currently in

### **Work Orders and Work Control**

- Copy of work order currently being used and priority system description
- Copy of work order/work control procedures
- Current backlog by craft area (if available)
- Planning and Scheduling Procedures
- Work management procedures
- Time-keeping methods (operations personnel and maintenance personnel)

### **CMMS**

- System name and date initially installed
- CMMS system administrator's name and contact information
- Names of other key staff with responsibilities for data integrity:
- Parts information
- Equipment/asset information
- PM/PdM procedures
- Maintenance budgeting and service charge backs

- Shop-level planning and scheduling
- Project-type planning and scheduling
- Your primary CMMS vendor support person and contact information

### **Maintenance Performance Reports**

- Copy of any reports or current information that is being used to evaluate maintenance performance
- Summary of key performance indicators that you feel are needed
- Operations performance report
- Copy of any reports or information used to evaluate operations performance that uses maintenance-related data (i.e., equipment uptime [availability])
- (b) Develop schedule and implementation plan for the assessment
- (c) Develop and implement a communication plan within the organization to inform all about the process

### **Step 4: Conduct Assessment of Total Maintenance Operation**

- (a) Assign team members to specific evaluation categories (ideally, in twoperson teams for each category)
- (b) Conduct kickoff meeting, firm up specific interview and observation schedules, etc.
- (c) Conduct the assessment, record observations, and assign scores to each evaluation item
- (d) Ensure CMMS is an effective business management tool for maintenance

#### **Step 5: Analyze, Review, and Present Results**

- (a) Review all scoring for consistency
- (b) Develop final results of the assessment and document in a written report
- (c) Determine strengths/weaknesses and priorities for action
- (d) Define potential benefits, either direct or indirect savings, or gained value from existing resources
- (e) Gain internal team consensus on methodology for determining benefits and the value and type of savings
- (f) Present results to top leaders with specific benefits and improvement potential clearly defined
- (g) Refine results based on feedback from top leaders
- (h) Gain commitment from top leaders for investments to implement recommendations

### **Step 6: Develop Path Forward for Maintenance Excellence**

- (a) Develop a strategic plan of action for implementing best practices
- (b) Define tactical plans and operational plan of actions
- (c) Define key performance measures, especially those that will validate projected benefits
- (d) Implement methodology to measure performance and results
- (e) Measure benefits and validate Return on Investment (ROI)
- (f) Maintain a continuous reliability improvement process (i.e., repeat assessment process)
- Follow-up initial use of Scoreboard for Maintenance Excellence with periodic assessments every 6–9 months

- Follow-up initial use of CMMS benchmarking system
- Continuously validate results with Maintenance Excellence Index

Invest in External Resources: It is extremely important to know where your organization stands on physical asset management and maintenance issues and challenges so that it can quickly identify areas for improvement. Every delay along the way delays receiving the potential benefits and added value. Self-assessments are recommended and very good starting points when nothing else is available for using external support. However, a more comprehensive, objective assessment performed by external consulting resources (or possibly qualified corporate-level staff with decades of maintenance-focused expertise) is highly recommended. In the long run, external resources will provide additional justification and measurable results. Therefore, take a look at using an external resource to support this essential first step after your organization makes the initial commitment.

Typical Project Plan of Action: The recommended path forward offers an excellent opportunity for immediate results at the pilot site plus the time to learn from this assessment before conducting future assessments. TMEII highly recommends having a maintenance excellence strategy team in place to provide overall leadership, support, and direction. The measurement of results ensures that initial projections of benefits are achieved and that the ROI for this pilot effort exceeds expectations. Included in Figure 5.15 is a typical project schedule in which the self-assessment includes two sites.

# Recommended Next Steps after the Scoreboard for Maintenance Excellence Assessment

Document Assessment Results: After The Scoreboard for Maintenance Excellence assessment has been completed, a written and oral report to top leaders will document the results with a presentation of recommendations and a plan of action. Key areas of the report presentation will help you to

- Determine strengths/weaknesses and priorities for action
- Benchmark your CMMS installation
- Maximize benefits of CMMS
- Develop maintenance as a profit center
- Define potential savings
- Develop recommended plan of action (and implement)

Path Forward Action Items	Weeks after Project Initiation					
	Pre-Work	Week 1	Week 2	Week 3	Week 4	Week 5
Step 1: Define Impact on Quality,						
Capacity and Customer Service						
Step 2: Establish Client Scoreboard						
Step 3: Conduct Pilot Assessments						
Site One						
Site Two						
Step 4: Define Specific Opportunities						
Step 5: Define Potential Benefits						
Step 6: Plan for Pilot Implementation						
Step 7: Establish Measure Pilot Results						
Step 8: Refine Client Scoreboard						
Step 9: Plan Additional Assessments						
Step 10: Present Pilot Assessment Results						
Step 11: Begin Other Assessments					After W	eek 5

# Figure 5.15 Typical project schedule in which the assessment includes two sites.

- Develop method to measure and validate results
- Initiate a maintenance excellence index

Determine Strengths/Weaknesses and Priorities for Action: After an objective assessment is completed, it is very easy to identify strengths and weaknesses, which then leads to defining the priorities for action. In some operations it is very often back to the basics, such as

- PM has been neglected; no time to do it
- The understanding of predictive technologies is limited
- The application of continuous reliability improvement was never initiated
- The parts storeroom was never given the proper attention it needed
- The accountability for craft time is not being done
- The charge back to the customer was not done or is incomplete
- A reactive, fire-fighting repair strategy is in place
- Valuable craft time is wasted (e.g., chasing parts/materials, waiting, unplanned work)
- There is never time to do the job right the first time
- The asset uptime is uncertain and the manufacturing operation is not reliable
- Quality is inconsistent because of maintenance processes
- There is never time for craft training
- The CMMS was purchased as "the solution" and not "the tool."

### • The existing CMMS functionality is not being fully used

Very often, the CMMS takes the hit as the cause of all of the weaknesses. CMMS is blamed for not being able to do this and that, causing all types of problems and extra work. This attitude will generally always be the case when the CMMS was purchased as "the solution" and not "the tool". The bottom line here is that most systems are underutilized, and when fully used with all of their intended functionality they will serve their primary IT purpose.

Therefore, just as we can benchmark a total maintenance operation and its best-practice application with the 38-category Scoreboard for Maintenance Excellence, we can also benchmark the CMMS that is in place. We really need to evaluate the CMMS and its current application as to its effectiveness in supporting all best practices. Is your CMMS enhancing current and future best practices or not? Are we getting maximum value from this IT investment? Is your CMMS truly a maintenance business management system? How can we improve the current use of the system? In Chapter 8, "Planner Review of a Critical Planning Tool Evaluating Your CMMS Systems Effectiveness," we will answer and take action on these key questions for reliable maintenance planning, estimating, and scheduling.

## **Chapter 6**

### Planners Must Understand Productivity and How Reliable Maintenance Planning, Estimating and Scheduling (RMPES) Enhances Total Operations Excellence

\_

### **Abstract**

This chapter is extremely important for the planner to understand how they impact productivity improvement within the craft workforce as well as across the total operation. The profit and customer-centered maintenance operation must clearly understand productivity and be committed to measuring craft productivity. All the best practices we discuss in this book contribute either directly or indirectly to improving craft productivity and physical asset productivity. I know for sure that it applies to the profit and customer-centered maintenance contractor striving to meet contract terms and conditions. Defining overall productivity from the total maintenance process of the total operations can be a slippery task. Attempting to increase productivity can be even more difficult if managers mistake efficiency for productivity.

### **Keywords**

ACE Team; cost avoidance; direct cost savings; effectiveness factor; gained value; OCE; OEE;

### Overall Craft Effectiveness, Overall Equipment Effectiveness; performance factor; planning times; quality factor; wrench time

This chapter is extremely important for the planner to understand how they impact productivity improvement within the craft workforce as well as across the total operation. The profit and customer-centered maintenance operation must clearly understand productivity and be committed to measuring craft productivity. All the best practices we discuss in this book contribute either directly or indirectly to improving craft productivity and physical asset productivity. I know for sure that it applies to the profit and customer-centered maintenance contractor striving to meet contract terms and conditions. Defining overall productivity from the total maintenance process of the total operations can be a slippery task. Attempting to increase productivity can be even more difficult if managers mistake efficiency for productivity.

We can be very efficient doing the wrong things such as firefighting and reacting to emergency repairs. A focus on increasing work order completion rates may sacrifice quality of repair work. Cutting costs by specifying cheap, prone-to-fail equipment or parts yields the high cost of low-bid buying and maybe achieving short-term budget requirements. Doctors and lawyers practice medicine and law; maintenance and good engineering need to get it right the first time!

Today's economic climate requires that we define and then improve maintenance and engineering productivity. Every employee must take ownership in the organizational mission and the maintenance mission. One manager for the decision support for operations and maintenance program at the Pacific National Laboratory in Richland, Washington, categorizes productivity into four levels: (1) Survival: In a low-productivity environment, the goal is survival. Chronic operations and maintenance problems will plague such an organization, and low reliability or outright equipment failures characterize this category. (2) Adequacy: Uncertainty might characterize this category, but the department is keeping equipment running. Low efficiency and low productivity are classic traits of this category. (3) Accuracy: Departments in this segment are secure in their knowledge of operating and maintaining their facilities but would like better performance measurements and want to know how their operations and maintenance affect facility processes. (4) Optimized: These departments know the slope of their performance curve. They search for ways to optimize the state

of an already effective maintenance process.

What is productivity? One definition of productivity is that it is a measure relating to quantity or quality of output compared to the inputs required to produce it. When we look at just three elements of total plant productivity, production labor, production equipment productivity, and craft labor productivity all have the same three key factors in common. The same applies to craft employees performing repair and preventive maintenance (PM) to support production operation customer. My definition includes three key factors for productivity:

- 1. The Effectiveness Factor—Doing the right things.
- 2. The Efficiency or Performance Factor—Doing the right things and giving the best personal performance as possible.
- 3. The Quality Factor—Doing the right things giving the best personal performance as possible with high quality results.

These three factors apply to production labor productivity, to asset productivity overall equipment effectiveness (OEE), and to craft labor productivity as shown in Figure 6.1.

Supporting the improvement of craft productivity can easily provide a return on investment of six equivalent craft employees to one qualified planner. In addition, craft labor productivity can be measured for all three elements. Surveys consistently show that wrench time (craft utilization (CU)), one element of craft productivity within a reactive, firefighting maintenance environment, is in the range of 30–40%. A study using work sampling of a major corporation's maintenance operation revealed 26%. My surveys from speech and seminar attendees over the past 15 years shows some people that think their true wrench time is 15%, 20%, or 25% and much lower than 30%. Therefore, if your baseline pure wrench time baseline is conservatively at 40%, this means that for a 10-h day, there are only 4 h of actual hands-on, wrench time. You can do the math on other levels, 10%, 20%, or 30%. Craft workforce should not take all the blame: Typically, most of the lost wrench time is not the fault of the craft workforce. Lost wrench time can be attributed to the following reasons:

PRODUCTIVITY: THREE KEY FACTORS				
Productivity Factors	Production Employees	Production Equipment	Craft  Employees  % True Wrench Time or Craft Utilization	
Effectiveness	% Time on Direct Labor Adding Value	% Availability to Add Value		
Efficiency	% Performance Against a Standard Time	% Performance Against Design Speed	% Craft Performance Against a Standard Planning Time	
Standard Labo	% Good Compared to Total Produced	% Good Compared to Total Produced	% Good Repairs Compared to Total Repairs	
	Standard Labor Cost Variance	Overall Equipment Effectiveness (OEE)	Overall Craft Effectiveness (OCE)	

# Figure 6.1 Three key productivity factors compared for three elements of total plant productivity.

Note: Total plant productivity would also include material variances, actual throughput compared to capacity, and net profit.

- 1. Running from emergency to emergency; a reactive, firefighting operation.
- 2. Waiting on parts and finding parts or part information.
- 3. Waiting on other information, drawings, instructions, manuals, etc.
- 4. Waiting for the equipment to be shut down.
- 5. Waiting on rental equipment to arrive.
- 6. Waiting on other crafts to finish their part of the job.
- 7. Travel to/from job site.
- 8. Lack of effective planning and scheduling.
- 9. Make ready, put away, clean up, meetings.
- 10. Troubleshooting, however, is another story: (1) With a "hit-and-miss approach" it can be wasted time. (2) But it can also be scheduled by the planner, performed by a qualified person to really determine the scope of work and parts needed so a true planned job can occur.

There is a question by some maintenance gurus about whether we can or should measure craft productivity directly. My answer to this is a resounding yes! A reliable planner will be able to establish reliable repair times for many reasons other than measuring craft labor performance. We will describe in detail a method that is easy to use and acceptable to the craft workforce that we call the ACE (a consensus of experts) Team Benchmarking Process<sup>TM</sup> to be discussed in detailed in Chapter 15, Developing Improved Repair Methods plus Reliable Maintenance Planning Times with the ACE Team Process. Craft resources are

becoming more difficult to find in many areas and there is a true crisis and shortage of craft labor. One question we want to answer for you is, "How can we get maximum value from craft labor resources and achieve higher craft productivity?"

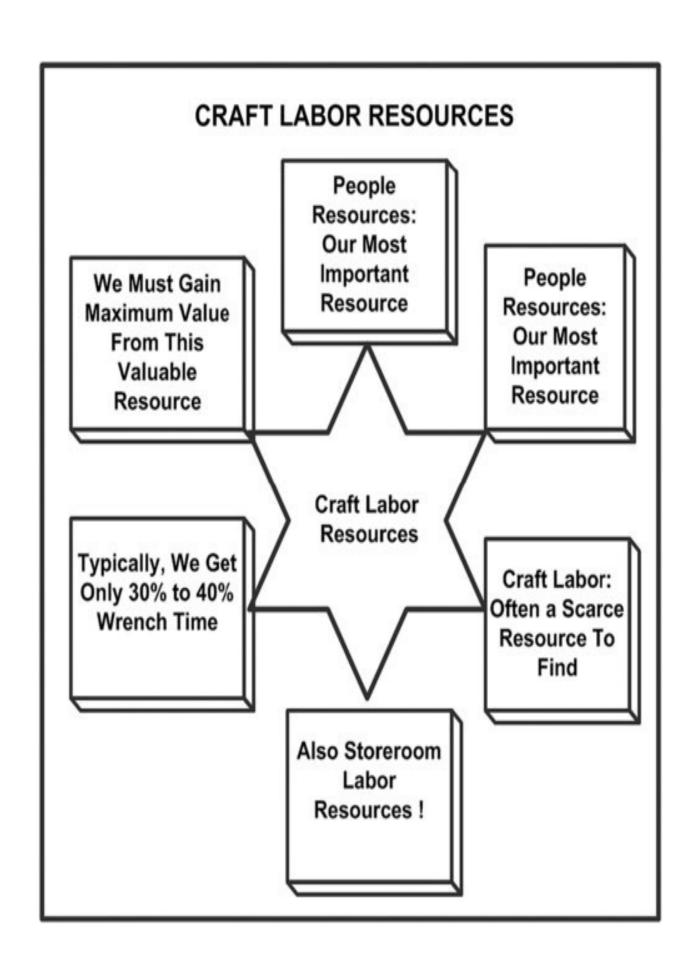
First, we must be able to measure it: Maintenance operations that continue to operate in a reactive, run-to-failure, firefighting mode and disregard implementation of today's best practices will continue to waste their most valuable asset and very costly resource—craft time. Often true wrench time is within the 20–30% range for operations covering a wide geographic service area. An example is PM and maintenance of a countrywide pipeline like in Oman. With best practices such as effective maintenance planning/scheduling, preventive/predictive maintenance, more effective storerooms and parts support, delivery to job site, crafts skill training, and the best tools, we can contribute to proactive, planned maintenance, and more productive hands-on "wrench time." The sticky question of craft productivity measurement and improvements in union plants often comes up. Consistent craft productivity measurement and improvements in union manufacturing in U.S. plants must occur.

Union plants cannot increase hourly rates higher and higher with little or no productivity. This is not mathematically possible forever. I have said before that we cannot perform maintenance off shore, except for maybe troubleshooting via online monitoring/operation of process control systems and worst case, moving the plant. Maybe we can send items offshore for rebuilding, etc. What are our options when current productivity of both production operators and crafts people do not increase as union labor rates continuously go higher and higher? At some point, higher wages without productivity gains will lead to plant closings due to profits and offshore relocation for cheaper labor. We might replace union maintenance with contractor maintenance or even move plants to right-to-work states. After seeing the Cooper Tool Group move six unionized plants from the North (Plumb, Crescent, Wiss, Lufkin, Weller, and Nicholson saw and the Nicholson file plant) to the South, there must be significant cost improvement. Craft productivity can be measured and improved. In addition, if we can do it for in-house maintenance, we can surely do it for maintenance contractors as well. Therefore, what your wrench time or CU is can be shown in Figure 6.2. Figure 6.3 illustrates craft labor resources and key factors for keeping them as our most important maintenance resource.

### How Your Valuable Craft Time Can Slip Away Total Available Craft Days: 52 Weeks/Yr x 5 Days per Week = 260 Available Craft Days Maximum Without Overtime 260 Total Craft Days - 10 Holidays Per Year = 250 Craft Days Now Available 250 Days/Yr - 15 Vacation/Sick Days Average Per Year = 235 Craft Days Now Available 235 Days -15 Days Break Time\* Per Year = 220 Craft Days/Year Now Available **BOTTOM LINE** 220 Days ÷ 260 Days = .846 = Note: Example with 85% +/- Maximum 15 min x 2 breaks/ Craft Time Available for Work day = 1/2 hour/day x 235 days = 117.5 85% = Maximum Craft Utilization hours + 8 hours/day = 15 Total Days Per 70% = World Class Wrench Year for Break Time Levels of Craft Labor Utilization Time 60% = Very Good Wrench time Pure Wrench Time 50%= Good Wrench Time 30% to 40% Typical for Reactive Unplanned 10% to 20% On Call Like the Maytag Repair Man

What is Your Craft Labor Utilization?

Figure 6.2 How valuable craft time can slip away.



# Figure 6.3 Craft labor resources—our most important maintenance resource.

With a good planning, estimating, and scheduling process, significant gained value is available from increased wrench time or hands-on tools time. An improvement in actual wrench time from 40% to 50% represents a 25% net gain in craft time available equivalent and a significant gained value. When we are able to combine gains in wrench time with increased craft performance (CP) when doing the job, we increase our total gain in craft productivity. Measuring and improving overall craft productivity should be a key metric/KPI to justify effective planning and scheduling, CMMS, and other investments for maintenance improvement. Increased reliability that increases asset uptime and throughput is likewise very important.

Before further addressing overall craft effectiveness, I want to cover three types of cost improvements:

- 1. Direct cost savings. They come from direct savings in standard labor and materials cost. For maintenance, this can come via staff reductions, by using contractors, or parts procurement of like quality parts at reduced costs.
- 2. Cost avoidances. A good maintenance example is when PM/PdM/CBM detects a problem when it can be a planned repair before a catastrophic, high consequence failure occurs. With a little estimating between cost of planned work versus possible cost of major unexpected failure, this extra can give you valid cost avoidances and return on investment (ROI) for PM/PdM/CBM activities.
- 3. Gained Value. This one is the value of (1) gained labor productivity or (2) value of gained production. It can be said simply as doing more with existing resources, i.e., gained value.

Planners, pay attention, as we will now look at a new term, overall craft effectiveness (OCE). As we saw previously, OCE has the same basic factors as (OEE; availability, performance, and quality) but applied to craft productivity and people resources as compared to OEE, focused upon critical physical assets and physical asset productivity.

The profit and customer-centered maintenance leader (in house or contractor) must consider total asset management in terms of improvement opportunities across all maintenance resources. There are many questions to be asked about how we can improve the contribution that each of these six resources (from Chapter 5) makes toward your goal for maintenance excellence:

- Physical resources: equipment and facilities.
- People resources: craft labor and equipment operators.
- Technical skill resources: craft labor that is enhanced by effective training.
- Material resources: maintenance repair operations (MRO) parts and supplies.
- Information resources: useful planning, scheduling, and reliability information, and not a sea of useless data.
- Hidden resources: The seemingly magical synergy of teamwork as a true people asset multiplier.

Measuring and improving OCE must be one of many components to continuous reliability improvement process and total asset management. OCE includes three key elements very closely related to the three elements of the OEE Factor.

### **Overall Equipment Effectiveness**

We must clearly understand the elements of OCE and how the OCE factor relates to better use of our craft workforce. Most everyone recognizes and understands the world-class metric OEE that measures the combination of three elements for the physical asset: equipment asset availability, performance, and quality output. OEE is about measuring asset productivity. The calculation of OEE is shown in Figure 6.4.

The OCE factor focuses upon craft labor productivity and measuring/improving the value-added contribution that people assets make. Just like OEE, there are three elements to the OCE factor:

- Effectiveness factor: CU for OCE and Asset availability for OEE.
- Efficiency factor: CP for OCE and Asset performance for OEE.
- Quality factor: Craft service quality (CSQ) for OCE and Quality of asset output for OEE.

# The OEE Factor = % Availability(A) x % Performance(P) x % Quality(Q)

# An OEE Factor of 85% is recognized as world-class

Therefore OEE of 85% requires at least the 95% level for each of the 3 elements:

So if OEE = A x P x Q then if each factor is 95% or .95

OEE=.95 x .95 x 95 ± 85%

### Figure 6.4 Overall craft effectiveness.

All three elements of OCE can be as well defined as all three of the OEE factors. We will now review the three key elements for measuring OCE and see how they very closely align with the three elements for determining the OEE factor for equipment assets. Figure 6.5 provides a comparative summary and Figure 6.6 defines how OCE is calculated.

OCE focuses upon your craft labor resources: I strongly believe in basic maintenance best practices as the foundation for maintenance excellence. This is what I call continuous reliability improvement (CRI). CRI is about maintenance business process improvement that includes opportunities across all maintenance resources: equipment and facility assets, as well as people resources—our crafts workforce and equipment operators. CRI must also include MRO materials management assets, maintenance informational assets, and the added value resource of synergistic teambased processes. CRI improves the total maintenance operation and can start with measuring and improving OCE.

The Maintenance Excellence Institute International advocates, supports, and clearly understands the need for reliability-centered maintenance (RCM) and total productive maintenance (TPM) types of improvement processes. But out on the shop floor, we see today's trend toward forgetting about the basics of "blocking and tackling" while going for the long touchdown pass with some new "analysis paralysis" scheme. RCM and root cause analysis (RCA) are not really analysis paralysis when done correctly with true information and when they are not based upon "precisely inaccurate" data.

Build upon the basics: Your approach must be built upon the basics and then include, but go well beyond, the traditional RCM/TPM approaches to CRI (Figure 6.7).

Maintenance excellence can start with PRIDE in maintenance: Do not take a piecemeal approach that focuses only RCM-type processes on physical assets and equipment resources. Often the maintenance information resource piece, among others, is a missing link for the successful RCM-type process. RCM alone can often become analysis paralysis with no data or

bad data. Your approach should be about improvement opportunities across all maintenance resources. There of course must be priorities as to where we start and where we make investments. I have been asked numerous times what would I want first in starting a new maintenance operation? I reply that after finding the best craft people available (with PRIDE in maintenance) I would establish effective planning, estimating and scheduling, an effective PM/PdM program, and a responsive parts storeroom and procurement process.

Overall Craft Effectiveness (OCE)	Overall Equipment Effectiveness (OEE)	Elements of OEE and OCE
1. Craft Utilization or Pure Wrench Time (CU)	Asset Availability/Utilization (A)	Effectiveness
2. Craft Performance (CP)	Asset Performance (P)	Efficiency
3. Craft Service Quality (CSQ)	Quality of Asset's Output (Q)	Quality

Figure 6.5 Summary comparisons of overall craft effectiveness (OCE) and overall equipment effectiveness (OEE).

The OCE Factor = % Craft Utilization (CU) x % Craft Performance (CP) x % Craft Service

Quality (CSQ) Therefore OCE = % CU x % CP x % CSQ

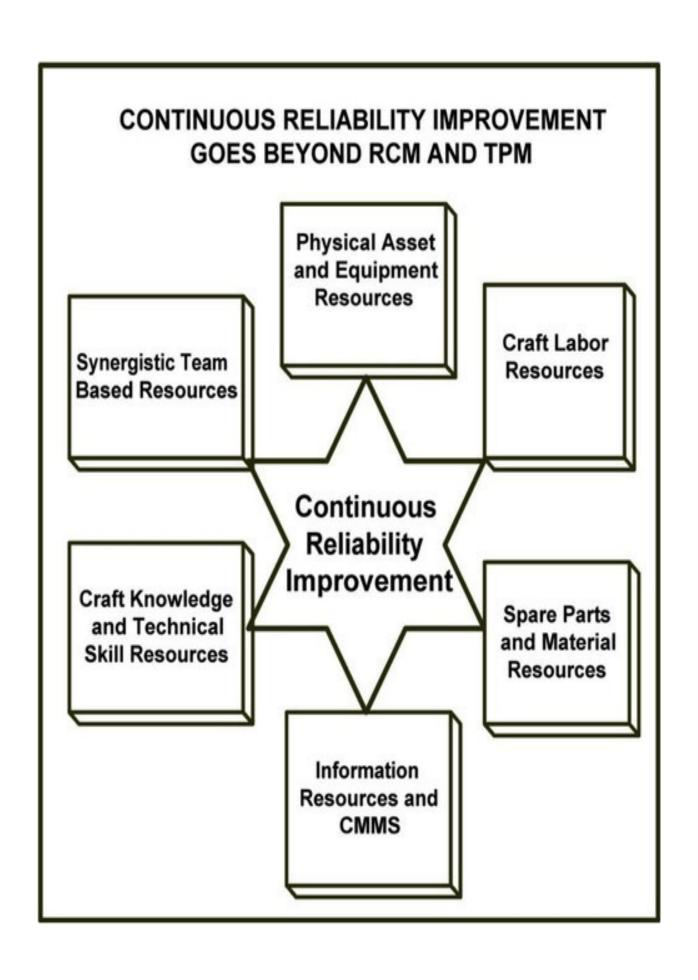
Typically CU and CP can be easily measured.

Craft Service Quality (CSQ) is somewhat harder to measure and can be more subjective.

NOTE: Later we will see how all three elements of OCE can be measured and

how all three contribute to increased craft productivity

Figure 6.6 Calculating overall craft effectiveness (OCE).

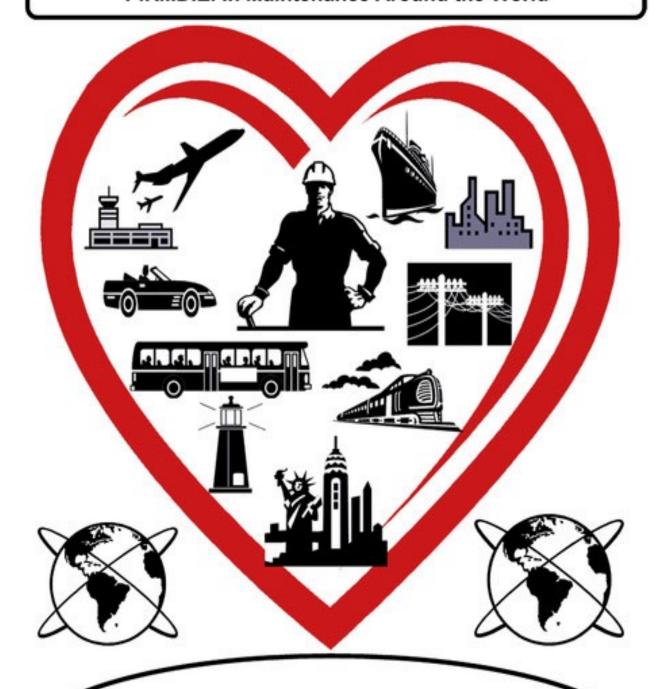


#### Figure 6.7 Continuous Reliability Improvements (CRI).

For example, with the crafts labor resource, we can easily measure the three elements of OCE, as we will see later. However, we can start the journey toward maintenance excellence by just helping to achieve PRIDE in maintenance from within the crafts workforce and among maintenance leaders at all levels and PRIDE in maintenance around the world as illustrated in Figure 6.8.

A very important question for the crafts workforce: I have seen maintenance operations and talked to crafts people all around the world, starting in South Vietnam in 1970. Almost all attendees at hundreds of my workshops also agree that their crafts people want to do a good job and be appreciated for what they do to help achieve the mission of the organization. In addition, when asked the following question, I have received positive responses from almost 100% of the thousands of dedicated professional crafts people I have interviewed. Dedicated union leaders and union crafts people are also included in my personal sample.

### P.R.I.D.E. in Maintenance Around the World



People Really Interested in Developing Excellence in Maintenance

### Figure 6.8 PRIDE in maintenance around the world.

The question I always ask is, "How would you do this job, lead this crew, or lead maintenance if it were in fact your own maintenance business?" What if we could get attitudes that are more positive plus action from all our crafts focused on this important question? I think you as maintenance leaders and especially planner/schedulers can do it with a combination of many things from this book. So again I ask you to apply what you think will work and then test other ideas that you may not fully agree with right now from previous chapters.

Your own internal people can add greater value to your maintenance operation with a profit and customer-centered attitude about their job and the profession of maintenance. We feel strongly that maintenance excellence begins with PRIDE in maintenance. We will later see "How OCE Impacts Your Bottom Line" and how we can measure and improve the productivity of two important maintenance resources: craft labor as well as contractor performance expectations.

Remember that craft labor is a terrible thing to waste: How to improve OCE is a very key question we need to answer. Getting maximum value from craft labor resources and higher craft productivity requires measurement and as well as the big picture of knowing where you are now with a Scoreboard assessment. Maintenance operations that continue to operate in a reactive, run-to-failure, firefighting mode and disregard implementation of today's best practices will continue to waste their most valuable asset and very costly resource—craft time. Typically, due to no fault of the craft workforce, surveys and baseline measurements consistently show that only about 30–40% of an 8-h day is devoted to actual, hands-on wrench time. It is very important to understand, "How your valuable craft time can slip away," as illustrated in. Best practices such as effective maintenance planning/scheduling, preventive/predictive maintenance, more effective storerooms, and parts support all contribute to proactive, planned maintenance and more productive hands-on "wrench time." Measuring and improving OCE must be one of many components to CRI process and total asset management. OCE includes three key elements very closely related to the three elements of the OEE factor (Figure 6.9), which we will discuss next

in more detail().

### **Craft Utilization**

CU: The first element of the OCE Factor is CU or pure wrench time. This element of OCE relates to measuring how effective we are in planning and scheduling craft resources so that these assets are doing value-added, productive work (wrench time). Effective planning/scheduling within a proactive maintenance process is one important key to increased wrench time and CU. It is also about having an effective storeroom with the right part, at the right place in time to do scheduled work with minimal nonproductive time on the part of the crafts person or crew assigned to the job. Your valuable craft time can just slip away to a level of 30–40% or below when crafts service a large geographic area—a large plant, refinery, or facilities complex.

Overall Craft Effectiveness (OCE)	Overall Equipment Effectiveness (OEE)	Elements of OEE and OCE
1. Craft Utilization or Pure Wrench Time (CU)	Asset Availability/Utilization (A)	Effectiveness
2. Craft Performance (CP)	Asset Performance (P)	Efficiency
3. Craft Service Quality (CSQ)	Quality of Asset's Output (Q)	Quality

### Figure 6.9 The three elements of overall craft effectiveness (OCE).

Pure wrench time is just that and does not include time caused by the following:

- 1. Running/traveling from emergency to emergency in a reactive, firefighting mode.
- 2. Waiting on parts issue, actually finding parts, or getting parts information.
- 3. Waiting on other asset info, asset drawings, repair instructions, documentation, etc.
- 4. Waiting for the equipment or asset to be shut down to begin work with all necessary risk assessments.
- 5. Waiting on rental equipment or contractor support to arrive at job site.
- 6. Waiting on other crafts or crews to finish their part of the job.
- 7. Traveling to/from job site.
- 8. All other make-ready, put-away, or shop cleanup time.
- 9. Meetings, normal breaks, training time, and excessive troubleshooting due to lack of technical skills.
- 10. Lack of effective planning and scheduling.

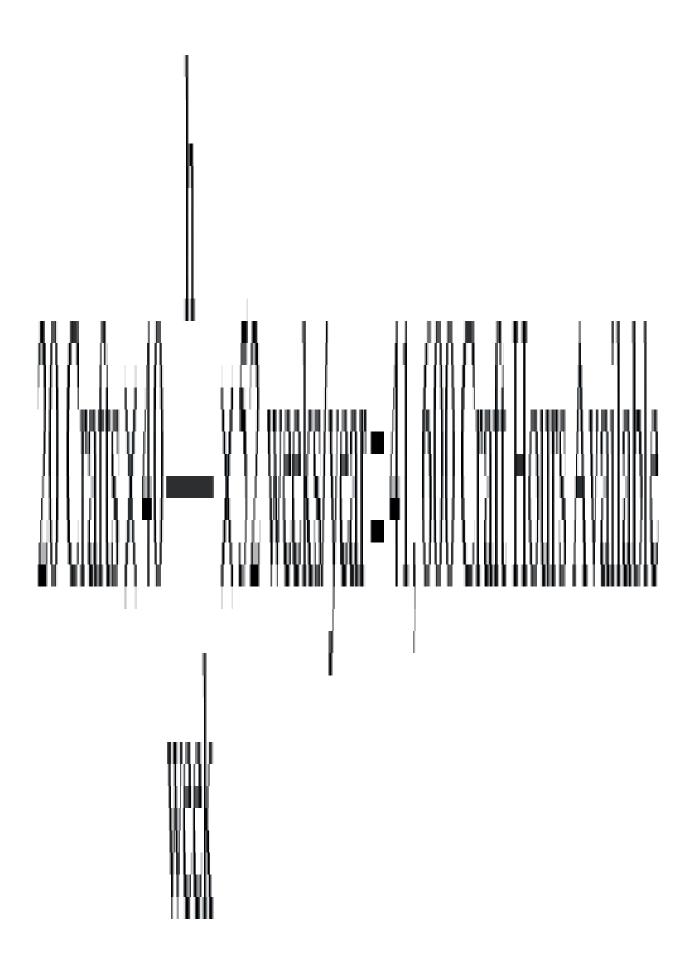
CU (or wrench time) can be measured and expressed simply as shown in Figure 6.10 as the ratio of:

Improve wrench time first Go on the attack to increase wrench time in your operation even if you do nothing to improve the other two OCE factors: CP and the CSQ level. As we will see in the following examples, very dramatic and significant tangible benefits can be realized with just focusing on increasing wrench time. Improvement of 10–30% points from your current baseline of wrench time can typically be expected. In addition, often this can be achieved just from more effective maintenance planning and scheduling.

Let us now look at several examples showing the value of CU improvement within a 20-person workforce with an average hourly rate of \$18.00 and see the significant benefits that a 10% increase in CU can provide.

Gained value of 10% in wrench time: What if through better planning and scheduling, good parts availability, and having equipment available to fix it on a scheduled basis, we are able to increase actual wrench time by just 10% from a baseline of 40%? What is the gained value to us if we get a wrench time increase across the board for a 20-person crew being paid an average hourly rate of \$18/h? First let us look at what it is really costing us at various levels of wrench time.

**Total Craft Hours Available and Annual Craft Labor Costs for Crew of 20 Crafts** 



41,600 Craft Hours @ \$18/h = \$748,800 Craft Labor Cost/Year

# CU% = Total Productive (Wrench Time)

# Total Craft Hours Available & Paid x 100

### Figure 6.10 Craft utilization (CU) calculation.

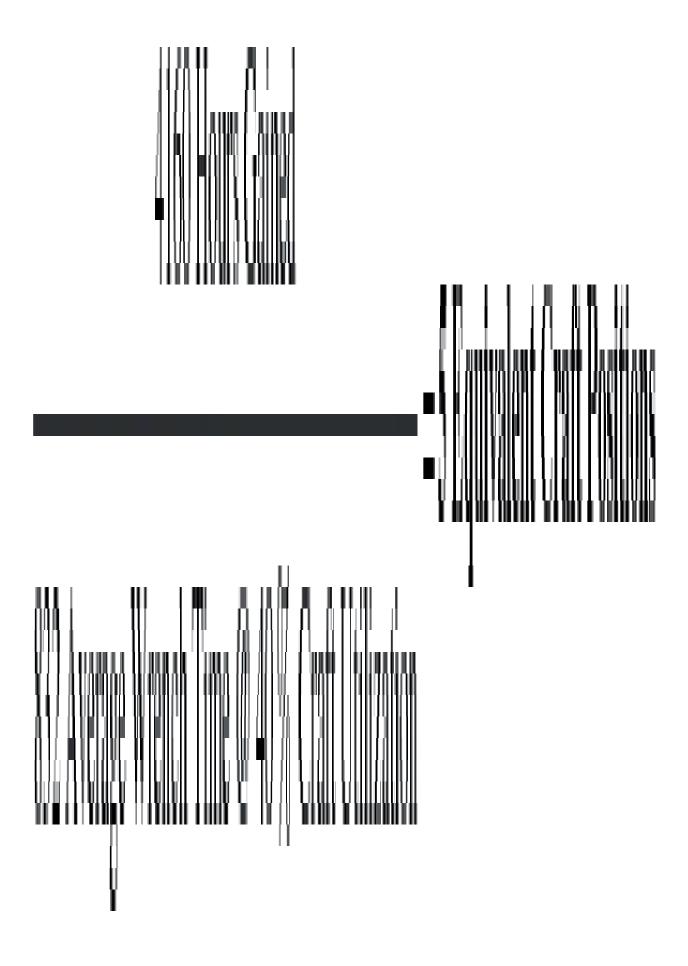
## Wrench Time and Actual Costs Per Hour at Various Levels of CU

Example: What if baseline for wrench time is 40%? With effective planning and scheduling we can achieve at a minimum of a 10-point improvement in CU from our current baseline. Starting from a baseline of 40% and increasing wrench time up to a level of 50%, we in effect get a 25% increase in craft capacity for doing actual work.

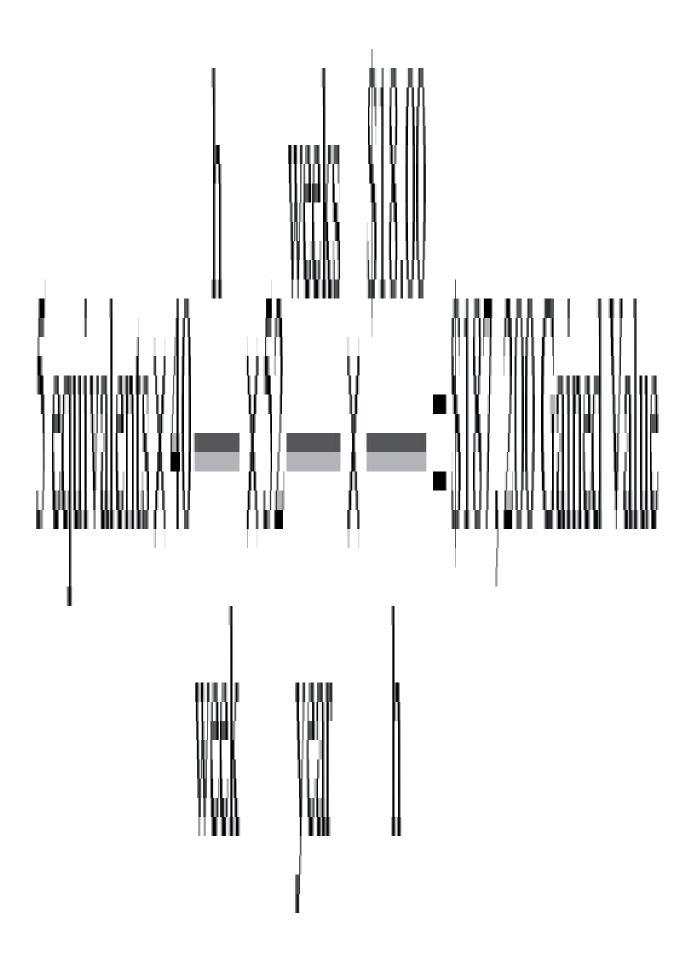
• Total hours gained in wrench time: 4160 h

20,800 h @ 50% - 16,640 h @ 40% = 4160 h gained

• Total gain in equivalent number of crafts positions: 5



• Total gained value of 5 equivalent positions: \$187,200



Valuable craft time can be regained: For the 20-person craft workforce, just a 10% improvement up to 50% wrench time is 4160 h of added wrench time. This gain represents a 25% increase in overall craft labor capacity. The maintenance best practice for planning and scheduling requires a dedicated planner(s). An effective maintenance planner can support and plan for 20 to 30 crafts positions. With only a 10% increase in CU for a 20-person craft workforce, we can get more than a 5 to 1 return to offset a maintenance planner position.

Example B: What if wrench time is 30%? For many operations, wrench time is only about 30% and sometimes below 30%. Again, with effective planning and scheduling, good PM/PdM and parts availability we can eliminate excessive non-wrench time. An improvement of at least 20 points in CU is very realistic. If we begin from a baseline of 30% up to a level of 50%, we are in effect getting a 67% percent increase in craft capacity for actual hands-on work.

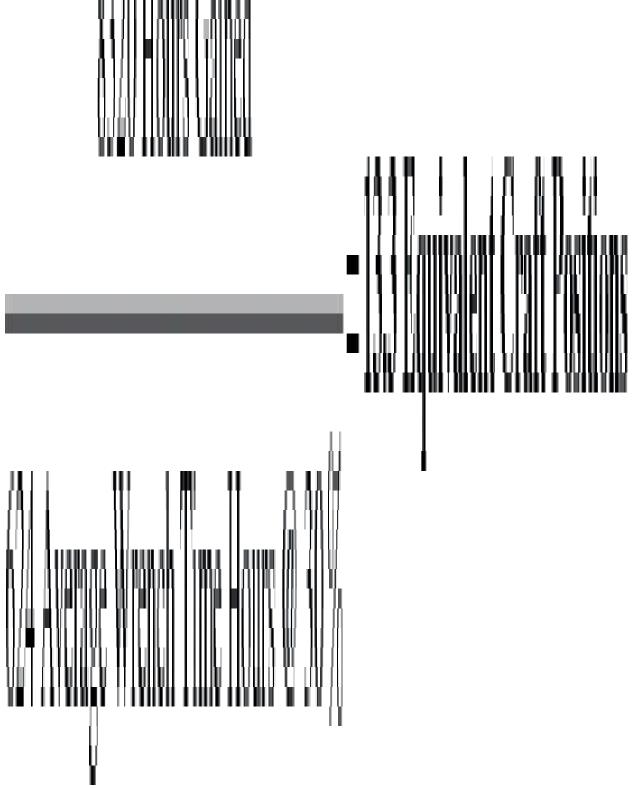
The gained value of going from 30% up to 50% wrench time:

• Total hours gained in wrench time: 8320 h

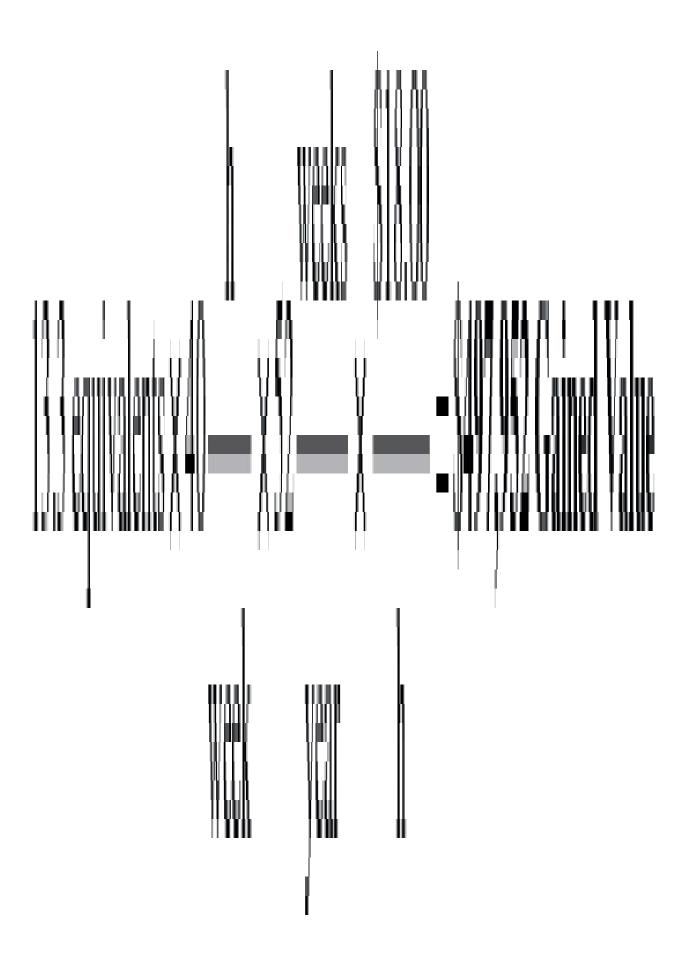
20,800 h @ 50% – 12,480 h @ 30% = 8320 h gained

• Total gain in equivalent number of crafts positions: 13





• Total gained value of 13.3 equivalent positions: \$497,952

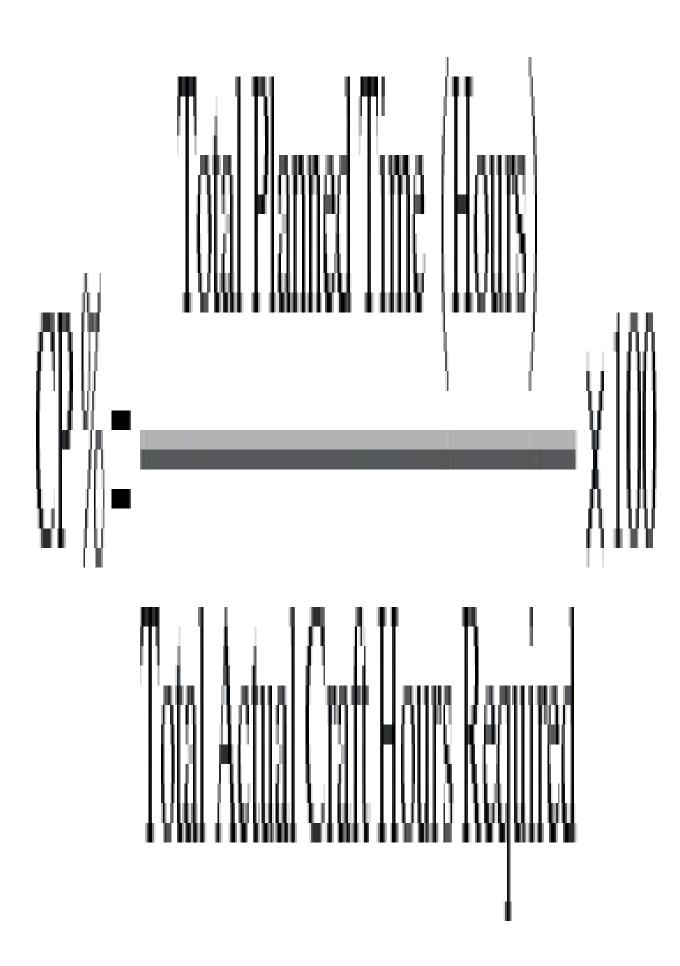


Valuable craft time can be regained: Tremendous opportunities are available for the 20-person craft workforce with wrench time currently in the 30–40% range. Just a 10–20% improvement up to 50% wrench time can be from 4000 to 8000 h of added wrench time. This gain represents a 25–67% increase in overall net craft labor capacity. There is one important best practice needed to help you regain valuable craft resources. The maintenance best practice for planning and scheduling requires dedicated planners that are effective maintenance planners/schedulers that can support and plan for 20 to 30 crafts positions.

Use your CMMS/EAM as a mission-essential information technology tool that supports planning and scheduling, better MRO materials management, and effective preventive/predictive maintenance. They are three best practices for improving craft wrench time. Bottom line results that give us 5–13 more equivalent craft positions and up to \$500,000 in gained value of more wrench time with existing staff can be dramatic proof that internal maintenance operations can be profit centered.

### **Craft Performance**

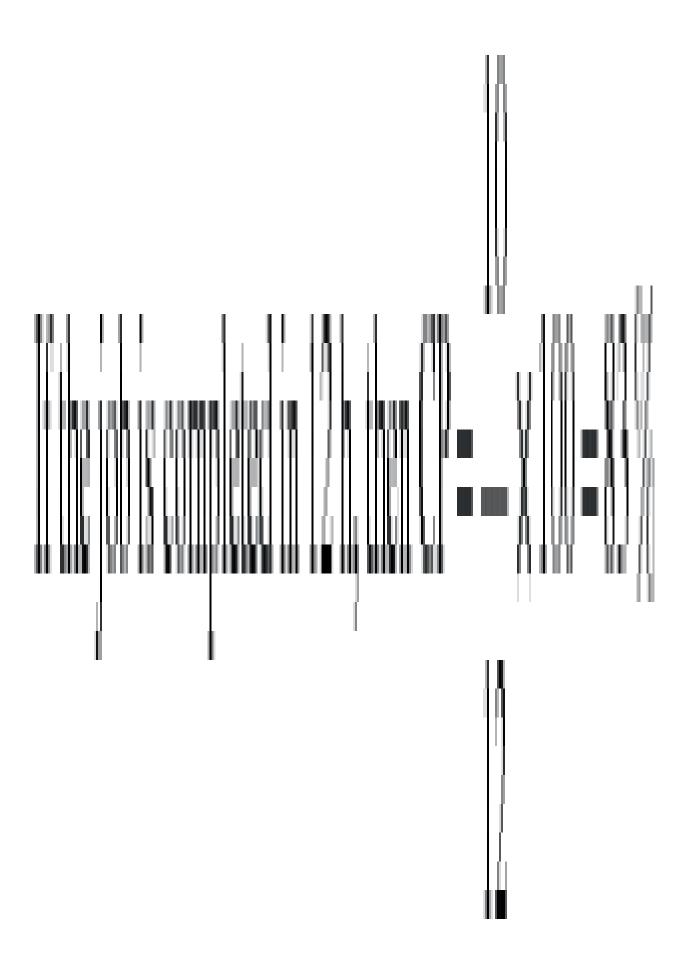
CP: The second key element affecting OCE is CP. This element relates to how efficient we are in actually doing hands-on craft work when compared to an established planned time or performance standard. CP is expressed as the ratio of:



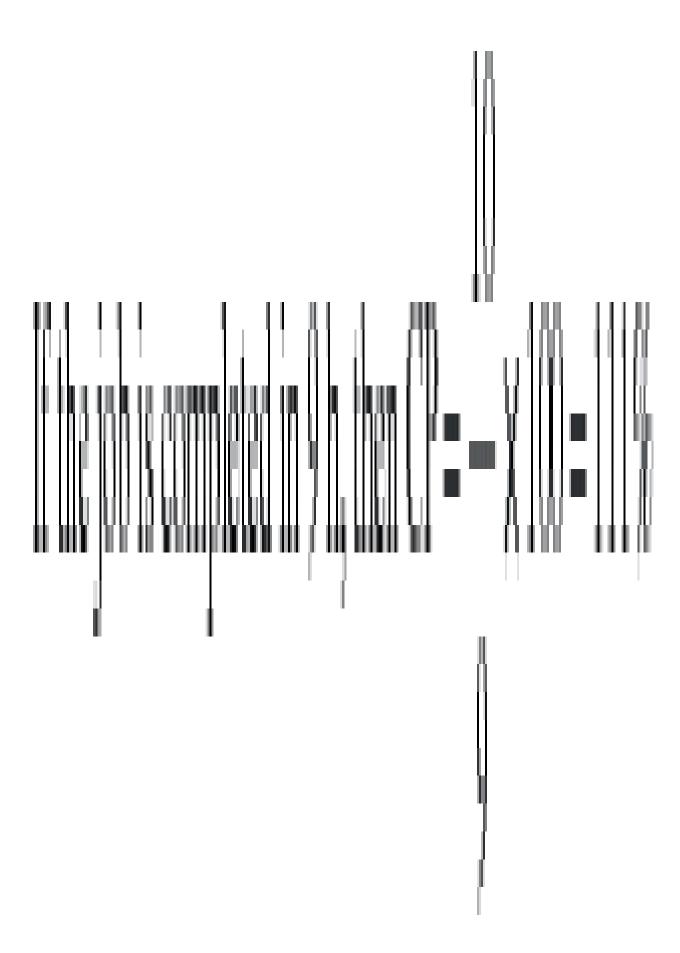
CP is directly related to the level of individual craft skills and overall trades experience as well as the personal motivation and effort of each craftsperson or crew. Effective craft skills training, technical development, and PRIDE in maintenance all contribute to a high level of CP.

CP calculation: For example, the planned time for a minor overhaul or planned repair is 10 h based on a standard procedure with parts list, special tools, permits required, etc.

•



•			



An effective planning and scheduling function requires reasonable repair estimates. They are what I call reliable planning times needed for scheduling, and they should be established for as much maintenance work as possible. Because maintenance work is not highly repetitive, the task of developing reliable planning times is more difficult. However, there are a number of methods for establishing planning times for maintenance work including:

- Reasonable estimates: A knowledgeable person, either a supervisor or planner, uses their experience to provide their best estimate of the time required. This approach does not scope out the job in much detail to determine method nor outline job tasks or special equipment needed. However, it can have value when there is no reliable work measurement method in place.
- Historical data: The results of past experience are captured via the CMMS or other means to get average times to do a specific task. Over time, a database of estimated time is developed that can be updated with a running average time computed for the tasks. I often call this "hysterical data" due to inconsistencies in reporting time, actual location of work, and delays in getting parts or equipment access, etc.
- Predetermined standard data: Standard data tables for a wide range of small maintenance tasks have been developed. Standard data represents the building blocks that can then be used to estimate larger, more complex jobs. Each standard data table provides what the operation is, what is included in the time value, and the table of standard data time for the variables that are included. The universal maintenance standards (UMS) method used back in the 1970s and developed by the U.S. Navy and H. B. Maynard Inc. represents a predetermined standard data method. We used this method in the early 1970s to train 65 fleet maintenance planners for the North Carolina Department of Transportation's Division of Highways. UMS is a very detailed method when using standard data for every motion and turns of all types of tools used by a mechanic to complete a "benchmark job." Benchmark jobs were put on a "spreadsheet" for "slotting" to get wrench time, upon which allowances were added to create the planning time for scheduling. Once "spreadsheets" were developed for all trade areas and types of work, the relatively small number of benchmark jobs analyzed for putting on "spreadsheets" allows a good planner to estimate wrench time for a wide number of incoming jobs. In addition, the accuracy of the slotting process is 95% within the respective UMS time ranges.

• The ACE team benchmarking process: As a means to overcome many of the inherent difficulties associated with developing maintenance performance standards, the ACE team benchmarking process was developed. This process is detailed in Chapter 15, with complete forms in Appendix H. This process was developed back in 1978 by Ralph W. "Pete" Peters, founder of The Maintenance Excellence Institute International (TMEII) as part of a Masters program in management information systems at North Carolina State University. This method is based upon UMS slotting and range-of-time concept principles plus the principles of the Delphi technique to gain a consensus. It relies primarily on the combined experience and estimating and methods improvement ability of a group of skilled crafts personnel, planners, and supervisor. The objective is to determine reliable planning times for a number of selected "benchmark" jobs. This team-based process that uses skilled crafts people places a high emphasis on continuous maintenance improvement to reflect improvements in performance and repair methods plus repair quality.

Generally, the ACE team benchmarking process parallels the UMS approach in that the "range-of-time concept" and the "slotting" technique is used once the work content times for a representative number of "benchmark jobs" have been established. The ACE team benchmarking process focuses primarily on three key areas: (1) repair methods improvement to reduce mean time to repair (MTTR); (2) repair quality and safety; and (3) on the development of work content times for representative "benchmark jobs" that are typical types of craft work being performed.

Once a number of benchmark job times have been established, these jobs are then categorized onto spreadsheets by craft and task area and according to work groups that represent various ranges of times. Spreadsheets are then set up with four work groups/sheet with each work group having a time slot or "range of time." For example, work group E would be for benchmark jobs ranging from 0.9 h up to 1.5 h and assigned a standard time (slot time) of 1.2 h. Likewise, work group F would be for benchmark jobs ranging from 1.5 h up to 2.5 h and assigned a standard time of 2.0 h. Spreadsheets include brief descriptions of the benchmark jobs and represent pure wrench time. Work content comparison is then done by an experienced person, typically a trained planner, to establish planning times within the 95% confidence range. A users guide complete with step-by-step procedures and forms for establishing the ACE team benchmarking process is available in Appendix G. Figure 6.11 below illustrates the ACE team time ranges for work groups A to T with a time range of up to 30 h, ranging from

Planning times are essential: Planning times provide a number of key benefits for the planning/scheduling process. First, they provide a means to determine existing workloads for scheduling by craft areas and backlog of work in each trade area. Planning times allow the maintenance planner to balance repair priorities against available craft hours and to establish realistic repair schedules that can be accomplished as promised. Secondly, planning times provide a target or goal for each job that allows for measurement of CP. Due to the variability of maintenance type work and the inherent sensitivity toward measurement, the objective is not so much the measurement of individual CP. The planner must always remember that one real objective is measurement of the overall performance of the craft workforce as a whole. While measurement of the individual crafts person is possible, CP measurement is intended to be for the maintenance craft labor resources and getting maximum value as shown in Figure 6.12.

## The ACE System Time Ranges

	ACE S	ACE SYSTEM TIME RANGES		
WORK GROUP	FROM	STANDARD TIME (Slot time)	то	
Α	0.0	.1	.15	
В	.15	.2	.25	
С	.25	.4	.5	
D	.5	.7	.9	
E	.9	1.2	1.5	
F	1.5	2.0	2.5	
G	2.5	3.0	3.5	
Н	3.5	4.0	4.5	
	4.5	5.0	5.5	
J	5.5	6.0	6.5	
K	6.5	7.3	8.0	
L	8.0	9.0	10.0	
М	10.0	11.0	12.0	
N	12.0	13.0	14.0	
0	14.0	15.0	16.0	
P	16.0	17.0	18.0	
Q	18.0	19.0	20.0	
R	20.0	22.0	24.0	
S	24.0	26.0	28.0	
T	28.0	30.0	32.0	

Figure 6.11 Illustrates the ACE (a consensus of experts) team time ranges for work groups A to T.

Range of Overall Craft Effectiveness Element Values				
OCE Elements	Low	Medium	High	
1. Craft Utilization (CU)	30%	50%	70%	
2. Craft Performance (CP)	>80%	90%	95%	
3. Craft Service Level CSQ)	>90%	95%	98%	
The OCE Factor	22%	43%	65%	

### Figure 6.12 Range of overall craft effectiveness (OCE) element values.

CSQ: The third element affecting OCE relates to the relative quality of the repair work. This element includes quality of the actual work, where certain jobs possibly require a callback to the initial repair, thus requiring another trip to fix it right the second time. Recall the last time you had to call back a repair person to your home for a job not performed to your satisfaction. This is not a good thing for a real profit-centered maintenance company! However, CSQ can be negatively impacted within a plant or facility complex due to no fault of the crafts person when hasty repairs, patch jobs, or inferior repair parts/materials create the need for a callback.

We can measure callbacks via the CMMS with special coding of callback work orders. Typically, the CSQ element of OCE is a more subjective value and therefore it must be viewed accordingly in each operation. However, the CSQ level does affect overall craft labor productivity and the bottom line results of the entire maintenance process. When reliable data are present for all three elements of OCE, then the OCE factor can be determined by multiplying each of these three elements:

What OCE can you expect? Since OCE is a rather new concept, there are actually a limited number of case studies outside the real worldwide experiences of MEI staff and alliance members. Some organizations try to measure just wrench time, and it is accepted that 30–40% is typical and 70% is great. Other organizations may measure and track CP if a sound planning process and reliable planning times are in place. Also, other good consulting firms shy away from the often sensitive issue of measuring craft labor at all, especially within a union environment. The Maintenance Excellence Institute International does recommend measurement even for a union shop. This is because at some point high wages, growing continuously without productivity improvement, will make the operation a candidate for contract maintenance.

The Maintenance Excellence Institute International (TMEII) feels strongly that measuring and improving productivity of craft labor resources is essential to profit-centered maintenance and continuous reliability improvement. Measuring and improving OCE must be addressed by today's in-house maintenance operation. Likewise, we feel that the range of OCE element values shown in Figure 6.13 represents the high, medium, and low combinations for OCE. Successful operations can expect an OCE factor in the high range of 65% or more.

Level of Craft Utilization	Total Wrench Time (Hours)	Actual Hands On Cost Per Hour	Average Wrench Time Hours Per Craft Position
30%	12,480	\$60.00	624
40%	16,640	\$45.00	832
50%	20,800	\$36.00	1040
60%	24,960	\$30.00	1248
70%	29,120	\$25.71	1456
80%	49,920	\$22.50	1664
*85%	35,360	\$21.18	1768
90%	37,440	\$20.00	1872
100%	41,600	\$18.00	2080

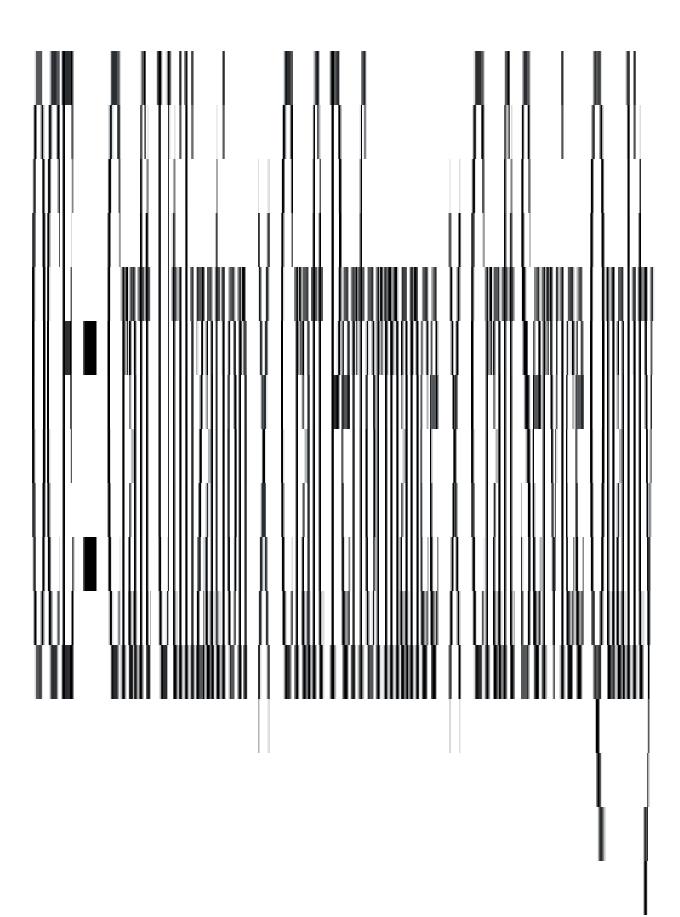
### Figure 6.13 Actual cost per hour at various levels of wrench time.

Note: Maximum possible CU is 85% (as shown previously in Figure 6.2 above considering paid holidays, vacation time, breaks, but not shop cleanup, employee meetings, craft training, etc.).

All three elements of OCE are important: Maintenance craft labor may be very efficient with 100% CP and still not be effective if CU is low and craft service quality is poor.

Note: This is the prime example of having high efficiency but doing low quality work and having low actual wrench time putting out fires from emergency, nonplanned work.

The nature of determining the value of CSQ can be accomplished and requires a "good call" by the respective supervisor responsible for work execution. This element typically can used for calculating OCE if callbacks are recorded correctly. Plus, there should not be many callbacks as a percentage of work orders completed. The element of quality of repairs is a very important element of OCE. It is an important part of effective planning and scheduling related to monitoring and control of work. Another key part of planning is determining the scope of the repair job and the special tools or equipment that are required for a quality repair. That is also why Category 27, Maintenance and Quality Control, is included as a best practice category on the Scoreboard. A continuing concern of the maintenance planning function should be on improving existing repair methods whether by using better tools, repair procedures, or diagnostic equipment and using the right skills for the job. Providing the best possible tools, special equipment, shop areas, repair procedures, and craft skills can be a key contributor to improving CSQ. And CSQ is a key performance indicator that is determined from periodic review of callbacks, customer complaints, and customer surveys. Therefore, The Maintenance Excellence Institute International (TMEII) feels that the OCE factor is best determined by using all three elements for the OCE factor calculations:



The impact of improving both craft utilization and performance: Improved CU through more effective planning of all resources will increase available wrench time. Improved performance results from the fact that work is planned and the right tools, equipment, and parts are available made by planning the right craftsperson or crew for the job with the type of skills needed. Improving CP is a continuous process with a program for craft skills training and methods improvement to do the job right the first time in a safe and efficient manner. The ACE team benchmarking process mentioned earlier provides reliable planning times based upon "ACE" and a tremendous repair methods improvement effort as benchmark jobs are analyzed.

### Example C: What if We Increase Wrench Time from 30% to 50% and CP from 80% to 90%

When we look at the combination of improving both craft utilization and performance, we see an even greater opportunity for a return on investment. Let us now look at a very realistic 20-point improvement in CU and a 10-point increase in CP for the same 20-person craft workforce shown in Figure 6.14, actual cost per hour at various levels of wrench time, and having an average hourly rate of \$18.00.

### **Example C Details**

 $\bullet$  Baseline Cost per Direct Maintenance Hour @ 30% Utilization and 80% Performance

# 

Baseline Cost:  $$748,800 \div 9984$  Direct Hours = \$75 Cost per Direct Craft Hour

}		CUASVA	W/1/52
	Canadan		

### Figure 6.14 Summary comparisons of previous examples.

• Improved Cost per Hour with 50% CU and 90% CP

# 

### Cost per Direct Craft Hour @ 50% CU and 90% CP = \$40

\$748,800 ÷ 18,720 Direct Hours = \$40 Cost per Direct Hour.

• Total Direct Craft Hours Gained = 8736 Total Direct Hours Gained (87% Increase)

18,720 direct hrs – 9984 direct hrs @ Baseline = 8736 Direct Craft Hours Gained

8736 direct hrs Gained  $\div$  9984 direct hrs @ Baseline =  $0.87.5 \times 100 = 87\%$  Gain in Direct Craft Hours

• Total Gain in Equivalent Number of Craft Position: 17 Equivalent Craft Positions

20 crafts  $\times$  0.87 (% Hours Gained) = 17.4 Equivalent Craft Positions

8736 h Gained ÷ 499 h/Craft Baseline Average = 17.4 Equivalent Craft Positions

• Total Gained Value = \$655,200

Gain of 8736 Direct Craft Hours × \$75 Baseline Cost/Direct Hour = \$655,200 Gained Value

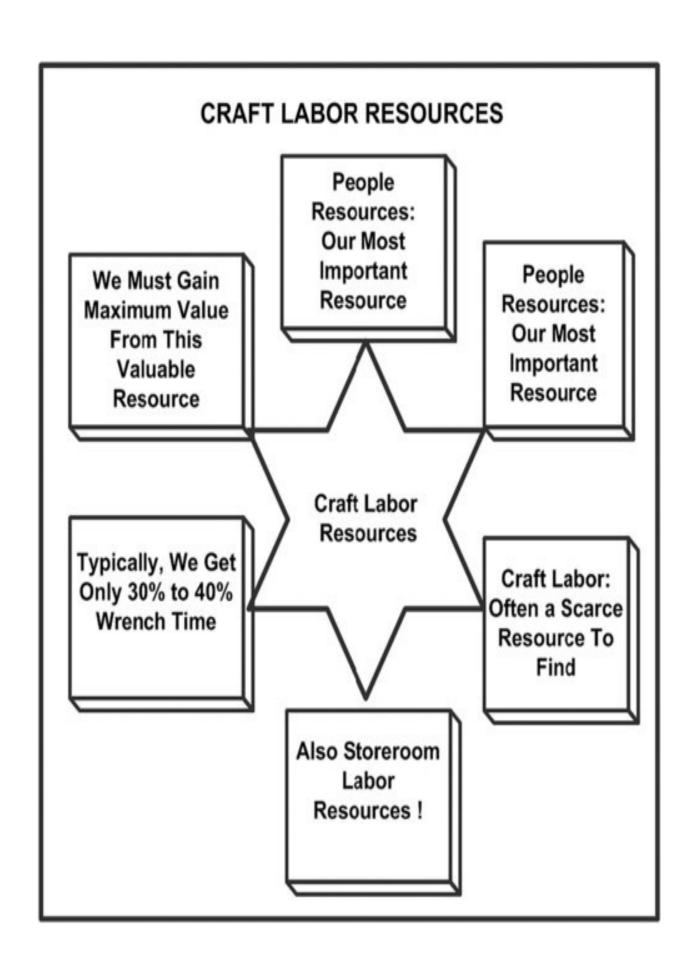
\$655,200 ÷ \$748,800 = 87% Gain from a Baseline of 30% Wrench Time and 80% CP

Summary of our previous examples: The previous examples have illustrated that increasing OCE provides greater craft capacity and gained value from increased wrench time. Improving CP in combination with improving CU simply compounds our return on investment, an astronomical amount of 87% as shown in Figure 6.15.

Where can we apply OCE gained value? Maintenance operations that continually fight fires and react to emergency repairs never have enough time to cover all the work (core requirements) that needs to be done. Over time, more crafts people or more contracted services typically seem to be

the only answers. Improving CU provides additional craft capacity in terms of total productive craft hours available. In relation to OEE, OCE is increased people asset availability and capacity. It is gained value that can be calculated and estimated and then measured. The additional equivalent craft hours can then be used to reduce overtime, devote to PM/PdM, reduce the current backlog, and attack deferred maintenance, which does not go away. Previously, Figure 6.2 showed, "How your valuable craft time can just slip away."

Indiscriminate cutting of maintenance is bloodletting: Typically, operations that gain productive craft hours desperately need them to invest the time elsewhere. Likewise, we cannot automatically and indiscriminately reduce head count when we improve overall craft productivity. Indiscriminate cutting of maintenance is killing the goose that lays the golden egg. If an organization is not achieving core requirements for maintenance, the cutting of craft positions to meet budgets is like using bloodletting as a new cure for a heart attack. It will not work. Just like the high cost of low-bid buying, gambling with maintenance costs can be fatal. Long-term stabilization and reduction of head count can occur. Attrition can absorb valid staff reductions that may result over the long term. We also may regain our competitive edge and get back some of the contract work we lost previously to low performance and productivity. We cannot indiscriminately cut craft labor resources when we increase OCE. The planner/scheduler helps ensure greater craft productivity and then maintains the total maintenance requirements from backlog management to use the gained craft capacity.



### Figure 6.15 Craft labor resources.

Think profit centered: Today's maintenance leaders (supervisors and planners included) and crafts people must develop the "maintenance-for-profit" mindset that the competition uses to stay in business. Measuring and improving OCE and the gained value received from improving our craft productivity is an important part of successful total asset management. Profit-centered in-house maintenance in combination with the wise use of high quality contract maintenance services will be the key to the final evolution that occurs. There will be revolution within organizations that do not fully recognize maintenance as a core business requirement and establish the necessary core competencies for maintenance. The bill will come due for those operations that have subscribed to the "pay me later syndrome" for deferred maintenance. It will be revolution within those operations that have gambled with maintenance and have lost with no time left before profit-centered contract maintenance provides the best financial option for a real solution.

Maintenance is forever: Contract maintenance will be an even greater option and business opportunity in the future. Again, we must remember that maintenance is forever! Some organizations today have neglected maintaining core competencies in maintenance to the point that they have lost complete control. The core requirement for maintenance still remains, but the core competency is missing. In some cases, the best and often only solution may be value-added outsourcing. Maintenance is a core requirement for profitable survival and total operations success. If the internal core competency for maintenance is not present, it must be regained. Neglect of the past must be overcome. It will be overcome with a growing number of profit-centered maintenance providers that clearly understand OCE and providing value added maintenance service at a profit. Your planner/schedulers can help your organization take a profits-centered approach.

Technology supports data collection for measuring OCE: We can easily collect data with today's technology (which, in fact, has been available for a long time). Bar coding can support asset tagging and identification, parts

identification, as well as the work order itself. Parts charged to a work order that has a bar code is fast and accurate. But one challenge is linking a work order to an asset of a subcomponent of an asset. Often we see companies that have not finished the task of numbering all of their assets. The planner must make sure that asset numbering is complete. One way to get complete asset numbering is to do it "correctly the second time." During this second time numbering activity, many important things can occur:

- 1. Existing asset number can be confirmed. Many times migration of data to a new CMMS is done hastily and not really validated.
- 2. Missing asset numbers can be established. Missing data from an old system stays missing upon data migration unless it is validated.
- 3. Parent—child relationships can be reviewed. For example, one rule of thumb is that if a critical subsystem or component has a need for reliability improvement and its related failure data, then it should have an asset number.
- 4. A complete list of asset numbers to correct items 1, 2, and 3 above is the ideal time to affix appropriate bar codes to item outside and those inside the confines of the facility.
- 5. With assets now bar coded along with a bar-coded work order we can link the work performed to the asset, a subsystem, or a critical component with all the labor charged back to a work center or department account number.
- 6. The next step forward can be handheld devices that can wirelessly receive new work orders, contain complete PM task lists, collect time to a work order, and have clock on and off of a job as required. Prompts can be in place for defining type failure and cause of failures as well.
- 7. With all of the above in place, the once tedious task of using special codes for non-wrench time can be eliminated. Since we are most interested in two key areas of OCE, CP and CU (wrench time), they can now be easily accounted for due to bar coding on the asset.
- 8. The crafts person is assigned a job and "the total job clock starts." They clock on at the asset to begin their wrench-time work (hopefully planned with all items needed for the repair). If they must clock off to get parts, they clock off by swiping the bar code. When they come back, they clock on the job to finish it

and clock off again.

- 9. All of the time clocked on the job is wrench time and all other non-wrench activities, such as travel to/from the site, personal fatigue and delays (PF&D), hopefully have been designated as job allowances for scheduling purposes.
- 10. When the crafts person reviews and provides all required input for the work order, they do it and then close the job to maintenance before required approvals are given and before final review by the planner.

Summary: So what does all this application of handheld devices and bar coding give us?

- 1. First, we can have time reporting for pay purposes with simple clock in and clock out at the site entrance.
- 2. We can easily track available hours charged to work orders where the goal can approach 100%. From the tracking of total planned time accrued to work orders, we can get actual time worked and therefore CP that we want to measure, across the entire workforce.
- 3. By clocking on and clocking off for actual hands on time, we are getting a much better picture of wrench time to give a better measure of CU.
- 4. We are also able to see the impact of emergency work when a person is pulled off and put back on a planned job.
- 5. Scope changes can be readily be analyzed for additional planned times or extremes when planned time is much more than originally planned.

Overall, the use of bar coding is not new for some maintenance operations. Some I have seen even included assigning a hardened laptop for each crafts person. Some make use of the phone system approach, while others use a handheld data collection device. The return on investment to enhance craft productivity and reliable data for RCM and root cause analysis (RCA) can be high when all elements we have discussed are in place.

\_

### What to Look for When Hiring a Reliable Planner/Scheduler

\_

### **Abstract**

This chapter provides a comprehensive review of a planner/scheduler position. The primary scope and role of planning and scheduling is to improve craft labor productivity and quality through the elimination of unforeseen obstacles such as potential delays, coronation parts, machine time, and available resources. Therefore, the planner/scheduler is responsible for planning, estimating, and scheduling of all maintenance work performed across their area of responsibility. They support direct liaison and coordination between operations and the maintenance department, along with maintaining appropriate records and files that can lead to meaningful analysis and reporting of results from execution of work. They must clearly define the scope of work and check the requested work priority and requested completion dates to see if they are realistic, and in turn determine if they provide realistic lead time.

### **Keywords**

Backlog; Blanket work orders; Job packages; Job plans; KAHADA; Measure contractors; Planner; Planner/scheduler; Plant engineering; Ready backlog; Scheduler; Scope of work; Special skills; Standing

### work orders; Total backlog; Total maintenance requirements; Troubleshooting; Work order; Work requests

A. Typical Roles and Responsibilities of a Planner/Scheduler: Let us first look at the overall roles and responsibilities of a planner/scheduler as a baseline for upcoming topics related to each area of the planner position. Taking a fairly complete picture of the roles and responsibilities of planner/schedulers is a good first step. In this chapter, I provide some hints, observations, and recommendations that can assist you as maintenance leader, those who are in a planner/scheduler position, or someone that has just been selected for such a position. I also strive to illustrate how the planner/scheduler can make a significant impact on improving reliability and be a key leader for continuous improvement.

- 1. The title of this book, Reliable Maintenance Planning, Estimating, and Scheduling, indicates that this book will address a planner's additional responsibilities for supporting the site's reliability improvement process. The planner's unique position in the organization provides many natural job-related opportunities to contribute.
- 2. Maintenance planners/schedulers typically report to the maintenance leader.
- 3. The primary scope and role of planning and scheduling is to improve craft labor productivity and quality through the elimination of unforeseen obstacles, such as potential delays, coronation parts, machine time, and available resources. Therefore, the planner/scheduler is responsible for planning, estimating, and scheduling of all maintenance work performed across his or her areas of responsibility. The planner/scheduler supports direct liaison and coordination between operations and the maintenance department, along with maintaining appropriate records and files that can lead to meaningful analysis and reporting of results from the execution of work.
- 4. Remember that small operations may have a combination planner/scheduler, whereas larger plants, such as a large refinery, will normally have separate planners and schedulers. In some cases, I have seen day-to-day planners plus shutdown turnaround outage planners, along with planners for your facilities maintenance, such as control room office buildings and testing laboratories.

- 5. As stated, this position acts as the principal contact and liaison between maintenance and the various plant departments/customers that are served by maintenance. This person ensures his or her areas of responsibility for functions receives prompt efficient and quality service from maintenance. The planner/scheduler also strives to ensure that maintenance can provide this service and operations allows equipment to be shut down for various types of maintenance, including preventive and predictive maintenance's inspections.
- 6. The planner serves as the central point where all work requests are received and reviews these before they are turned into official work orders. True emergency work will typically go directly to the first-line supervisor or crew leader of the trade area required for the work. The work order in this case may be completed after the fact and would come back through the planner through a supervisor or craftsperson.
- 7. Reviewing and screening of each work order is a very critical task performed by the planner/scheduler. First, the planner/scheduler defines whether the work order is filled out correctly or if additional clarification is needed for the work requests. Here, the planner plays a big role in training and encouraging the operations staff to request work properly. In large refining operations, each operating unit may have a maintenance coordinator, who supports direct coordination with the planner as well the craft workforce when they come to perform repairs. For any type of operation, it is good practice to have someone designated within the department to create work orders and be able to see the ongoing status (hopefully online and in real time).
- 8. Other key areas during the review of work orders include clearly defining the scope of work, as well as checking the requested work/priority and requested completion dates to see if they are realistic and provide realistic lead times. One key point about planning is that we must have lead times. Without lead times, everything is unplanned reactive maintenance,
- 9. The planner/scheduler makes sure that accounting codes and other coding for chargebacks are correct and that all required approvals have been received.
- 10. At times, the planner/scheduler may need to discuss the details of the job with the person requesting the job when appropriate. If a maintenance coordinator is assigned within each unit of a large refinery, then that person typically will have written up the job request and has knowledge of the location

within the unit and the problems to be repaired. In many cases, this is an engineer or experienced operator who should be able to define complete requirements or a work request.

- 11. The planner/scheduler will also assemble drawings, PID diagrams, and make additional diagrams in order to clarify work included on the work order.
- 12. At times, the work requests may not be valid. The originator should be questioned and issues should be readily resolved with operations. If issues are not readily resolved, the maintenance leader can be contacted in the next step that the planner/scheduler takes for resolution.
- 13. Some work orders may require information from plant engineering, so the planner might refer some work orders for further review by engineering.
- 14. If planned work orders involve the participation of several shops or functional crews, they are crossed over to a planner in that area. However, a single planner/scheduler must plan and then coordinate various functional crews with their respective supervisors during the scheduling process.
- 15. Planners should examine jobs to be done during the scoping process and determine the best way or method to accomplish the work. Planners may consult with the requester, maintenance supervisors, and subject matter experts within the craft workforce.
- 16. For job packages for more complex jobs, the documentation required may be much more than normal. It may include blueprints, drawings, parts list, special procedures, or repair or instructional manuals for the repair—all that is needed to clarify the intent of the work order to the craftsperson doing the job.
- 17. Planners normally will identify parts and materials required. They may create the purchase requisition, monitor status of incoming parts not in inventory, and arrange for kitting or delivery to the job site, shop, or secure job boxes as appropriate throughout the site.
- 18. Planners should determine if critical spares/insurance items are in stock by verifying availability with stores or via direct online access. Note that planners are in an excellent position to recommend items to consider for including within the storeroom as critical spares. They see what is repetitively coming up for nonstock item purchasing as well as what is being repaired over and over again.

Being active in this area can support improving reliability and uptime.

- 19. A top priority for the planner is ensuring that safety needs are met as well as all health, safety, security, and environmental issues.
- 20. For reliable estimations, the sequence of job steps should be well defined and come from doing a good scope of work. Also, for each step, the number of technicians that were required, man-hours for each step, and total duration of the job should be established. A parts list should be developed, along with any special tools or equipment that might be needed.
- 21. A reliable method to estimate times for scheduling must be in place. The Maintenance Excellence Institute International highly recommends use of the ACE (A Consensus of Experts) team benchmarking process. This method is based on the slotting concept but uses a consensus of experts via a crossfunctional team to analyze benchmark jobs (for wrench time), which then are used in slotting with site-specific allowances added to determine a reliable time scheduling purposes. More details for applying the ACE team process are provided in Chapter 15.
- 22. Cost estimates may be required for selected jobs, including direct labor costs, material costs, and rental equipment costs, to reach a total estimated cost. As discussed previously, one good performance metric is to establish a reasonable cost variance, typically from 5% to 10%. My philosophy has always been to measure contractors just as we measure our in-house craft personnel related to costs and productivity. Therefore, an extreme cost variance by a contractor may become obvious early on before the total cost has exceeded all expectations and it is too late to make adjustments. Planners should be accountable for cost estimates that they make, and project engineers should be accountable for their cost estimates as well.
- 23. Maintaining the total maintenance requirements in the form of backlog is a critical role of the planner/scheduler. This is a backlog file of work orders waiting for scheduling in accordance with their priority limits with an estimated date for completion. Work orders without parts in hand are never ever included on a weekly schedule. Proactive planning occurs when a part comes in, the equipment is made available, and the repair is made with the needed parts.
- 24. The total maintenance requirement backlog consists of total backlog plus

ready backlog. It should be accurate and readily available for the maintenance leader to see and to brief top leaders on staffing needs, use of overtime, and work that can be referred until shutdown occurs. However, deferred maintenance needing immediate attention that will be of greater cost if left unrepaired should be reported to top leaders at every opportunity.

- 25. Based upon approved schedules, the planner assembles all relevant work orders plus supporting documents for the area supervisors. At this time, any planning/job packages are discussed, along with any special instructions or considerations to be observed in the execution of the job. Any new upcoming jobs are also reviewed. All work orders, including emergencies for tracking purposes, come through the planner.
- 26. Follow-up to progress being made on the current schedule is important and can come from a number of sources. The key source is from the maintenance supervisor who monitors order progress and provides feedback to the planner. The planner then carefully reviews the completed schedule and corresponding work orders. If real-time labor reporting is being done for a big job, then good visibility of status is available. In this case, the planner, supervisor, and person requesting the job can track hours spent versus hours planned for a status. However, it is the supervisor's responsibility to inform the planner or customer of the true job status. With staffing adjustments, the supervisor may bring a job back on schedule. For jobs that will not meet their scheduled completion times, the supervisor must notify both the planner and the customer.
- 27. Based on current control procedures, the planner provides a final review of work orders and administrative support performs the final closeout in the CMMS (computerized maintenance management system) system. This is an important step toward work order closure, allowing the planner to ensure that key information is accurately charged to the work order, such as valid work completion, cause of failure, failure codes, and craft time.
- 28. Selected jobs may be charged to standing work orders/blanket work orders for minor repairs or for asset logbook-type jobs. The planner needs to be kept advised as to the status of these jobs. Generally, they are closed out monthly and reported, with a new blanket order created for the next month's work with this type of general-purpose work order. Note that troubleshooting is an important skill. It can often be scheduled by a planner needing the true scope of work that is not visible until the item is disassembled and parts for replacement are

determined. My recommendation is to consider this time as wrench time and track it as a work type if need be. This is also an area for additional training to ensure systematic troubleshooting practices are used by all. There are a number of technical training companies that offer both electrical and mechanical troubleshooting courses.

- 29. Where there are multiple planners across a large site, each planner must ensure that they coordinate complex multiskilled jobs with the applicable shops served by other planners.
- 30. Planners should schedule other weekly meetings with operations supervisors and maintenance supervisors who work in relevant areas regarding facilities or equipment to be maintained and work requests generated.
- 31. A skilled planner can make excellent recommendations to the operations team related to long-term maintenance needs. In collaboration with production, the planner can prepare a weekly or monthly forecast of work expected to be scheduled. At times, the planner may solicit relatively simple corrective maintenance in order to avoid major repairs at a later date. As we discussed previously, finding small repairable items from PM tasks, which can be planned and scheduled before a catastrophic failure, provides direct cost avoidance and return on investments for PM and PdM. It is a good rule of thumb to track these work types with a separate repair type code, showing jobs that were generated as a result of PM/PdM. Even better is when the planner can extract related actual repair costs to projected costs of a catastrophic failure.
- 32. Planners should always maintain part of their ready backlog that can be scheduled when windows of opportunity occur as equipment is not being used for any reason.
- 33. When the ready backlog has all the resources necessary to schedule, the planner can file these by supervisor and by completion date. This can be readily accomplished by a computerized system to include visibility to the requester with regard to their specific work requests (now the form of work orders), status of work orders on the schedule, and completed work orders in their respective areas. However, the planner maintains the master backlog summary, which must be accurate and define all completed jobs without delay, jobs that are questionable, backlog status, and estimated times, especially for current backlog jobs ready for scheduling.

- 34. After the job is fully planned, with man-hours and job duration established, the planner verifies the availability of parts material and any special tools prior to scheduling. Always remember that a job does not appear on a schedule unless all parts, materials, and special tools/equipment are available.
- 35. With regards to PM/PdM, the planner should have knowledge of required resources within each department and attempt to level load this type of work to ensure that all annual PMs are spread out across the year and do not all come at the same time.
- 36. As a schedule is being firmed up for the next week, generally the planner will convene a scheduling meeting during the last days of the current week. Typically, the day may be Thursday (or Wednesday in the Middle East, where there is a Sunday to Thursday work week). At times, this may include planner participation as part of a regularly scheduled production/operations review meeting, with the planner scheduled on the agenda to review next week's schedule. It is at these scheduling meetings that commitment is gained for equipment to be available for PMs and other scheduled repairs. It is a good practice to have operations agree and formally sign off on next week's schedule.
- 37. For a continuous process operation, such as a refinery, gas plant, or petrochemical operation running 24/7, much can occur on Friday. Saturday, and Sunday if the scheduling meeting is held on Thursday afternoon, for example. Therefore, work generated after the schedule is put in place must be viewed in terms of priority. Whether or not it should be added to the schedule can be finalized after the weekend.
- 38. It is highly recommended that the first day of the scheduled week be as firmly established as is possible.
- 39. If anything is rigidly flexible, it must be the weekly schedule. Best practice is for operations to approve any break in an established schedule by signing off at the scheduling meeting. As stated previously, critical spares coming in during the schedule week that can be used for critical equipment repair are coordinated with operations, equipment is made available, and repairs are made by adjusting lesser priority items on the schedule. Again, this is very proactive planning process that does count toward customer service (i.e., schedule compliance).
- 40. As a planner begins to develop a schedule, craft labor availability must be

known on a daily basis. It is generally a supervisor's responsibility to let the planner know about planned vacations and sick leave. This affects the labor resources that are available on a daily basis during the weekly schedule.

- 41. When developing a schedule, the planner considers the ready backlog in each supervisor's area and/or trade group. At this point, the planner must match labor requirements with labor availability and take into account any carryover work from the previous week's schedule. All known skill requirements are determined, and one planner may need to make arrangements with other planners. For example, a job such as on-site fabrication with welding may come from coordination with a central shop planner. The planner may also have visibility across a number of shops, monitoring backlog and seeing differences in workloads. Therefore, it is recommended that craft resources be cross-leveled to accomplish work in areas with greater backlog.
- 42. At times, there may be special skills involved that require planner knowledge of the workforce to designate specific crafts resources to these type of jobs. Normally, this is common knowledge between the planner and the supervisor. Nonetheless, the planner coordinates with the supervisor so that specific individuals can be assigned with the technical skills needed for a particular job.
- 43. While planners do not actually assign crafts to specific jobs, they allocate and coordinate these requirements through a maintenance supervisor and, in some cases, the maintenance leader.
- 44. When selecting jobs for scheduling, the planner strives to meet the deadlines established by the requesting department while maintaining the preventive maintenance schedule. This is essential. If any work orders cannot be scheduled within the requested priority lead time, the department management and the requester should be given prompt notification so that appropriate actions can be taken to get the work done in a satisfactory and timely manner. Here is where our organizational structure, with the planner as the direct liaison, comes into effect by creating close communications when schedule complete dates cannot be met or equipment may not be released for repairs.
- 45. As discussed, the planner attends meetings with the operations planning department and participates actively in the overall plant scheduling for the following week's work. Here, the planner negotiates downtime during which preventive or corrective repair can be performed. At this point, the next week's

schedule can be finalized to ensure that scheduled work balances with the labor resources available so that a full day's work is provided for each person. This relates directly to a term I first heard from George Smith: "keep a half a day ahead" (KAHADA). In general, this is accomplished via the supervisor. It can be as simple as putting in work orders and a slot for each craftsperson or as sophisticated as wireless communication of work orders to a handheld device used by the craftsperson for work orders and time reporting, as we discuss in Chapter 6.

- 46. Why is the KAHADA system a good thing to practice? It like knowing who your next opponent is for a game in sports. It gives you time to have a mental picture and think about the first job tomorrow morning—to get psyched up, so to speak. On the other hand, if the job looks to be tough, then a person might decide to take a vacation day—not really! Most maintenance people welcome a challenge, so KAHADA helps them while allowing the storeroom to have the right parts and the planner and supervisor to avoid a hectic shift startup.
- 47. One area directly related to reliability is for the planner to recommend equipment that might be included within the preventive maintenance program. Also, the practice of continuous renewal of work orders should be taken from feedback as the craft workforce completes each PM/PdM task. Here, the planner can help encourage craftspeople to make recommended changes and have the major responsibility for updating PM/PdM task descriptions, frequencies, and estimated times.
- 48. The planning and scheduling of PMs must be coordinated with operations and maintenance supervisors. There must be a well-defined timeframe for completion of each PM on the schedule. Normally, PM compliance is calculated on a monthly basis; however, PMs should be released on a weekly basis. This helps to eliminate last-minute completions at the end of the month. This method establishes a sense of discipline so that PMs are scheduled on a weekly basis and hopefully completed on a weekly basis, depending on the equipment availability. PdM that can be performed with the equipment running is ideal. This can be done by an individual with, for example, a vibration monitoring device, infrared device, or by continuous monitoring via wireless communications to the plant's control center.
- 49. With regard to man-hours required for a PM or PdM program, it is always good for the planners to know the total equivalent man-hours required to achieve

100% PM compliance. This can be done when reliable estimates are in place, simply by calculating the number of occurrences per year for weekly, monthly, semiannual, and annual requirements to get the total man-hours required, then dividing by average man-hours worked per year by a craft position. Figure 7.1 provides a structure for determining the equivalent number of craftspeople required for 100% PM/PdM compliance.

Top leaders must clearly understand the resources needed for an effective PM/PdM program that achieves 100% compliance to existing tasks. I have seen some organizations complete project work to the point that PMs were being almost totally neglected. If all PMs have estimated times and frequencies, this calculation is very straightforward to compile from the PM task database. Often, a trained planner can do it with just Microsoft Excel or Crystal Reports. Also, with SAP Business Objects Analysis edition for Microsoft Office, it is to easy analyze, digest, and share data from multidimensional sources in a Microsoft Office environment and use powerful analytics to discover, compare, and forecast business drivers in Excel. SAP Crystal Reports that produces clear and customizable reports for all types of business insight that are easy to understand and act upon, delivered upon demand.

### VERY IMPORTANT: Define the Required Staffing for Your Preventive/Predictive Maintenance Program

Frequency of Routines	Craft Hours per Occurrence	Repetitions per Year	Craft Hours per Year
Daily	?	365	?
Weekly	?	52	?
Monthly	?	12	?
Quarterly	?	4	?
Semi-Annual	?	2	?
Annual	?	1	?
Other (Overhauls0)	?	.5 to .1	?
		Total/Year <b>♦</b>	27,000 Hrs. (example)
		Required Staff @ 1800 Hrs/Yr ➡	15 Equivalent Crafts

Note: Do not develop this staffing estimate from history. The proper estimate is for achieving 100% PM/PdM Compliance; the current program, if you had the needed craft resources.

### Figure 7.1 A method for defining total staffing requirements for PM/PdM needs.

- 50. Just as planners can support reliability improvement, they can also review with the maintenance supervisors the actual hours required versus estimated labor and material used for completed jobs. This may be in order to determine any corrective action needed to improve the accuracy of estimating and for improving methods of doing work.
- 51. Planners can assist maintenance and operations management with periodic reviews of cost and where recommended corrective actions are needed to reduce maintenance costs. Planners are in an excellent position to see this type of information as it comes through via the completed work orders.
- 52. Another important responsibility of the planner is to keep the maintenance leader properly informed on all abnormal or critical situations and to seek advice on matters outside the planner's knowledge or authority. The planner should have the knowledge to make suggested improvements to the planning and scheduling process and other areas within maintenance, even some denoted from the Scoreboard for Maintenance Excellence. As stated in Chapter 5, the planner should be able to see the big picture across his or her total maintenance operation regarding best practices that could help their own organizations.
- 53. Another important database that the planner develops is the file of standard work orders for job plans. These are regularly occurring repair jobs seen from history that can simplify the planning process by these jobs becoming templates for other jobs.
- 54. A file of job packages for major jobs also may include templates taken from previously performed job plans. Therefore, maintaining a good record and file of job packages is also important for the planner, along with other records, files, and reports, to include preparation and distribution of meaningful and accurate control reports, such as The Reliable Maintenance Excellence Index.
- 55. This position also has the responsibility of performing other tasks and special assignments as needed by the maintenance leader.

- B. Summary of Position Goals and Relationships: The primary goals of the planner/scheduler can be summarized as follows:
- 1. Ensuring that the production/operations areas are served and receive prompt efficient and quality service from the maintenance function, which operates at a high level of productivity
- 2. Ensuring that the maintenance function is given every opportunity to provide production/operations with the service that it requires
- 3. Accurately defining and providing reliable estimates for work requests
- 4. Properly preparing schedules and distributing them along with other meaningful control reports.

Relationships: The maintenance planner/scheduler coordinates with many areas within a plant. While reporting to the maintenance leader, this position works closely with maintenance supervisors, operational supervisors, stores, and procurement personnel, and maintains good working relationships with all other organizational units within the plant.

- C. Selection Criteria: Requirements and Qualifications: The selection of the right person for a planner/scheduler position is an important decision process. Ideally, the following areas should be a part of the position requirements and qualifications:
- 1. It is necessary to have a mechanical/electrical background, with technical school training desired.
- 2. This position should have adequate trade knowledge to establish reliable estimated labor hours and materials as well as to visualize the job to be performed. Proper scoping of the work will ensure that the required job tasks are considered.
- 3. Good communication skills by oral/written means are very desirable and critical to the success of a planner/scheduler.
- 4. At all times, the planner/scheduler should display a high degree of respect for and be able to tactfully deal with both senior and subordinate employees.

- 5. This position must have the ability and willingness to handle and organize various types of paperwork and have higher than average administrative and mathematical skills.
- 6. Planners in today's modern technology world must have or acquire a good knowledge of personal computers and possess reasonable data entry and typing skills.
- 7. Planning and organizational skills must be well developed or acquired via concentrated formal and informal training.
- 8. Planners/schedulers must be the champions of a proactive maintenance strategy as they are the cornerstone for the overall improvement process within maintenance.
- 9. Good work instructions must be understood and developed by planners/schedulers who know and understand what good work instructions are.
- 10. The ability to read and understand blueprints and shop drawings is a necessary skill.
- 11. In turn, planners/schedulers should be able to produce easily understood sketches, etc., that can clarify work instructions when needed.
- 12. Planners/schedulers must thoroughly understand the overall work management process, including the use of work orders, priorities, planning methods, scheduling techniques, etc.
- 13. The ability to monitor multiple jobs in a controlled situation while simultaneously considering new jobs coming in and closing out completed jobs is needed.
- 14. The planner/scheduler must gain the respect of his or her peers, have tough skin during tough times, and be able to function well under pressure.
- 15. Maintenance at times can be in a state of chaos. Planner/schedulers in turn must be able to bring order to the situation at hand.
- 16. Planners/schedulers must always Remember Who They Work For?—the customer of maintenance working with a mindset and commitment to good

customer service.

- 17. They must possess a personal leadership style and a demonstrated level of capability that will gain respect from within both maintenance and the production operations.
- 18. Lastly, they must enjoy their work, have fun, and always demonstrate a philosophy of positive expectations during all encounters with maintenance staff.

Summary: Planners/schedulers should always remember that they were selected for a very important purpose. Often, they may be near the pay level of a maintenance supervisor or foreman. We have just seen the extensive list of roles and responsibilities each person in this position is expected to fill. New or current planners/schedulers must realize the importance of their position and what they can do to improve the productivity of both people and physical assets. This position is an excellent steppingstone to greater responsibilities. I have seen this happen firsthand with the planners we recruited, selected, and trained from 65 mechanics who became service managers within the North Carolina Department of Transportation. All of them became either a division superintendent, an equipment inspector, or a shop supervisor.

\_

8

### Planner Review of the Maintenance Business System —Your CMMS-EAM System

\_

#### **Abstract**

This chapter introduces the CMMS Benchmarking System as the second benchmarking tool and the improvement process that the planner or others can take to gain better use of your CMMS and information technology for maintenance. This benchmarking tool is introduced as a means to help the planner/scheduler evaluate the effectiveness of their current CMMS, to define functional gaps, and to define how to enhance current use or to help upgrade functional gaps. It is also a methodology to help develop and justify a CMMS replacement strategy where many existing planners can play a critical role. It includes 50 evaluation criteria to help gain maximum value from an existing CMMS system.

#### **Keywords**

Asset history; Asset numbering structure; Bill of materials; Budget and cost control; CMMS benchmarking; CMMS training; Computerized maintenance management system (CMMS); Craft utilization; Critical spares; Cycle counting; Data

integrity; Data migration; Deferred maintenance; Life cycle costing; Maintenance repair operations (MRO); MRO materials management; Online work orders; Parts inventory master; Parts kitting; Planning and scheduling; Predictive maintenance (PdM); Preventive maintenance (PM); Work control

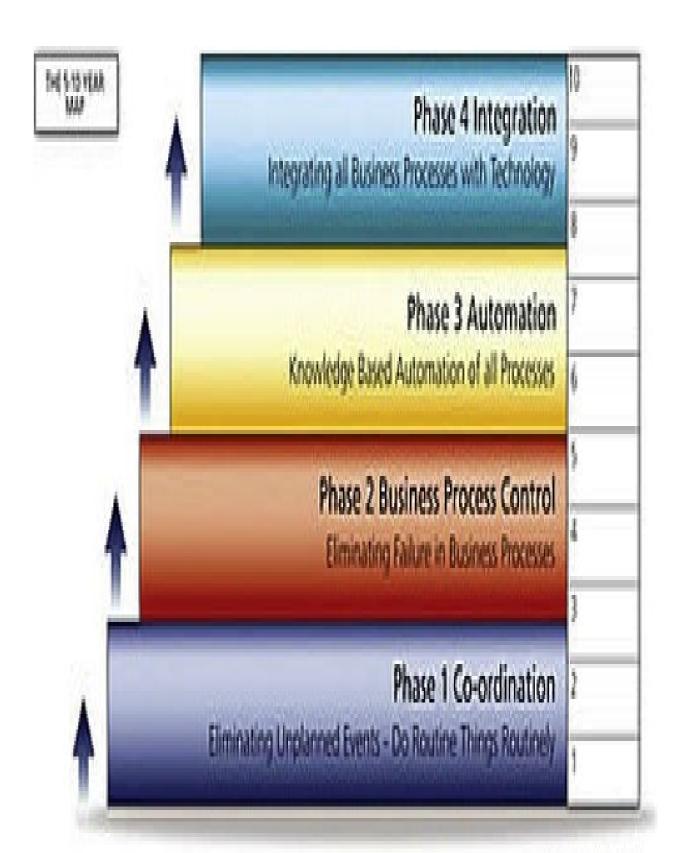
Planners today very seldom operate without a computerized maintenance management system (CMMS), which I like to refer to as the maintenance business management system. With a payroll module plus purchase order creation, it could fit that purpose. This chapter introduces the CMMS Benchmarking System as the second benchmarking tool and the improvement process the planner or others can take to gain better use of your CMMS and information technology for maintenance. This benchmarking tool is introduced as a means to help the planner/scheduler evaluate the effectiveness of their current CMMS, to define functional gaps, and to define how to enhance current use or to help upgrade functional gaps. It is also a methodology to help develop and justify a CMMS replacement strategy where many existing planners can play a critical role.

Often this is the data migration from a stand alone system into an enterprise asset management (EAM) system such as SAP, JD Edwards One World, and others. Often a change provides a company with a chance to get it right the second time. It has been said many times that computerizing a bad process workflow and procedures only increases the magnitude of the problem. Therefore, the key to successful implementation is to ensure the correct best practices are in place such as planning and scheduling, and a good preventive and predictive maintenance (PM/PdM) program and well-planned storeroom and parts inventory is in place. In the 1980s, I developed this from a concept used by the late Oliver Wight, the guru for materials requirements planning (MRP II) for shop floor production control systems that were emerging. Our plant was the pilot for all of Cooper Industries divisions and plants. A little background from Oliver Wight International would be very appropriate here on your journey toward maintenance excellence.

Journey to Business Excellence.

The journey to excellence is never ending. It encompasses every part and every process in your company. The will to sustain such a journey depends on visible results delivered continually to all your stakeholders. For this reason, the journey begins with short projects that produce results quickly and grows into a longer business improvement program that assures success in the future.

How do you measure your progress? The Oliver Wight Business Maturity Map enables you to understand the maturity of your business and the projects within your business improvement program that will deliver the best real gain now. This is addressed in Oliver Wight education, which is arranged both publicly and privately in all parts of the world.



Is the journey worth the effort? Only the excellent companies consistently win in business, and the standard of excellence is raised every day as customers expect more value and shareholders expect more return. An excellence program unites your people, your customers, and your suppliers by engaging them in a common set of goals, and achieves a pace of change to outperform competition and differentiate your company in the marketplace.

"Our new Sixth Edition Class A Checklist excellence standard will be more demanding upon companies and may require a longer period of improvement. These higher standards reflect the realities of today's increasingly competitive markets. While the journey may be long, the rewards arrive relatively quickly. You can expect that each project within your business improvement program will offer significant and sustainable benefits with rapid payback to your business. I encourage you to sign up for their site and use the excellent free knowledge base of manufacturing info available at http://www.oliverwight.com/checklist.htm. The Checklist raises the standard of demonstrated superior business performance to qualify for the coveted Class A award. No longer an MRP checklist or a manufacturing excellence standard, the Sixth Edition Checklist is a standard of excellence for all businesses. Take up the challenge and begin a journey to Class A with Oliver Wight International, and use the Scoreboard and CMMS benchmarking for your journey to maintenance.

The CMMS Benchmarking System has nine benchmark categories and 50 benchmark items, is easily adaptable, and can be specifically tailored to all CMMS systems for their intended application and operating context. The CMMS system is an internal benchmarking tool like the Scoreboard that is becoming a model process for benchmarking effective use of CMMS. It is designed as a methodology for developing a benchmark rating of your current CMMS into four classifications (Class A, B, C, or D) to determine how well this tool is supporting best practices and the total maintenance process. It is not designed to compare the functionality of various CMMS systems nor is it intended to compare vendors. The CMMS Benchmarking System provides a methodology for developing a benchmark rating of your existing CMMS to determine how well this tool is supporting best practices and the total maintenance process in all operations, large or small.

#### **CRAFT LABOR RESOURCES** People Resources: **Our Most** What if We Important We Must Gain Train Them & Resource Maximum Value They Leave? From This Valuable What if They Resource Stay? Craft Labor Resources Typically, We Get Craft Labor: Only 30% to 40% Often a Scarce **Wrench Time** Resource To Find Also Storeroom Labor Resources!

Figure 8.1 Effective computerized maintenance management system is key to continuous reliability improvement.

It can also be used as a method to measure the future success and progress of a CMMS system implementation that is now being installed. Maintenance best practices are the key and the CMMS is the information technology tool that links it all together. Maintenance information is one of the key maintenance resources (Figure 8.1) and must be a part of your approach to continuous reliability improvement, which covers all six maintenance resources.

A summary of The CMMS Benchmarking System is shown in Figure 8.2 with the nine assessment categories that include a total of 50 benchmark items for benchmarking your CMMS installation. The CMMS Benchmarking System rating scale is shown in Figure 8.3.

#### **Conducting the CMMS Benchmark Evaluation?**

The CMMS benchmark evaluation can be conducted internally by the planner/scheduler, maintenance leader, or via an internal team effort of knowledgeable maintenance people. Other options include using support from an independent resource to provide an objective maintenance benchmarking resource. The Scoreboard for Maintenance Excellence<sup>TM</sup> process in combination with the CMMS Benchmarking System provides powerful tools to help achieve greater value from all the six types of maintenance resources across all types of maintenance operations.

The CMMS Benchmarking System provides a means to evaluate and classify your current installation as either "Class A, B, C or D." Nine major categories are included along with 50 specific benchmark items. Each benchmark item that is rated as being accomplished satisfactorily receives a maximum score of 4 points. If an area is currently being "worked on," a score of 1, 2, or 3 can be assigned based on the level of progress achieved. For example, if spare parts inventory accuracy is at 92% compared to the target of 98%, a score of 3 points is given. A maximum of 200 points is possible. A benchmark rating of "Class A" is within the 180 to 200 point range. The complete CMMS Benchmarking System is included as an Appendix, and a sample is included below in Figure 8.4 for Category A-CMMS Data Integrity; Items #1 and #2.

#### The CMMS Benchmarking System

CMMS BENCHMARK CATEGORIES	Benchmark Items
1. CMMS Data Integrity	6
2. CMMS Education and Training	4
3. Work Control	5
4. Budget and Cost Control	5
5. Planning and Scheduling	7
6. MRO Materials Management	7
7. Preventive and Predictive Maintenance	6
8. Maintenance Performance Measurement	4
9. Other Uses of CMMS	6
TOTAL CMMS BENCHMARK ITEMS	50

Figure 8.2 Summary—the computerized maintenance management system (CMMS) Benchmarking System best practice categories.

CMMS BENCHMARKING SYSTEM RATING SCALE				
Class A 180 - 200 points (90% +)				
Class B	140 - 179 points (70% to 89%)			
Class C	100 - 139 points (50% to 69%)			
Class D	0 - 99 points (up to 49%)			

Figure 8.3 The computerized maintenance management system (CMMS)

Benchmarking System rating scale.

Developing a future "Class A" CMMS installation requires that each organization start early in the implementation phase with establishing how they will determine the overall success of their installation. The CMMS Benchmarking System provides the framework for internal benchmarking of the CMMS installation as it matures. It is recommended that a team process be used for the CMMS benchmarking evaluation and that it be included as part of the CMMS evaluation team's initial work. Appendix D includes a charter format for a Leadership Driven, Self-Managed Team at GRIDCO Ghana for first evaluating, selecting, and implementing CMMS with concurrent best practices of which planning and scheduling was a critical need across all six regions of Ghana's power transmission grid.

CMMS BENCHMARKING CATEGORIES and ITEM DESCRIPTIONS	YES (4 Points)	NO (0 Points)	WORKING ON IT (1, 2 or 3 Points)
A. CMMS DATA INTEGRITY			
Equipment (asset) history data complete and     accuracy 98% or better			
2. Spare parts inventory master record accuracy 98% or better			

#### Figure 8.4 Example Category A—computerized maintenance management system (CMMS) data integrity from the CMMS Benchmarking System

Establishing a "Class A" CMMS requires that a number of key databases be established and that a number of maintenance best practices be in place. Data integrity, accuracy, and continuous maintenance of the key databases provide the foundation for a "Class A" CMMS installation. There are a number of other factors related to the CMMS and to maintenance best practices that in combination produce a future "Class A" installation.

We will now review each of the nine major categories from the CMMS Benchmarking System and provide key recommendations and examples for each of the 50 benchmark items to get your CMMS implementation started on the right track from day one.

-

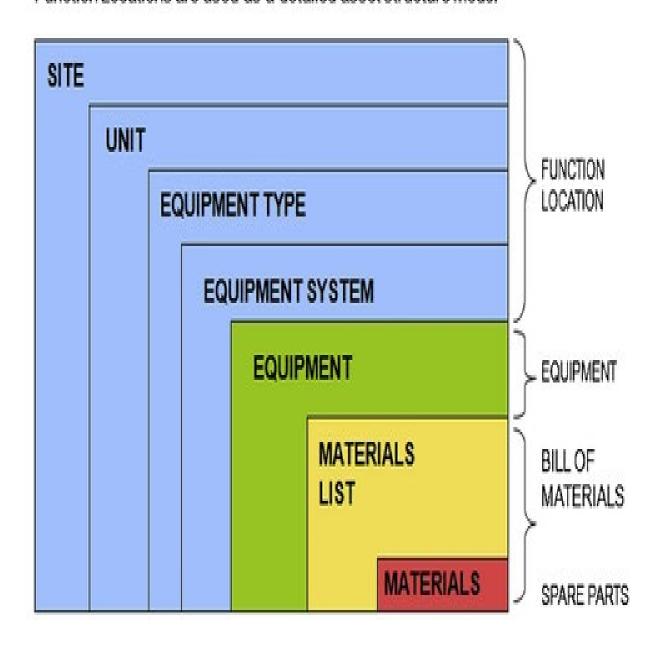
## A. Computerized maintenance management system data integrity

- 1. Equipment (asset) history data complete and accuracy 98% or better
- 2. Spare parts inventory master record accuracy 98% or better
- 3. Bill of materials for critical equipment includes listing of critical spare parts
- 4. Preventive maintenance tasks/frequencies data complete for 95% of applicable assets
- 5. Direct responsibilities for maintaining parts inventory database are assigned
- 6. Direct responsibilities for maintaining equipment/asset database are assigned

1. Accuracy of equipment history database: The equipment database represents one of the essential databases that must be developed or updated as part of implementing a new CMMS. It requires that a complete review of all equipment be made to include all parent/child systems and subsystems that will be tracked for costs, repairs performed, etc. The work to develop or update this database should begin as soon as possible after the data structure of the equipment master file for the new CMMS is known. A number of examples from a refinery's use of SAP are included.

#### SAP Structure and Function Location

Function Locations are used as a detailed asset structure model



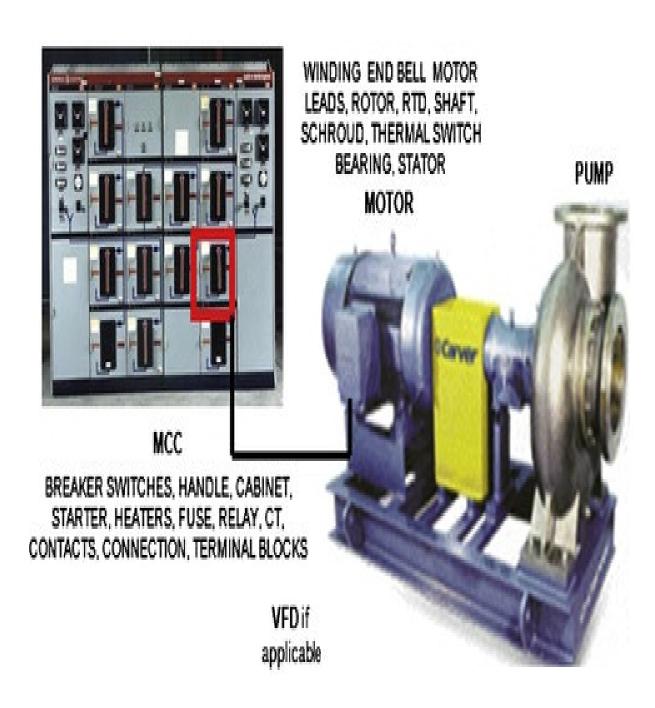
The equipment master information for a piece of equipment (parent/child), manufacturer, serial number, equipment specs, and location will all need to be established. If the installation and removal of components within certain process type operations requires tracking by serial number and compliance to process safety management requirements, these equipment items will have to be designated in the equipment database.

If an equipment database exists as part of an old CMMS, now is the time to review the accuracy of the old equipment database prior to conversion to the new system. Conversion of the new equipment master database into the new system should be done only after a thorough and complete update of the old database has occurred. Once the new equipment master database has been converted to the new CMMS, a process to maintain it at an accuracy level of 98% or above should be established.

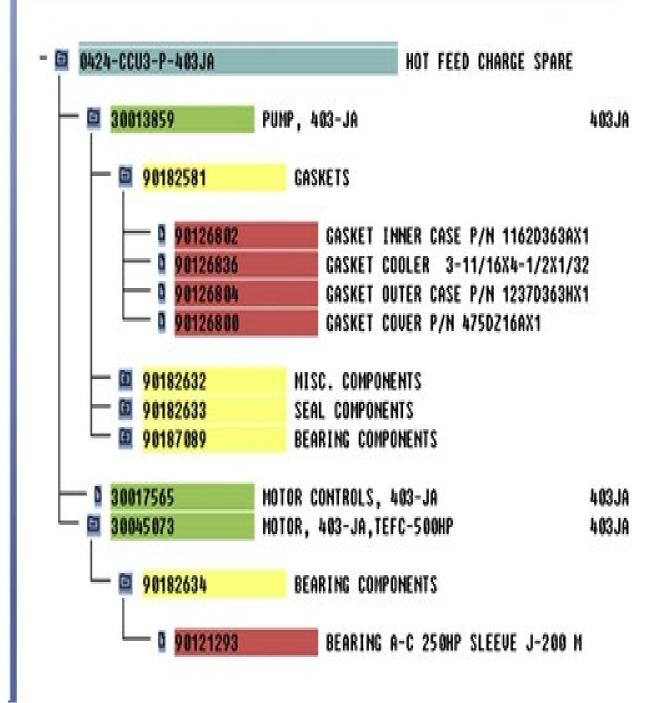
# SAP Structure and Operation

- 00	042	4-ACID	ACID PLANT
- 1	042	4-ADMN	REFINERY ADMIN
- 🖻	042	4-ALK2	ALKY #2
-	<b>• •</b>	0424-ALK2-A	Safety
-	- (0)	0424-ALK2-C	Compressors
-	- W	0424-ALK2-E	Electrical
	- (E)	0424-ALK2-F	Furnaces, Heaters, Boilers
-	- (B)	0424-ALK2-G	General
-	<b>• •</b>	0424-ALK2-H	Exchangers, Air Coolers, etc.
-	- w	0424-ALK2-I	Instrumentation
	- <b>(11)</b>	0424-ALK2-K	Buildings
-	- Œ	0424-ALK2-L	Lines, Piping, Valves
	- <b>(1</b> )	0424-ALK2-N	Non Maintenance
-	<b>- (1)</b>	0424-ALK2-P	Pumps/Other Rotating Equipment
-	- <b>a</b>	0424-ALK2-R	Reactors, Regenerators
-	- <b>(3</b> )	0424-ALK2-S	Systems
-	- œ	0424-ALK2-V	Vessels, Towers, Drums, Tanks
	Œ	0424-ALK2-X	Relief Values
- 00	842	4-ALK3	ALKY #3
	-	4-ARUA	AROMATICS RECOVERY A
· 00		4-ARUB	AROMATICS RECOVERY B

## Typical Rotating Equipment



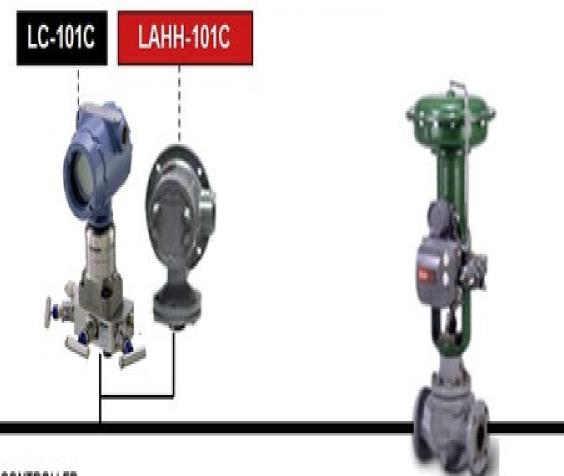
#### SAP Structure and Operation



### Typical Instrument Equipment

INSTRUMENT FUNCTION LOCATION

0424-SRUC-I-L101C



CONTROLLER

ELEMENT

GAUGE

as required

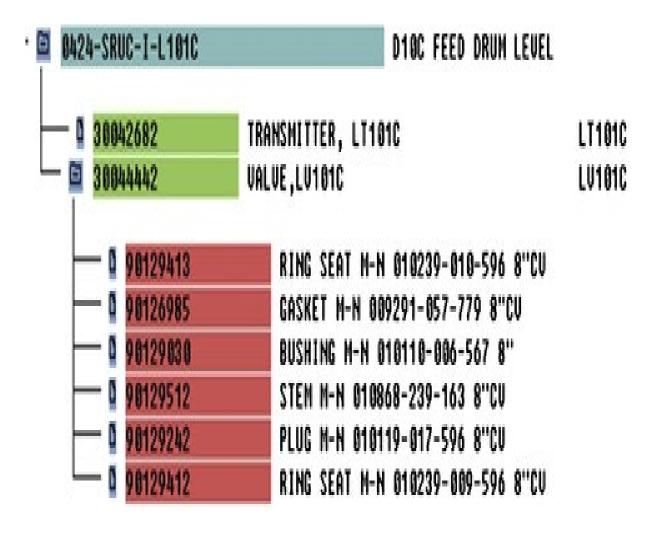
# SAP Structure and Operation

- 00 0424-ACID	ACID PLANT
- @ 0424-ADHN	REFINERY ADMIN
- 1 0424-ALK2	ALKY #2
— ₪ 0424-ALK2-A	Safety
─ @ 0424-ALK2-C	Compressors
─ 0424-ALK2-E	Electrical
─ @ 0424-ALK2-F	Furnaces, Heaters, Boilers
- 0 0424-ALK2-G	General
─ @ 0424-ALK2-H	Exchangers, Air Coolers, etc.
─ @ 0424-ALK2-I	Instrumentation
■ 0424-ALK2-K	Buildings
- 0 0424-ALK2-L	Lines, Piping, Valves
─ @ 0424-ALK2-N	Non Maintenance
— 00 0424-ALK2-P	Pumps/Other Rotating Equipment
─ @ 0424-ALK2-R	Reactors, Regenerators
— @ 0424-ALK2-S	Sustens
- 0424-ALK2-V	Vessels, Towers, Drums, Tanks
─ @ 0424-ALK2-X	Relief Valves
- ⊞ 8424-ALK3	ALKY #3
- 00 0424-ARUA	AROMATICS RECOVERY A
- CD 0424-ARUB	AROMATICS RECOVERY B
- VICT MOV	MUNIMITOS NEGOVENI O

## SAP Instrument Structure

00	0424-SRUA	SULFUR RECOVERY A	
00	0424-SRUB	SULFUR RECOVERY B	
0	0424-SRUC	SULFUR RECOVERY C	
-	□ 0424-SRUC-A	Safety	
-	■ 0424-SRUC-C	Conpressors	
Н	0424-SRUC-E	Electrical	
-	- @ 0424-SRUC-F	Furnaces, Heaters, Boilers	
-	- 00 0424-SRUC-G	General	
-		Exchangers, Air Coolers, etc.	
-		Instrumentation	
1	T		40000000
		D-2C REFLUX DRUM	19000359
		E-3C-1 AHINE REBOILER	19000359
		E-3C-2 ANINE REBOILER	19808359 19808359
	- 00 0424-SRUC-I-L103C2 - 00 0424-SRUC-I-L104C	TIC BOTTOM LEVEL	19888359
	00 8424-SRUC-I-L105C	D2C REFLUX DRUM LEVEL	19000359
	00 0424-SRUC-1-L107C1	E-AC-1 ANIME REBOILER	19000359
	00 0424-SRUC-1-L107C2	E-4G-2 ANINE REBOILER	19000359
	- 00 0424-SRUC-1-L114C1	E-2C-1 AHINE REBOILER	19000359
	- 00 0424-SRUC-1-L114C2	E-2C-2 ANINE REBOILER	19000359
	0 0424-SRUC-1-L117	TK-10 FRESH ANINE TANK	19000359
	0 8424-SRUC-I-L131C	DIOC AMINE FEED DRUM	19888359
	- 00 0424-SRUC-1-L132C	TIC STRIP BOTTOMS	19000359
	- 00 0424-SRUC-1-L133C	D-2C AMINE REFLUX DRUM	19000359
	□ 0424-SRUC-1-L134C	D-2C HIGH LEVEL PRE S/D	19000359
	M 0424-SRUC-1-L135C	D-2C ANINE REFLUX DRUM	19000359
	0 0424-SRUC-1-L136C	DIOC ANINE FEED DRUH LEVEL	19000359
	0 0424-SRUC-1-L138C	D1 ANINE FEED DRUM LEVEL	19000359
	─	TC1 STRIP BOTTONS	19000359
	- 0 0424-SRUC-I-L165C1	COHO POT FOR E-4C-1 ANIHE RE	19000359

### SAP Instrument Structure



2. Accuracy of spare parts database: The spare parts database represents another key database that must be developed or updated as part of implementing a new CMMS. For operations not having a parts inventory system, this will require doing a complete physical inventory of spare parts and materials. All inventory master record data for each item will need to be developed based on the inventory master record structure for the new CMMS and loaded directly to the inventory module.

# Win-Win Control of Materials, Tools and Equipment



Operations that have an existing spare parts database should take the time to do a complete review of it prior to conversion. Typically, this will allow for purging the database of obsolete parts and doing a complete review of the inventory master record data. This can be a very time-consuming process, but it allows the operation an excellent opportunity to revise part descriptions, review safety stock levels, reorder points and vendor data, and start the new CMMS with an accurate parts inventory database.

# Personal Observations of Storerooms and MRO Materials Management

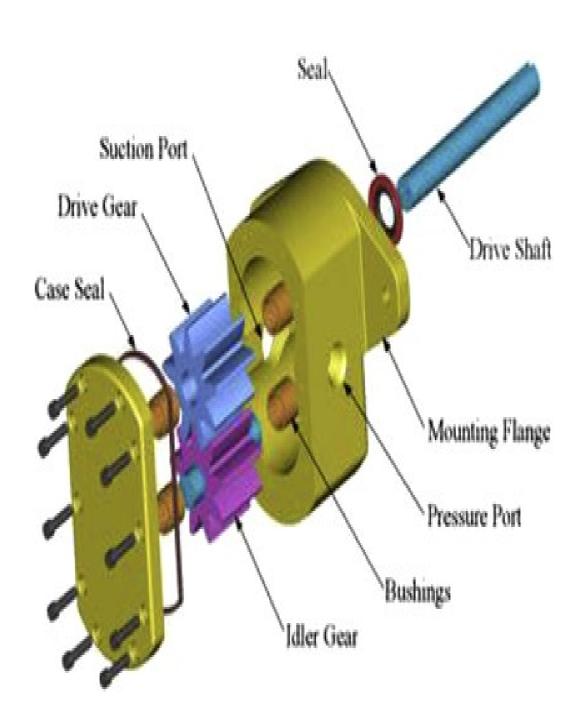
- Most storerooms are not organized, are inefficient, and are costly to operate.
- Few companies know what parts or tools they have on-hand or where they are.
- Parts databases are inaccurate, not up-to-date and contain duplications.
- Parts databases often never get set up correctly with new CMMS
- Parts-related downtime is very costly and reduces profit
- Parts storage areas represent a major source of corporate maintenance savings.
- Organized storerooms can correct inefficiencies of the past
- Successful planning and scheduling depends on having an effective storeroom

# Integration Between Maintenance, Storeroom, Vendors, Planning & Scheduling and Finance



3. Bill of materials: One key functional capability of CMMS is to provide a spare parts listing (bill of materials) within the equipment module. This requires researching where spare parts are used and linking inventory records with equipment master records that are component parts of an equipment asset. This function would also add, change, or delete items from an established spares list or copy a spares list to another equipment master record. In addition, this feature would copy all or part of a spares list to a work order job plan and create a parts requisition or pick list to the storeroom.

## How Pictures and Exploded Views Can Make Life Much Easier



The process of establishing a spares list is time-consuming and would involve only major spares that are currently carried in stock. Most CMMS systems have the capability to build the spare parts list as items are issued to or purchased for a piece of equipment. It is recommended that equipment bill of materials be established, but the conversion of equipment master data can take place without this information being available. Because bill of materials for spare parts is so beneficial for planning purposes, it is recommended that the process to identify and code key critical spares in the equipment master database be a priority to complete.

4. PM tasks/frequencies: The PM/PdM database is another key database necessary for establishing a "Class A" installation. If a current PM/PdM database is present, it is recommended that the existing procedures be reviewed and updated prior to conversion to the new system. If the existing PM/PdM database has been updated continuously on the old system, conversion can probably occur directly from the old to the new PM/PdM database; this, however, will depend on the PM/PdM database structure of the new system.

It is recommended that in the very early stages of a new CMMS benchmark/selection process, the status of the current PM/PdM program be evaluated; this is an excellent time to establish a team for applying reliability-centered maintenance. This process provides the best maintenance strategy for the failure within the equipment's operating context. If a process for the review/update of PM/PdM procedures has not been in place, then it is very important to get something started as soon as possible. This provides an excellent opportunity to establish a team of experienced craft people, engineers, and maintenance supervisors to work on PM/PdM procedures to review and update task descriptions, frequencies, and making sure that all equipment is covered by proper procedures. It is also a good idea to know the equivalent staffing needed to achieve 100% PM compliance. The format below is a good guideline for a summary of overall calculations.

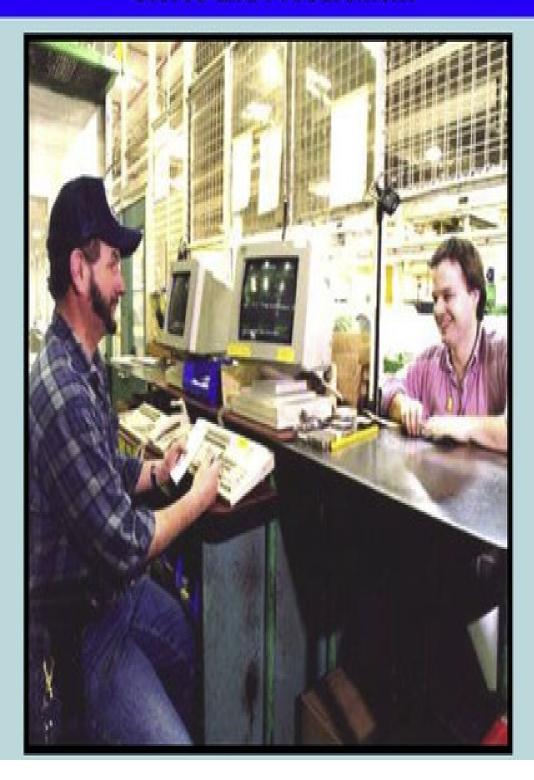
# VERY IMPORTANT: Define the Required Staffing for Your Preventive/Predictive Maintenance Program

Frequency of Routines	Craft Hours per Occurrence	Repetitions per Year	Craft Hours per Year
Daily	?	365	?
Weekly	?	52	?
Monthly	?	12	?
Quarterly	?	4	?
Semi-Annual	?	2	?
Annual	?	1	?
Other (Overhauls0	?	.5 to .1	?
		Total/Year ♥	27,000 Hrs. (example)
		Required Staff @ 1800 Hrs/Yr ♣	15 Equivalent Crafts

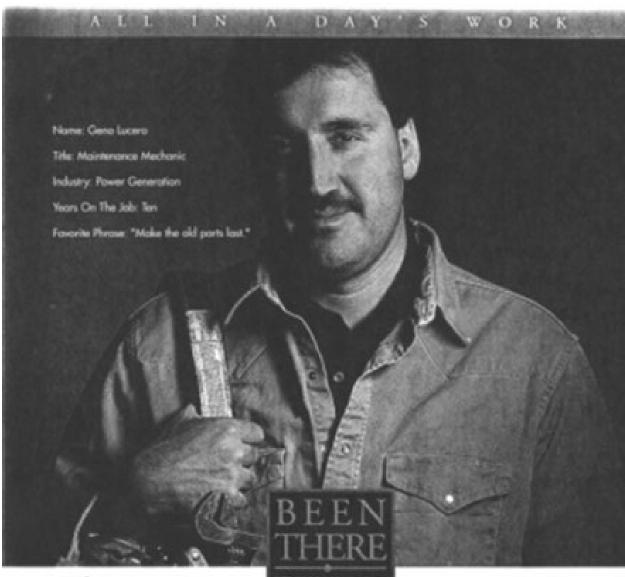
Note: Do not develop this staffing estimate from history. The proper estimate is for achieving 100% PM/PdM Compliance; the current program, if you had the needed craft resources.

5. Maintaining parts database: After a new CMMS is installed, it is highly recommended that one person be assigned direct responsibility for maintaining the parts database. This person would have responsibility for making all additions and deletions to inventory master records, changing stock levels, reordering points and safety stock levels, and changing any data contained in the inventory master records. This person could also be designated responsibility for coordinating the development of the spares list if this information is not available. This person would be responsible for recommending obsolete items based on monitoring of usage rates or due to equipment being removed from the operation. The practice of having one primary person assigned direct responsibility for the inventory master records can help ensure that parts database accuracy is 98% or greater.

## How Planning & Scheduling Depends on Effective Stores and Procurement



6. Maintaining equipment database: It is also highly recommended that one person also be assigned direct responsibility for maintaining the equipment database. This person would be responsible for making all changes to equipment master records. Information on new equipment would come to this person for setting up parent—child relationships of components in the equipment master records. Information on equipment being removed from the operation would also come to this person to delete equipment master records.





7:15AM Discovered a ween inlet elbow

on the mill chuse. No time to replace it.

Purty on Fel-Pro\* Wearing Compound with tough, ceramic heads and we're back in business. Fixed shat 10:20xxx Tom conveyor belt. Rapid Rubber Repair fixes this one like new and it's up and running in just three hours.

2:057% Time to reassemble a fewhigh temperature valvex and that always means C5-Av

around here. Parts go together smoothly and.

better yex, they won't soloe or gall. Fined that.

At the end of a busy day, Geno Lucero can say.

"Been there. Fixed that." You can two. Make Fel-Propart of your day's work. Call for technical advice.

Ach for a free catalog. 1-800-992-9799.

#### FEL-PRO

(iii) Total With Nov. Community Con. CO. 40072 Eqs. 305-200-5283. • 3412 West Single Ann. Lincolns and Cl. 100107. Lond Set Fol Prot Charming Products on the Inscisus on Sept-Vers and Lynn, industry and Coordination between this person and the person responsible for the parts database would be required to ensure that obsolete parts are identified and/or removed from the inventory system due to removal of equipment.

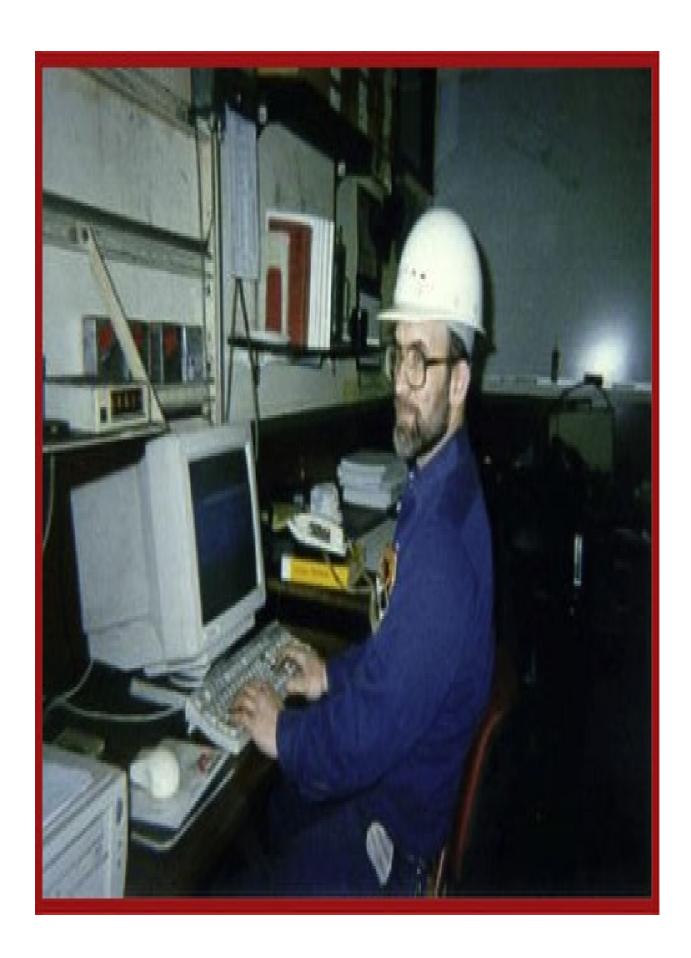
**B.** Computerized maintenance management system (CMMS) education and training

- 7. Initial CMMS orientation training for all maintenance employees
- 8. An ongoing CMMS training program for maintenance and storeroom employees
- 9. Initial CMMS orientation training for operations employees
- 10. CMMS systems administrator (and backup) designated and trained

7. Initial CMMS training: One of biggest roadblocks to an effective CMMS installation is the lack of initial training on the system. Many organizations never take the time up front to properly train their people on the system. Shop-level people must gain confidence in using the system for reporting work order information and knowing how to look up parts information. The CMMS implementation plan should include an adequate level of actual hands-on training on the system for all maintenance employees prior to the "go live" date. It is important to invest the time and expense to "train the trainers" who can in turn can assist with the training back in the shop. Many organizations set up "conference room pilots" where the CMMS software is set up and training occurs with actual data using CMMS vendor trainers or in-house trainers. It is

highly recommended that competency-based training be conducted so that each person can demonstrate competency in each function they must perform on the system. See Appendix L—An SAP Planner Training Checklist. Planners should be validated in their competency during the vendor training provided, whether it is SAP or any other system.

8. Ongoing CMMS training: The CMMS implementation plan must consider having an ongoing training program for maintenance and storeroom personnel. After the initial training, there must be someone in the organization with the responsibility for ongoing training.



If a good "trainer" (often the planner as a "super user") has been developed within the organization prior to the "go live" date, this person can be the key to future internal training on the new system. Ongoing training can include one-on-one support that helps to follow up on the initial training. Note: Very important in my opinion and experience is to select a person that can serve as a back up to the trainer.

- 9. Initial CMMS training for operations personnel: The customers of maintenance must gain a basic understanding of the system and know how to request work, check status of work requested, and understand the priority system. During implementation, operations personnel need to get an overview of how the total system will work and the specific things they will need to do to request work. If the organization has a formal planning and scheduling process, they will also need to know the internal procedures on how this will work.
- 10. CMMS systems administrator/backup trained: It is important that each site have one person trained and dedicated as the systems administrator with a backup trained whenever possible. Typically, this person will be from information services and have a complete knowledge of system software, hardware, database structures, interfaces with other systems, and report writing capabilities. The systems administrator will also have responsibility for direct contact with the CMMS vendor for debugging software problems and for coordinating software upgrades.



#### C. Work control

- 11. A work control function is established or a well-defined documented process is being used
- 12. Online work request (or manual system) used to request work based on priorities
- 13. Work order system used to account for 100% of all craft hours available
- 14. Backlog reports are prepared by type of work to include estimated hours required
- 15. Well-defined priority system is established based on criticality of equipment, safety factors, cost of downtime, etc.

-

11. Work control function established: A well-defined process for requesting work, planning, scheduling, assigning work, and closing work orders should be established. The work control function will depend on the size of the maintenance operation. Work control may involve calls coming directly to a dispatcher who creates the work order entry and forwards the work order to a supervisor for assignment. The work request could also be forwarded directly to an available crafts person by the dispatcher for execution of true emergency work.

Work control can also be where work requests are forwarded manually or electronically to a planner who goes through a formal planning process for determining scope of work, craft requirements, and parts requirements to develop a schedule. PM/PdM work would be generated and integrated into the

scheduling process. The status of the work order would be monitored, which might be in progress, awaiting parts, awaiting equipment, awaiting craft assignment, or awaiting engineering support, etc. A work order backlog would also be maintained to provide a clear picture of work order status. Effective work control provides systematic control of all incoming work through to the actual closing of the work order. The work control process should be documented with clearly defined written procedures unique to each maintenance operation.

#### 9. WORK MANAGEMENT AND CONTROL: MAINTENANCE AND REPAIR (M/R)

ITEM #	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5	RATING
I.	A work management function is established within the maintenance operation generally crafted along functionality of the CMMS.	
2.	Written work management procedures which governs work management and control per the current CMMS is available.	
3.	A printed or electronic work order form is used to capture key planning, cost, performance, and job priority information. 10=Bar coded assets, parts and work order.	
4.	A written procedure which governs the origination, authorization, and processing of all work orders is available and understood by all in maintenance and operations.	
5.	The responsibility for screening and processing of work orders is assigned and clearly defined.	
6.	Work orders are classified by type, e.g. emergency, planned equipment repairs, building systems, PM/PdM, project type work, planned work created from PM/PdM's.	
7,	Reasonable "date-required" is included on each work order with restrictions against "ASAP", etc.	
8.	The originating departments are required to indicate equipment location and number, work center number, and other applicable information on the work orders.	
9.	A well-defined procedure for determining the priority of repair work is established based on the criticality of the work and the criticality of equipment, safety factors, cost of downtime, etc.	
10.	Work orders are given a priority classification based on an established priority system.	
II.	Work orders provide complete description of repairs performed, type labor and parts used and coding to track causes of failure.	
12.	Work management system provides info back to customer; backlogs, work orders in progress, work completed, work schedules and actual cost charge backs to customer. 10= real time system	
	9. Work Management and Control: Maintenance and Repair SUBTOTAL SCORE POSSIBLE:	120

#### 10. WORK MANAGEMENT AND CONTROL: SHUTDOWN, TURNAROUNDS, AND OUTAGES (STO)

ITEM#	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less	RATING
I.	Work management and control is established for major overhaul repairs, shutdowns, turnarounds and outages (STO) and includes effective work management and control by in house staff and contracted resources.	
2.	Work management and control of major projects provide means for monitoring project costs, schedule compliance and performance of both in house and contracted resources with a robust project management system.	
3.	Work orders are used to provide key planning info, labor/material costs and performance info for major all STO and overhaul work.	
4.	Equipment history is updated with info from work orders generated from major overhaul repairs, and SATO work.	
5.	The responsibility for screening and processing of work orders for major repairs is assigned to one person or unit.	
6.	Change order procedures and control are clear to all and approved at the appropriate level based on company requirements.	
7.	Change orders are reviewed by planners just as they review all jobs; scope of work, key job steps, equipment required and total additional cost and impact on total STO duration and appropriate approvals received before work execution.	
8.	Work orders for major repairs, shutdown, and overhauls are monitored for schedule compliance, overall costs and performance info including both in house staff and contracted services.	
9.	Cost variances are measured at key milestone with cost variance info so extreme variance can be investigated sooner than later when it is too late. A 5%-10% variance is set as maximum with clear reason for increased scope of work.	
10.	Has the current level of plant maintenance/asset management achieved the desired reliability to make to make an STO a) needed at longer timeframe than normal b)needed at a shorter timeframe or c) needed the appropriate period based on age and state of asset capabilities in their operation context.? a)= 10,9,8; b)=5; c=7,6	
Ш	The organization has the capability to manage the turnaround program and be cost effective as compared to the best in the sector, has a strategy for reducing costs in the face of an ageing plant and rising manpower and material costs and where can we get high level technical advice?	
12.	The organization knows what manpower is available in-house, the competence levels where to get additional resources, who will lead the site team, who will do the work plus the cross functional team to design, monitor and control the event organization?	
13.	Have STO's received significant level of attention companies, have a history of tolerating higher than necessary downtime have older age of plants, see STO as a "necessary evil" are striving to lengthen the STO intervals from 12 – 24 months and even4, 5 and sometimes 8 years	
14.	The organization's history of planning & preparation for STO's has been: carried out more carefully, alignment of capital programs, has been scrutinizing and challenging scope of work	

15.	A process of assessing plant equipment deterioration is in place, the likely impact on reliability is known, the planning stocks and safeguarded and has partnering with major plant overhaul engineering contractors and have a learning organization from past history to manage STO's effectively	
16.	The plant beginning an STO has personnel available when required and capable of performing design specifications economically and a) safely for life of plant ,b) knows sum of activities performed to protect reliability of the plant , c) helps provide consistent means of production, d) help generate profit all with e) reducing the Total Cost of Ownership (TOC)	
17.	Top Leaders clearly understand that STO is a significant maintenance and engineering event during which new plant is installed, existing plant overhauled, and redundant plant removed which has a direct connection between successful accomplishment and the company's profitability	
18.	The company includes profit lost during period of STO is considered part of turnaround cost because they know the total true cost of event and the real impact can be assessed	
19.	All involved with STO's realize the potential hazard to plant reliability or can diminish or destroy reliability if not properly planned, prepared, executed, poor decisions by managers and engineers, bad workmanship, use of incorrect materials and damage done while plant is being shut down, overhauled, restarted	
20.	Technical uncertainty due to occurrence of unforeseen problems can be accurately reported, knowing when cost estimates are being exceeded, event's duration must be extended, how both cost and duration increases be justified. Are reasonable cost and time contingencies built into an STO plan with accurate loss of revenue/profit considered.	
21.	Have Top Leaders created their business strategy to manage the STO basic objectives to eliminate STO's all together unless proven it is absolutely necessary,	
22.	If an STO is proven to be necessary, the Top Leader ensures that it will align with maintenance objectives, production requirements, business goals.	
23.	When beginning as STO the Top Leader has formed a chartered leadership driven, self-managed (not a committee) forming a cross functional staff to help a committed company get the best STO value.	
24.	The STO team has senior managers, responsible for long-term strategy and meet at regular intervals throughout year to review current performance and formulate high-level strategies for management of events such as a long-term STO program	
25.	Is an STO truly aligned to overall business strategy which include an evolution of asset management's driven search for change to preventive/predictive maintenance, being driven by technical considerations and a philosophy of maintenance prevention and continuous reliability improvement.	
26.	STO"s are driven by business needs and question every maintenance practice to determine if it can be eliminated by addressing cause that generated the need and examines the largest maintenance initiatives first during an STO.	
	10. Work Management and Control: Shutdowns, Turnarounds and Outages (STO) SUBTOTAL SCORE POSSIBLE:	260

12. Online work request based on priorities: Requesting work online represents an advanced CMMS functional capability where the customer enters the work request directly into the system on a local area network or via e-mail. Online work requests would include basic information about work required, equipment location, date work is to be completed by, name of requestor, and priority of the work. This information would go to the work control function where the jobs would be planned, scheduled, and assigned based on the overall workload. The requestor would have the capability to track the status of their jobs online and even give final approval that the work was completed satisfactorily.

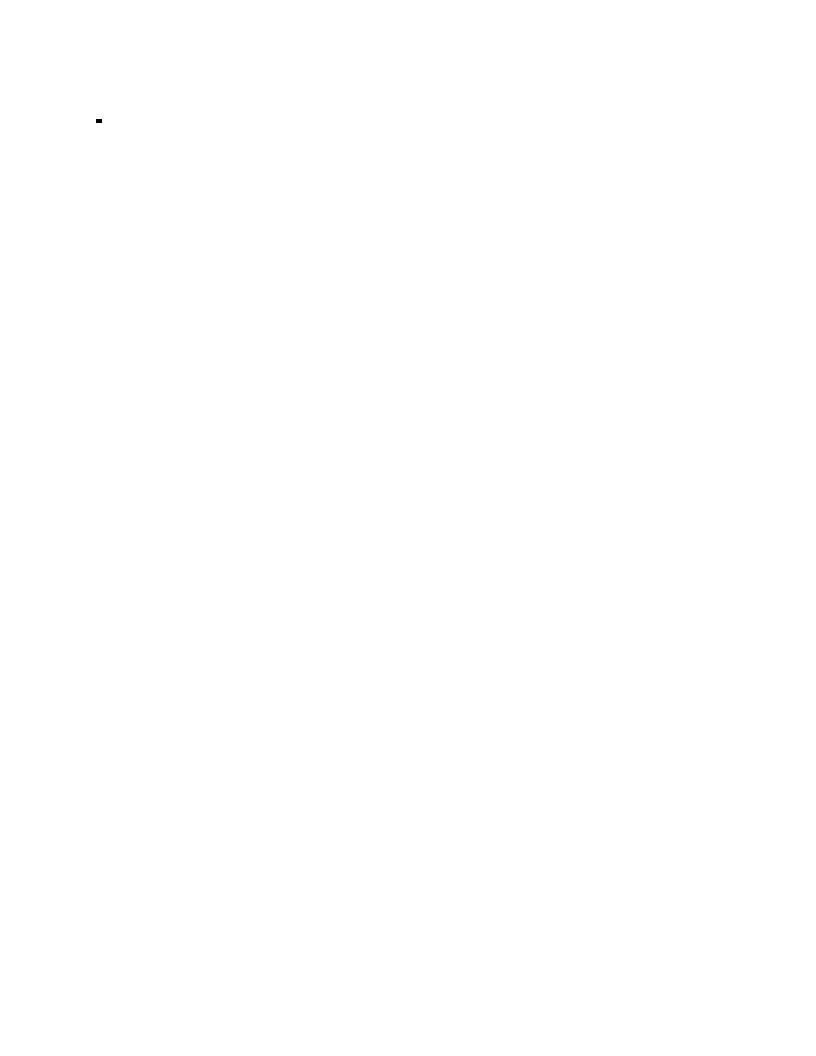




- 13. Work order system accounts for 100% of craft hours: Handled devices can have a high return on investment when applied to time reporting to work orders as well as wireless transfer of work orders to the crafts person. This method of data collection uses barcodes on work orders, assets, and on all parts. All craft work should be charged to a work order of some type. Accountability of labor resources is an important part of managing maintenance as an internal business. Quick reporting to standing work orders can be established for jobs of short duration within a department or for the reporting of non-craft time such as meetings, delays in getting the equipment to work on, training, and chasing parts.
- 14. Backlog reports: Maintaining good control of the work to be done is essential to the maintenance process. Having the capability to visually see the backlog helps to effectively plan and schedule craft resources.

The CMMS reporting system should provide the capability to show the backlog of work in a number of ways, some of which include:

• By type of work	• By overdue work orders
• By craft	• By parts status
• By department	By priority



							BF	EAK	DOWN	OF	SCHE	DUL	ED WC	RK		HEDULI HEDULI			BACI	COG.	% PERF	RMANC	
WEEK NO.	START DATE	A ACTUAL TOTAL M.H. WORKED	actual Total	M. SPE ON I	INT ICH INK	M. SPE ON UN	H INT ISCH INK		O DING			FIF SC	H	010 80 W0	ER H.	CRI PROD EQUI BREAM	ICAL UCTION PMENT DOWNS	OTI UNS WC	CH. PK	HOURS HOURS	K Weeks	EST. SCH. M.H. STD. HRS.	i
			M.H.	•	MH	1	M.H.	•	M.H.	•	W.K.	3	M.H.	,	MH	١	MH	,			L		
					_							_	_		_	_	_	_			-	_	
-	_				_								-				_					_	
																	Т						
													****				Own.						
							۸ı	11	٠H	۵	cŧ	W	۱ ۵	Δ	nΛ	rt to	•		Mb.				
			4				ni 		311	U	VL		9 I	U	PV		4			<u> </u>			
			100			C	0	e	ct	a	nc	l	jįs	p	lay	da	ta		_/_		-	_	
						-	1		M. 1	all (											+		
	7-7-				_	_											-	-					
This i	To Date Otr.																						
Wood This	dy Aug. Otr														- ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) (								
				-			-		H			-		-	-	-		-	-		+		

- 15. Priority system: A "Class A" CMMS installation will have in place a priority system that allows the most critical repairs to get done first. An effective priority system adds professionalism to the maintenance operation and directly supports effective planning and scheduling. There are two basic systems for establishing priorities:
- a. Straight numeric Priority 1, 2, 3, 4, 5 etc. where each priority level is defined by a definition, such as Priority 1: A true emergency repair that affects safety, health, or environmental issues.
- b. Ranking Index of Maintenance Expenditures (RIME) system The RIME is a system that combines the criticality index of the equipment (10 highest to 1 lowest) with criticality of the work type (10 highest to 1 lowest importance) to compute the RIME priority number. The RIME priority number equals the equipment criticality index multiplied by the criticality number of the work type. Many CMMS systems will compute the RIME number when assets are assigned critical values and work types designed the same way as shown below.

# RIME System Example (Distribution Center)

Work Type Priority → →  Asset Criticality		Safety & True Emergency (SAF)	Preventive and Predictive Maintenance (PM)(PDM)	Project Work (PRJ)	Corrective Maintenance and Warranty Work (CMA)	Operations Service (OPS)	Routine/Normal Safety (RNS)	Tenant Improvement (TIM)	Inspections (INS)	Miscellaneous (MIS)	Housekeeping (HSK)
		10	9	8	7	6	5	4	3	2	1
SORTER	10	100	90	80	70	60	50	40	30	20	10
Conveyor	9	90	81	72	63	54	45	36	27	18	9
Utilities	8	80	72	64	56	48	40	32	24	16	8
Turret Truck	7	70	63	156	49	42	35	28	21	14	7
Lift Truck	6	60	54	48	42	36	30	24	18	12	6
Stock Picker	5	50	45	40	35	30	25	20	15	10	5
Miscellaneous Mobile Equipment	4	40	36	32	28	24	20	16	12	8	4
Office Facilities	3	30	27	24	21	18	15	12	9	6	3
Miscellaneous support To Other Asset	2	20	18	16	14	12	10	8	6	4	2
Buildings, Roads and Grounds	1	10	9	8	7	6	5	4	3	2	1

#### **Ranking Index of Maintenance Expenditures**

\_

#### D. Budget and cost control

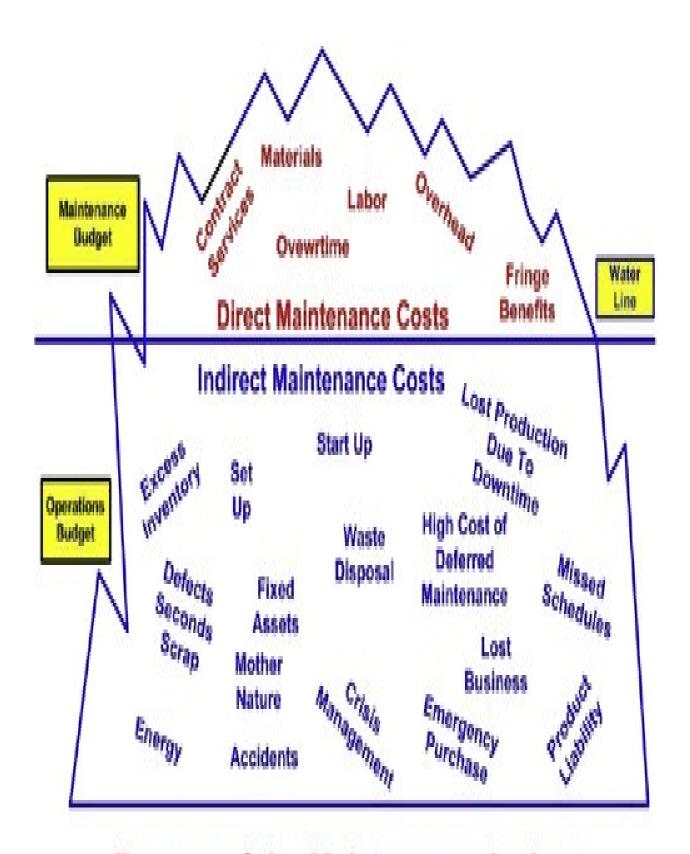
- 16. Craft labor, parts, and vendor support costs are charged to work order and accounted for in equipment/asset history file
- 17. Budget status on maintenance expenditures by operating departments is available
- 18. Cost improvements due to computerized maintenance management system and best practice implementation have been documented
- 19. Deferred maintenance and repairs are identified to management during budgeting process
- 20. Life cycle costing is supported by monitoring of repair costs to replacement value

-

- 16. Craft labor, parts, and vendor support costs: The equipment history file should provide the source of all costs charged to the asset. Here it is important to ensure that all labor is charged to the work orders for each asset and that parts are charged to the respective work orders.
- 17. Budget status—operating departments: Operating departments should be held accountable for their respective maintenance budgets. With an effective work order system in place for charging of all maintenance costs, the accounting

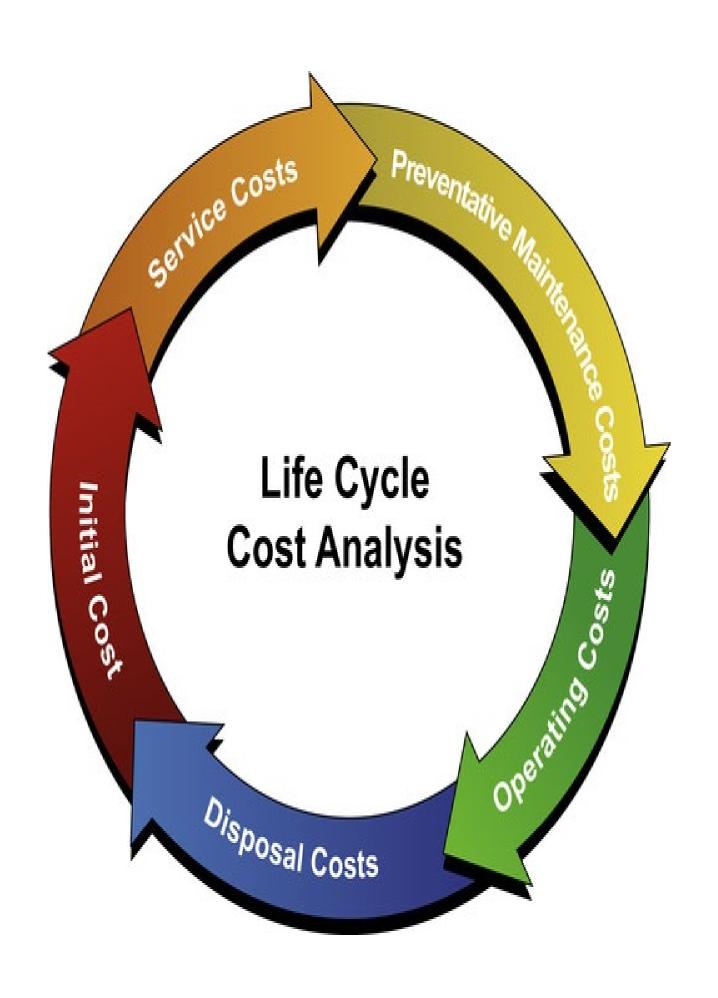
process should allow for monitoring the status of departmental budgets. One recommended practice is for maintenance to be established as a zero-based budget operation and that all labor and parts be charged back to the internal customer. This practice helps ensure accountability for all craft time, parts, and materials to work orders.

- 18. Cost improvements due to CMMS: The impact of a successful CMMS installation should be reduced costs and achieving gained value in terms of greater output from existing resources. The CMMS team should be held accountable for documenting the savings that are achieved from the new CMMS and the maintenance best practices that evolve. The areas that were used to justify the CMMS capital investment such as reduced parts inventory, increased uptime, and increased craft productivity should all be documented to show that improvements did occur.
- 19. Deferred maintenance identified: It is important that maintenance provides management with a clear picture of maintenance requirements that require funding for the annual budget. Deferred maintenance on critical assets can lead to excessive total costs and unexpected failures. Benefits from CMMS will provide improved capability to document deferred maintenance that must be given priority during the budgeting process each year.



Beware of the Maintenance Iceburg

20. Life cycle costing supported: Complete equipment repair history provides the base for making better replacement decisions. Many organizations often fail to have access to accurate equipment repair costs to support effective replacement decisions and continue to operate and maintain equipment beyond its economically useful life. As a result, the capital justification process then lacks the necessary life cycle costing information to support replacement decisions.



#### E. Planning and scheduling

- 21. A documented process for planning and scheduling has been established
- 22. The level of proactive, planned work is monitored and documented improvements have occurred
- 23. Craft utilization (true wrench time) is measured, and documented improvements have occurred
- 24. Daily or weekly work schedules are available for planned work
- 25. Status of parts on order is available for support to maintenance planning process
- 26. Scheduling coordination between maintenance and operations has increased
- 27. Emergency repairs, hours, and costs are tracked and analyzed for reduction

21. Planning and scheduling: This maintenance best practice area is essential to better customer service to operations and for greater utilization of craft resources. For most maintenance operations with 25–30 crafts people, a fulltime planner can be justified. The CMMS system functionality must support the planning process for control of work orders, backlog reporting, status of work orders, parts status, craft labor availability, etc. The planning and scheduling function supports changing from a "run-to-failure strategy" to one for proactive, planned maintenance.

#### 11. SHOP LEVEL RELIABLE PLANNING, ESTIMATING AND SCHEDULING (M/R)

ITEM#	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less	RATING
l.	A formal maintenance planning function has been established and staffed with qualified planners in an approximate ratio of 1 planner to 20-25 crafts people.	
2.	The screening of work orders, reliable estimating of repair times, coordinating of repair parts and planning of repair work is performed as a support service to the supervisor.	
	Planner/Schedulers realize their primary scope and role of planning and scheduling is to improve craft labor productivity and quality through the elimination of unforeseen obstacles such as potential delays coronation parts machine time and available resources.	
	Planner/Schedulers clearly understand the scope of their defined roles and responsibilities within your organization and are in an organization structure that promotes close coordination, cooperation and communications with their customer in operations.	
3.	The planner uses the priority system in combination with parts and craft labor availability to develop a start date for each planned job to be scheduled	
4,	A daily or weekly maintenance work schedule is available to the supervisor who schedules and assigns work to crafts personnel with multiple week "look a heads" if required.	
5.	The maintenance planner develops reliable and well accepted estimated times for planned repair work and includes on work order for each craft to allow performance reporting, backload levels and even documentation of work competency for selected jobs.	
6.	A day's planned work is available for each crafts person with at least keeping a half a day ahead (KAHADA) during the working day known in advance.	
1.	A master plan for all repairs is available indicating planned start date, duration, completion date, and type crafts required to define "total maintenance requirements".	
8.	The master plan is reviewed and updated by maintenance, operations, and engineering as required with project type work expected from maintenance. Care is taken not to overload maintenance with project work that causes PM/PdM and other work to be neglected.	
9.	Total maintenance requirements are a total of Total Backlog + Ready Backlog that has all resources (except labor or equipment availability) available to be scheduled.	
10.	A firm rule of thumb is never to put anything on the schedule without parts in house. But have contingency plan if needed parts arrive for critical equipment.	

11.	When parts arrive for critical equipment and can be inserted to the current schedule this is very proactive maintenance cooperation with operations.	
12.	Scheduling/progress meetings are held periodically with operations to ensure understanding, agreement and coordination of planned work, backlogs, and problem areas.	
13.	Operations cooperate with and support maintenance to accomplish repair and PM schedules.	
14,	Operations staff signs off the agreed upon schedule and are responsible to approve change in schedules and are accountable to TOP Leaders for adverse results.	
15.	Set-ups and changeovers are coordinated with maintenance to allow scheduling of selected maintenance repairs,  PM inspections, and lubrication services during scheduled downtime or unexpected "windows of opportunity" to insert Ready Backlog jobs into the schedule.	
16.	Planned repairs are scheduled by a valid priority system, completed on time and in line with completion dates promised to operations and measured accordingly.	
17.	Deferred maintenance is clearly defined on the master plan and increased costs are identified to management as too the impact of deferring critical repairs, overhauls, etc.	
18.	Maintenance planners and production planners work closely to support planned repairs, to adjust schedules and to ensure schedule compliance in a mutual goal.	
19.	The planning process directly supports the supervisor and provides means for effective scheduling of work, direct assignment of crafts and monitoring of work in progress by the supervisor.	
20.	Planners training has included formal training in planning/scheduling techniques, super user training on the CMMS, report generating software or via Excel and on the job training to include developing realistic planning times for craft work being planned. Understand use of MS Project or the company's larger project management system such as Primavera 6.	
21.	Benefits of planning/scheduling investments are being validated by various metrics that document areas such as reduced emergency work, improved craft productivity, improved schedule compliance, reduced cost and improved customer service.	
22.	Planning and scheduling procedures have been established defining work management and control procedures, the planning/scheduling process, the priority system, etc.	

23.	A reasonable number of backup planner/schedulers are selected and properly trained and used to cover for the full time staff. The number is based on the size and type work being planned. Ideally just like the full time planner should have good shop experience and sound technical experience.	
24.	If a maintenance coordinator is assigned within a unit of a large refinery or any production the planner will coordinate with that person about the job request, location within the unit, the problems to be repaired and related risks. In many cases this is an engineer or experienced operator who should be able to define complete requirements or a work request and in some case prepare a risk assessment for the planner to use for the job.	
25.	If issues and of any nature arise and are not readily resolved by the planner and operations, the maintenance leader should be the next step that the planner/scheduler takes for resolution.	
26.	If planned work orders involve participation by several shops or functional crews they are crossed over to a planner in that area. However a single planner/scheduler must plan and then coordinate various functional crews with the respective supervisors during the scheduling process.	1
27.	Planners are in an excellent position to ensure critical spares by asset are accounted for as well as to recommend items to consider for including within the storeroom as critical spares.	
29.	Planners see what is repetitively coming up for non-stock item purchasing as well as what is being repaired over and over again, Are your planners active in this area can support improving reliability and uptime.	
30.	Planners help ensure that warranted parts or equipment is denoted in the equipment file and that work orders for warranted parts or equipment are flagged during the planning process to document supplier reimbursements.	
	11. Shop Level Reliable Planning, Estimating and Scheduling M/R SUBTOTAL SCORE POSSIBLE:	300

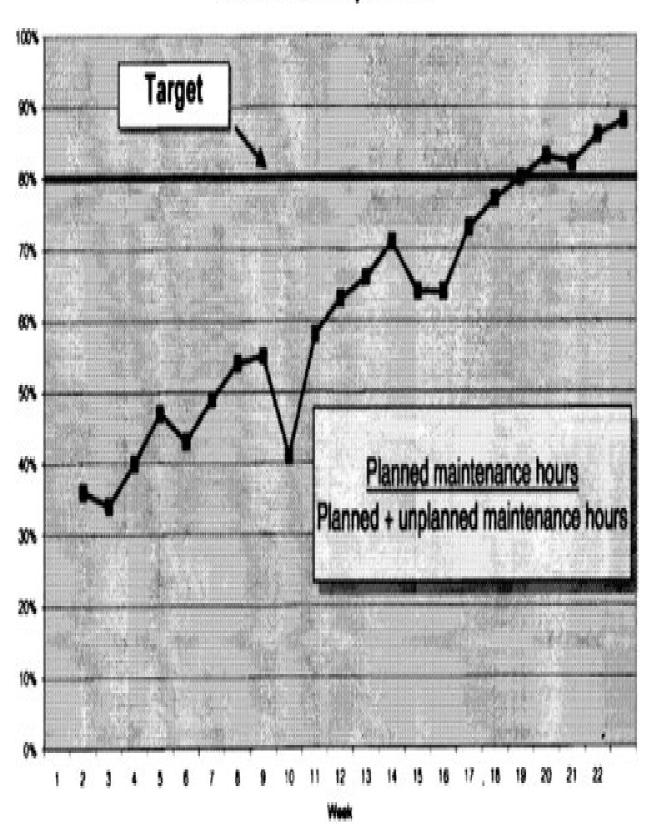
#### 12. STO AND MAJOR PLANNING/SCHEDULING WITH PROJECT MANAGEMENT

ITEM #	Rating: Excellent = 10, Very Good = 9, Good = 8, Average = 7, Below Average = 6, Poor = 5 or less	RATING
1.	The planning and scheduling function includes major repairs, overhauls and shutdown, turnaround and outage (STO) type work not considered as part of normal maintenance work and any work requiring an STO event,	
2.	The planner team is a resource (or member) for the STO team of senior managers and the Maintenance Leader.  Planners should meet at regular intervals to review current jobs awaiting a planned STO event.	
3,	Are your Total Backlog jobs coded and planned effectively to await an STO event. In large plants and refineries planners support the plant schedulers with normally detailed job packages for estimates of all required resources for an STO job	
4,	Schedulers from Item #3 coordinate parts/materials develop daily or weekly schedules, monitor status of work along with onsite observations, from the supervisor input and from a planner's job package which could include several crews, defined job steps and estimated time for each step. With real time reporting to a project management system or CMMS status including costs can be readily determined from progress reporting.	
5,	Current planning/scheduling manpower is available with the competency levels needed to support the site team during an STO.	
6.	All planners and schedulers involved with STO's must realize the potential hazard to plant reliability or can diminish or destroy reliability if not: properly planned, prepared and execute.	

7.	There may be even poor decisions by managers and engineers, bad workmanship, use of incorrect materials and damage done while plant is being shut down, overhauled or restarted. Planners realize that properly planned, well prepared work and work executed to all HSSE requirements is essential.	
8.	The use of work orders, estimating of repair times, coordinating and staging of repair parts/materials and planning/scheduling of internal resources and contractor support is also included for major work and STO work not considered day to day maintenance and repair.	
9.	A project work schedule or formal project management system is used to manage status and cost variance for STO work.	
10.	The current CMMS is integrated and linked to the project management system in real time when STO work orders or a change order work is approved.	
11.	Estimated labor and materials are established prior to project start using work orders with effective labor and material reporting to track overall cost, work progress, schedule compliance, etc.	
12.	The master plan for all major STO repairs, overhauls and new installation is available indicating planned start date, duration, completion date, and type crafts required.	
13.	Resources required for day to day maintenance work are not compromised by having to perform major repair type work, installation, modifications etc, consuming in house resources required for PM's and other day to day type work.	
14.	Scheduling/progress meetings are held periodically with operations to ensure understanding, agreement and coordination of major work and problem areas such as asset being ready for scheduled work.	
15.	Major work performed by contractors is preplanned, scheduled and includes measuring performance of contracted services.	
16.	Planning and scheduling procedures have been established for project type work.	
	12.STO and Major Maintenance Planning/Scheduling with Project Management SUBTOTAL SCORE POSSIBLE:	160

22. Planned work increasing: The bottom line results for the planning process are to actually increase the level of planned work. Percent planned work should be monitored and included as one of the overall maintenance performance metrics. In some organizations with effective PM/PdM programs, the level of planned work can be in the 90% range or more.

#### Planned vs. Unplanned



23. Craft utilization measured and improving: Effective planning and scheduling is essential to increasing the level of actual hands-on wrench time of the craft workforce. Improving craft utilization allows more work to get done with current staff by eliminating non-craft activities such as waiting for equipment, searching for parts, and scheduling the right sequence for different crafts on the job.

## **OCE Measures Craft Productivity**

#### Three OCE Factors =

% Craft Utilization (CU)

X

% Craft Performance (CP)

X

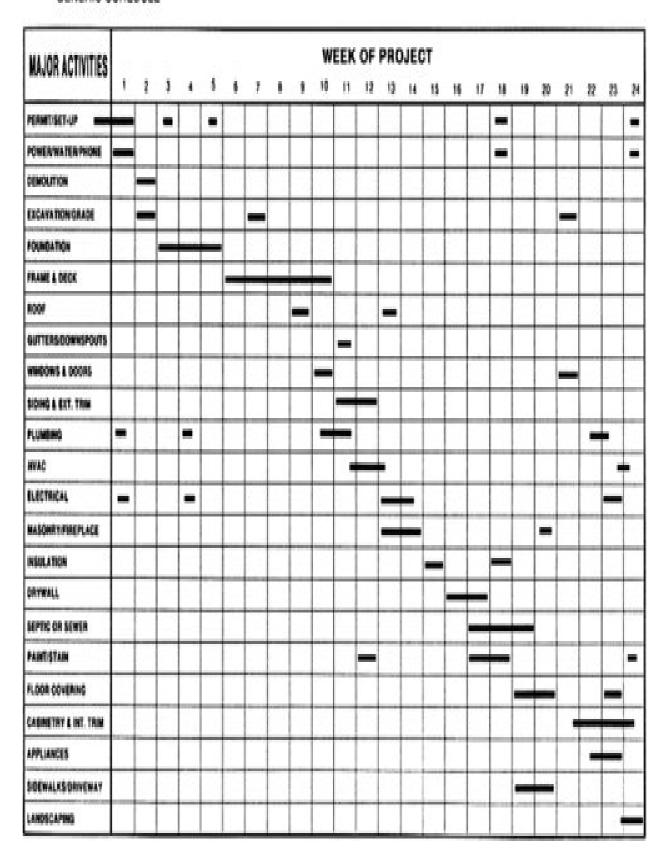
% Craft Service Quality (CSQ)

Therefore OCE = % CU x % CP x % CSQ

All Three OCE Factors Can Be Measured

24. Work schedules available: One key responsibility of the planning process is to establish realistic work schedules for bringing together the right type craft resources, the parts required, the equipment to be repaired or serviced, along with having the time available to complete the job right the first time. The actual schedule may only start with a one-day schedule and gradually work up to scheduling longer periods of time. Work schedules provide a very important customer service link with operations that helps to improve overall coordination between maintenance and operations.

#### GENERIC SCHEDULE



25. Spare parts status is available: One of the most essential areas to support effective planning is the maintenance storeroom and the accuracy of the parts inventory management system. Jobs should not be put on the schedule without parts being on hand. The planner must have complete visibility of inventory onhand balances, parts on order, and the capability to reserve parts for planned work.

- ✓ IC: Insufficient craft capacity; lack of cross training contributes to shortage of the right skills
- √ SO: Stock outs are frequent
  - √ Inaccurate inventory control
  - √ Excessive time finding what is in storeroom.
  - √ Parts not requisitioned
- PP: Planned jobs do not reflect reality
  - √ Scope expands
  - √ Plan for parts is incorrect
  - √ Job steps incomplete
  - ✓ Lockout, specifications and regulations not documented

- 26. Scheduling coordination with operations: As the planning function develops, there will be improved coordination with operations to develop and agree upon work schedules. This may involve coordination meetings near the end of each week to plan weekend work or to schedule major jobs for the upcoming week. Direct coordination with operations allows maintenance to review PM/PdM schedules or to review jobs where parts are available to allow the job to be scheduled based on operations scheduling equipment availability.
- 27. True emergency repairs tracked: Many organizations really focus on reducing true emergency repairs that create uncertainty for operations scheduling and contribute to significantly higher total repair costs than planned work. Improved reporting capabilities of an effective CMMS will allow for better tracking of emergency repairs, document causes for failures, and assist in the elimination of the root causes for failures.

Maintenance repair operations (MRO) materials management is the overall area of MRO parts and materials procurement, storage, inventory management, and issues represents another best practice area that often needs major work when implementing a CMMS and developing a "Class A" installation. Many organizations never take the time to set up a well-planned and controlled storeroom operation and often find out that their parts database is a weak link needing major updates before it can truly be used effectively.

## F. Maintenance repair operations (MRO) materials management

- 28. Inventory management module fully utilized and integrated with work order module
- 29. Inventory cycle counting based on defined criteria is used, and inventory

accuracy is 95% or better

- 30. Parts kitting and staging is available and used for planned jobs
- 31. Electronic requisitioning capability available and used
- 32. Critical and/or capital spares are designated in parts inventory master record database
- 33. Reorder notification for stock items is generated and used for reorder decisions
- 34. Warranty information and status is available

- 28. Inventory management module: The work order module must be fully integrated with an accurate parts inventory management module to charge parts back to work orders, to check parts availability status for planned work, to reserve parts, and to check status of direct purchases. A "Class A" CMMS installation will develop, maintain, and fully utilize the inventory module and ensure that it is fully integrated with the work order module.
- 29. Inventory cycle counting established: Inventory accuracy should be one of the key metrics for MRO materials management, and it can best be accomplished by cycle counting rather than annual physical inventories. Most CMMS systems will allow for your own criteria to be developed such as doing an ABC analysis of inventory items (based on either usage value or frequency of issue) and then scheduling of periodic counts for each classification of inventory item that you want to cycle count. For example, A items would be counted more frequently than B and C items. The real value of cycle counting is that it is a continuous process that creates a high level of discipline and allows for inventory problems and adjustments to be made throughout the year rather than once following the annual inventory.

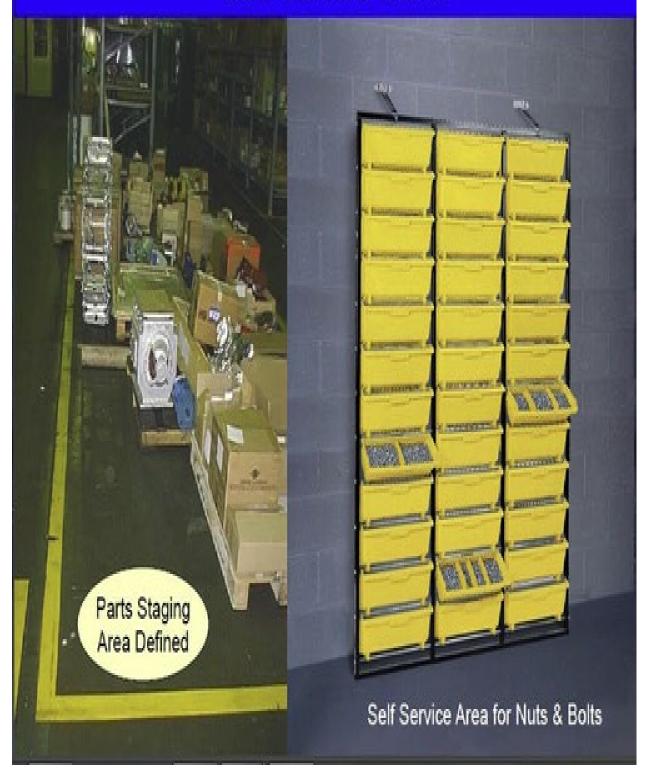
# Annual Physical Inventory versus Cycle Counting Best Practices

#### Definition of Cycle Counting

- Periodic <u>inventory system</u> audit-practice in which different portions of an inventory are counted or physically checked on a continuous <u>schedule</u>.
- Each portion is counted at a <u>definite</u>, preset <u>frequency</u> to <u>ensure</u> counting of each item at least once in an <u>accounting</u> <u>period</u> (usually an year).
- Fast-moving or more <u>expensive</u> items are counted more often than slower moving or less expensive ones, and certain items are counted every <u>day</u>. Also called <u>cycle</u> inventory.

30. Parts kitting and staging: This best practice area is key to the planning process and can evolve over time as the planning process matures to the point of being able to give the storeroom prior notification on the parts required for planned jobs. Controlled staging areas are set for parts that are either pulled from stock or received from direct purchases.

# Implementing Parts Staging, Delivery and Self Service Items



31. Electronic parts requisitioning: This functional capability can provide paperless work flow for requisitioning of parts directly from maintenance to the storeroom for creation of a pick list for the item or go to purchasing to create a purchase order for a stock item or direct purchase. In some cases, electronic requisitioning might go directly to the vendor using e-commerce capability.

# ELECTRONIC DATA INTERCHANGE (EDI) and ELECTRONIC COMMERCE (EC)

The Electronic Transmission of Standard Structured Documents Between Computer Applications



32. Critical spares identified: Critical spares (or insurance items) that may be a one-of-a-kind, high cost spare are often in the parts inventory system. It is recommended that these items be classified and identified in the item master record as such. This practice will help separate these items from the regular inventory management process and identify them as a separate part of the total inventory value that has been fixed. Critical spares should also be identified in the spares list for the equipment they have been purchased for.

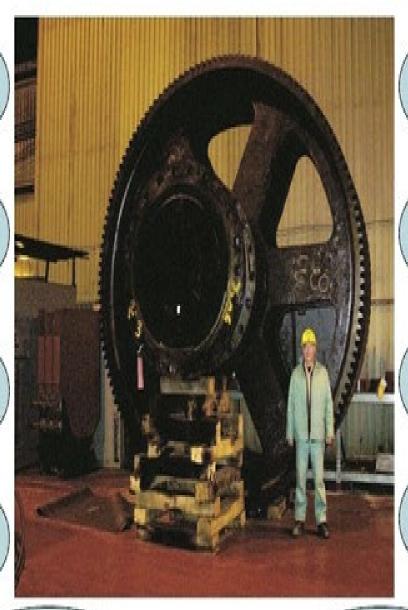
### Solving Special Storage Challenges

Electronic Components

Pipe & Metal for Fab'n

> Project Materials

> > Motors



Rebuild Kits

Belts

**Filters** 

Large Pumps

Other Special Storage Challenges? Space for Controlled Shop Stock

- 33. Reorder notification process: The capability to determine when and what to reorder based on a review of stock level reorder points is an important feature for a "Class A" installation. A recommended reorder report should be generated periodically and reviewed for validity as well as for any future needs that may not be reflected in current on-hand balances. Based on final review of the recommended reorder report, electronic requisitioning then could occur directly to purchasing.
- 34. Warranty information: Many organizations fail to have a process in place to track warranty information and in turn incur added costs by not being able to get proper credit for items under warranty. Tracking specific high value parts or components and specific equipment under warranty should be a CMMS functionality of the equipment master or the inventory item master database. The system should provide a quick reference and alert to the fact that the item is still under warranty and that a follow-up claim to the vendor is needed.

G. Preventive/predictive maintenance (PM/PdM)

- 35. PM/PdM change process is in place for continuous review/update of tasks/frequencies
- 36. PM/PdM compliance is measured and overall compliance is 98% or better
- 37. The long-range PM/PdM schedule is available and level loaded as needed with computerized maintenance management system (CMMS)
- 38. Lube service specifications, tasks, and frequencies included in CMMS database
- 39. CMMS provides mean time between failures, mean time to repair, failure trends, and other reliability data

40. PM/PdM task descriptions contain enough information for new crafts person to perform task

.

- 35. PM/PdM change process: This best practice area simply ensures that PM/PdM procedures are subject to a continuous review process and that all changes to the program are made in a timely manner. The CMMS system should provide an easy method to update task descriptions and task frequencies and allow for mass updating when the procedure applies to more than one piece of equipment.
- 36. PM/PdM compliance is measured: One key measure of overall maintenance performance should be how well the PM/PdM program is being executed based on the schedule. Measuring PM/PdM compliance ensures accountability from maintenance and from operations. Normally, a scheduling window of a week will be established to determine compliance. A goal of 98% or better for PM/PdM compliance should be expected.
- 37. Long range PM/PdM scheduling: As a PM/PdM schedule is loaded to the system, peaks and valleys may occur for the actual scheduling due to frequencies of tasks coming due at the same time period. The CMMS system should provide the capability to level load the actual PM/PdM schedule and to view upcoming PM/PdM work loads to assist in the overall planning process.
- 38. Lubrication services: Ideally, lubrication services, tasks, frequencies, and specifications should be included as part of the PM/PdM module. A continuous change process for this area should also be put in place as well as an audit process established to ensure all lube and PM/PdM tasks are being performed as scheduled.
- 39. CMMS captures reliability data: The elimination of root causes of problems is the goal rather than just more PM/PDM. One important feature of a "Class A" installation is being able to capture failure information that can in turn be used for reliability improvement. This requires development of a good coding system for defining causes for failures and accurately entering this information as the work order is closed.

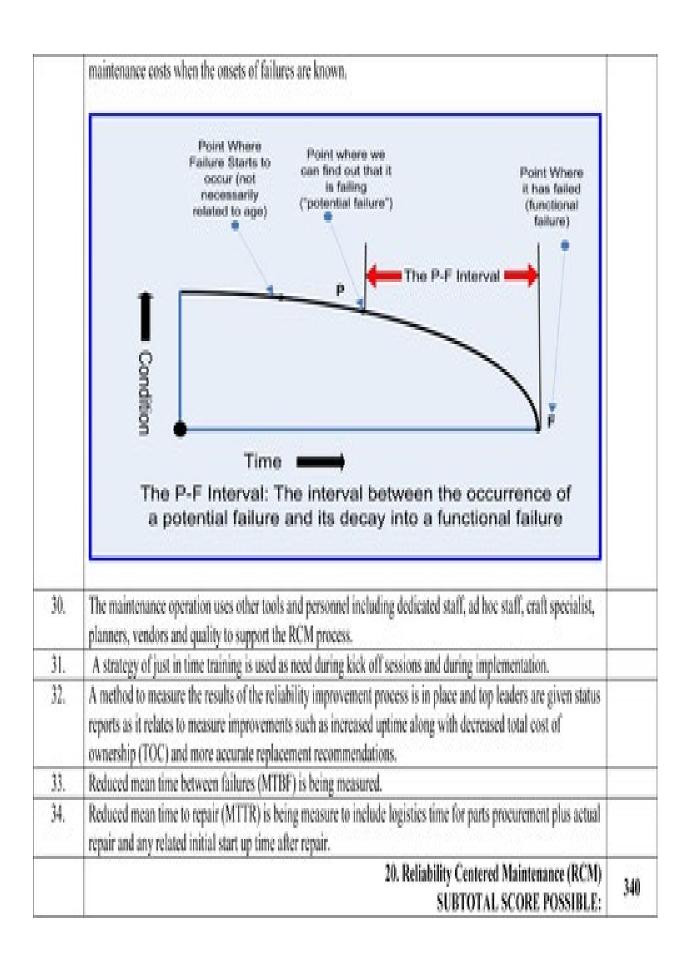
40. Complete PM/PDM task descriptions: PM/PdM task descriptions often provide vague terminology to check, adjust, inspect, etc. and do not provide clear direction for specifically what is to be done. Task descriptions should be reviewed periodically and details added that to the level that a new crafts person would understand exactly what is to be done and be able to adequately perform the stated task.

#### 20. RELIABILITY CENTERED MAINTENANCE (RCM)

ITEM#	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5	RATING
1.	A process such as RCM is used to determine the maintenance requirements of any critical physical asset in its operating context.	
2.	Criticality analysis to define top candidates for review has been conducted those factors in production consequence (pd), safety/ env. cons.(sf), service level (sl), redundancy(rf), frequency of failure (ff') and down time (dt)"	
3.	The maintenance team strives to ensure any physical asset continues to do whatever its users want it to do in its present operating context?	
4.	Operations context is clearly defined and understood by maintenance and operations to include the type of process which is the most important feature of the "operating context". Some areas must be very clear before starting the RCM process.  ✓ Continuous processing where failure may stop entire plant or failure could significantly reduce output ✓ Batch processing or discrete manufacturing	
5.	Other factors related to operating context of the asset include: Redundancy factors, Quality standards, Environmental standards, Actual physical location, Safety hazards, Shift arrangements, Work in process levels, Repair time & overall Mean Time to Repair (MTTR), Spares availability, Market demand, Raw material supply.	
6.	Strategies and operating principles are defined and characterize the key steps which are:  A focus on the preservation of system function  The identification of specific failure modes to define loss of function or functional failure  The prioritization of the importance of the failure modes, because not all functions or functional failures are equal  Failure consequences  The identification of effective and applicable PM/PdM tasks for the appropriate failure modes  Applicable means that the task will prevent, mitigate, detect the onset of, or discover the failure mode  Effective means that among competing candidates the selected PM/PdM task is the most cost-effective option	
7.	Maintenance can define ways the asset can fail to fulfill its function where a functional failure is defined as the inability of any asset to fulfill a function to a standard of performance which is acceptable to the user.	
8.	Maintenance understands that it is more accurate to define failure in terms of a specific function rather than the asset as a whole. Categories of functional failures may include Partial and total failure, Upper and lower limits, Gauges and indicators along with the operating context. The RCM process looks to define/record all functional failures with each function.	
9.	The organization's work order system captures functional failures, cause of failures and frequencies.	

10.	When defining functions the function statement should consist of a verb, object and a desired standard of performance; "To pump water from Tank X to Tank Y at not less than 300 gallons per minute.	
Ha	Performance standards are defined in two ways; Desired Performance: What the user wants the asset to do and Design Capability: What the asset can do?	
12.	Function statements may include the appropriate but different types of performance standards depending on the asset such as Multiple, Quantitative, Qualitative, Absolute, Variable or Upper and lower limit types of standards.	
13.	A failure mode that causes functional failures is being documented by the work order system there is by helping maintenance define the options for a maintenance strategy or development of caring equipment plans.	
14.	Based upon an analysis of work completed a reactive maintenance strategy of dealing with failure events after they occur is prevalent.	
15.	Proactive maintenance that deals with events before they occur or deciding, planning and scheduling how they should be dealt with is a solid strategy.	
16.	Failure Mode Categories are designated when a) Capability falls below desired performance b)Desired performance rises above capability and when Asset not capable from the start per design or operating procedures.	
17.	Failure Mode Categories Capability falling below desired performance can be identified as deterioration (all forms of "wear and tear, Lubrication failure, Dirt/dust, Disassembly where integrity of the assemblies (welds, rivets, bolts) decline due to fatigue or corrosion and human errors.	
18.	When desired performance rises above capability the following can be identified:  a) Sustained, deliberate overloading  b) Sustained, unintentional overloading and  c) Incorrect process materials	
19.	The Level of Detail in Defining Failure a Mode provides enough detail to select a suitable failure management strategy.	
20.	Failure modes which might reasonably be expected to occur in the current operating context are defined and will include; Failures that have occurred on the same or similar assets, Failure modes which are already under PM/PdM, Any other failure modes that are considered real possibilities and Where consequences are very severe if a failure occurs.	
21.	Failure effects and failure consequences' are not the same. Failure effects answer the question, "what happens", whereas failure consequences answer the question "how does it matter?" Failure consequences are factored as one element of component/equipment criticality rating method being used.	
22.	Describing the effects of a failure strives to answer this question "What evidence is there that the failure occurred" part of which may be answered by a maintenance planner?  In what way did the failure pose a threat to safety & the environment?  In what ways did the failure affect production or operations?  What physical damage is caused by the failure?  What must be done to repair the failure?  Is this reported correctly on a work order, is part of a standard procedure or becomes an after action report	
	completed for Total Cost of Down Time (TCDT).	

23.	Completing the Failure Modes and Effects Analysis (FMEA) utilizes steps 1 to 20 above that point's maintenance toward the best maintenance strategy to use.
24.	Failure consequences answer the question "How does it matter?" They're many consequences of failure that:  ✓ Impact on output, quality and customer service  ✓ Personal safety and environmental issues  ✓ Increase in operating cost, energy consumption  ✓ Related to Nature and severity of effects govern and whether the users of the asset really believe that a failure matters
25.	The focus on consequences starts the RCM process of task selection  ✓ Assessment of the effects of each failure mode  ✓ Classifying into 4 basic categories of consequences  1. Safety and environmental consequences  2. Operational consequences  3. Non-operational consequences  4. Hidden failure consequences
26.	What can be done to predict or prevent each failure?  ✓ Proactive tasks: Tasks undertaken before a failure occurs to prevent asset from going into a failed state.  They include: preventive, predictive, scheduled restoration/overhaul, scheduled discard/replacement, condition monitoring and proactive task is worth doing if it reduces the consequences of failure enough to justify the direct and indirect cost of doing the task
27.	The organization uses the RCM process to make the best failure management decision for critical assets by considering:  ✓ Age-related failures  ✓ Non-age related failures (operator error)  ✓ Cost factors for scheduled restoration/overhaul  ✓ Cost factors for scheduled discard/replacement  ✓ Identifying potential failures and the P-F Interval which are time that a potential failure begins and the time that a functional failure actually occurs and the question "Is the P-F interval enough time to deal with failure/consequences" and what condition monitoring options available?
28.	Decisions are made on what should be done if a suitable proactive task cannot be found?  For hidden functions that cause multiple failures look for a possible failure finding task; if one is not available maybe redesign?  If safety or environmental issue cannot be resolved by proactive task; redesign or change the process.  For operational consequences, if no proactive tasks available and costs are less then no scheduled maintenance (run to failure). Look to redesign if costs too high.  For non-operational consequences (same as above)
	There is a very clear and solid understanding about the P-F Interval Curve and the high cost of gambling with

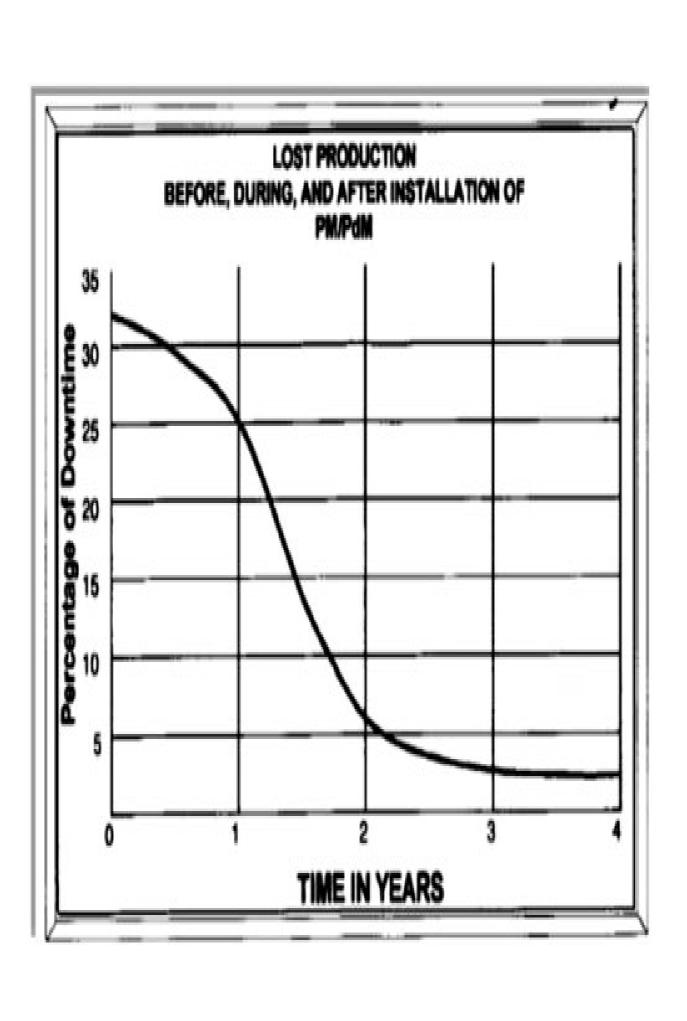


#### H. Maintenance performance measurement

- 41. Downtime (equipment/asset availability) due to maintenance is measured and documented improvements have occurred
- 42. Craft performance against estimated repair times is measured and documented improvements have occurred
- 43. Maintenance customer service levels are measured and documented; schedule compliance improvements have occurred
- 44. The maintenance performance process is well established and based on multiple indicators compared to baseline performance values

41. Equipment downtime reduction: Another key metric for measuring overall maintenance performance is increased equipment uptime. The improvement in this metric is a combination of many of the previously mentioned best practices all coming together for improved reliability. Downtime due to maintenance should be tracked and positive improvement trends should be occurring within a "Class A" installation.

\_



- 42. Craft performance: Two key areas affecting overall craft productivity are craft utilization (wrench time) and craft performance. Measurement of craft performance requires that realistic planning times be established for repair work and PM tasks. A standard job plan database can be developed for defining job scope, sequence of tasks, special tools listing, and estimated times. The goal is measurement of the overall craft workforce and not individual performance. Planning times are also an essential part of the planning process for developing a more accurate picture of workload and to support scheduling of overtime and staff additions.
- 43. Maintenance customer service: The results of improved maintenance planning must be improved customer service. The overall measurement process should include metrics such as compliance to meeting established schedules and jobs actually completed on schedule.
- 44. Maintenance performance measurement process: In this area, it is important to have a performance measurement process that includes a number of key metrics in each of the following major categories:
- a. Budget and cost
- b. Craft productivity
- c. Equipment uptime
- d. Planning and scheduling
- e. Customer service
- f. MRO materials management
- g. Preventive and predictive maintenance

The overall maintenance performance process should be established so that it clearly validates the benefits being received from the CMMS and maintenance best practice implementation.

100.000				-			anc								
A-Performance Measures	1. Actual Maintenance Cost Per Unit of Preduction	2.16 Major Work Completed within 5% of Cost Estimate	3.% Overall Maintenance Budget Compliance	4.% Overall Schedule Compliance	6.% Overall PM Compliance	6.% Planned Work	7.1% Craft Time for Customer Change Back	8.% Work Orders With Reliable Planned Time	9.% Oritical Asset Availability	10.55 Whench Time (Craft Utilization)	11.56 Craft: Performance	12.% Inventory Accuracy	13, Number of Stock Outs of Inventoried Stock bems	F. Performance Level Scores	Curren Month
B-Current Month Perf	\$1.30	90	94	90	94	68	75	50	90	34	90	90	15	Perf Level	Perf
C Performance Goals	\$1,00	95	98	95	100	80	85	60	95	50	95	98	10	10	
-	1.05	94	96	94	98	78	83	58	94	48	94	97	M	9	ı
Lewels II	1.10	93	94	93	96	76	81	56	93	46	93	95	12	8	1
§ ()	1.15	92	92	92	94	74	78	54	92	44	98	95	13	7	
§ "	1.20	91	90	91	92	72	75	52	91	12	91	94	14	6	
10.000	1.25	90	88	90	90	70	72	50	90	40	90	93	- 15	5	1
e § (}	\$1.30	89	86	89	88	68	69	48	89	38	89	92	16	4	
Baseline formance	1.35	88	84	88	86	-66	66	46	88	36	88	91	17	3 4	Baseline
Saselli Forma	1.40	87	82	87	84	64	63	44	87	34	87	U.	18		Perf.
	1.45	86	80	86	82	62	60	42	86	32	86	A	-17	THE R.	Level
P P P	1.50	85	78	85	80	60	57	40	93	30	85	87	20	0	
E-Performance Level Score	4	5	8	5	7	4	6	5	5	2	5	2	5	E-Perf. Level X	l.
G-Weighted Value Metric	10	6	6	7	11	7	6	4	13	8	8	6	5	G- Weighted Value	Tota RME
H-Performance Level Score (E) x Weight (G)	40	30	48	35	77	28	36	35	45	16		10	26	467	Valu
J-Total RMEI Value	Date	Jan 409	Feb 435	Mar 467	Apr	May	June	July	Aug	Sept	Oct	Dec	70-		ighted lue of

# I. Other uses of computerized maintenance management system (CMMS)

- 45. Maintenance leaders use CMMS to manage maintenance as internal business
- 46. Operations staff understand CMMS and use it for better maintenance service
- 47. Engineering changes related to equipment/asset data, drawings, and specifications are effectively implemented
- 48. Hierarchies of systems/subsystems used for equipment/asset numbering in CMMS database
- 49. Failure and repair codes used to track trends for reliability improvement
- 50. Maintenance standard task database available and used for recurring planned jobs

\_

- 45. Maintenance managed as a business: One true indicator for a successful CMMS installation is that it has changed the way that maintenance views its role in the organization. It should progress to the point that maintenance is viewed and managed as an internal business. This view requires greater accountability for labor and parts costs, greater concern for customer service, better planning, and greater attention to reliability improvement and increased concern for the maintenance contribution to the bottom line.
- 46. Operations understands benefits of CMMS: There is direct evidence that operations understands that an improved CMMS is a contributor to improved customer service. The scheduling process is continuously improving through better coordination and cooperation between maintenance and operations within

#### a "Class A" installation.

- 47. Engineering changes: Accurate engineering drawings are essential to maintenance planning and to actually making the repairs. Asset documentation must be kept up to date based on a formal engineering change process. Feedback to engineering must be made on all changes as they occur on the shop floor. Engineering must in turn ensure that master drawings are updated and that current revisions are made available to maintenance. Appendix I: Management of Change (MOC) Procedure Courtesy of Peru LNG is provided as an MOC guideline.
- 48. Equipment database structure: To provide equipment history information in a logical parent—child relationship, the equipment database structure has been developed using an identification of systems and subsystems. Accessing the equipment database should allow for drill down from a parent level to lower level child locations that are significant enough for equipment master information to be maintained. This definitely includes instrument loops within refineries and all continuous processing plants.

# SAP Instrument Structure

00	0424-SRUA	SULFUR RECOVERY A	
00	0424-SRUB	SULFUR RECOVERY B	
0	0424-SRUC	SULFUR RECOVERY C	
-	□ 0424-SRUC-A	Safety	
-	■ 0424-SRUC-C	Conpressors	
Н	0424-SRUC-E	Electrical	
-	- @ 0424-SRUC-F	Furnaces, Heaters, Boilers	
-	- 00 0424-SRUC-G	General	
-		Exchangers, Air Coolers, etc.	
-		Instrumentation	
1	T		40000000
		D-2C REFLUX DRUM	19000359
		E-3C-1 AHINE REBOILER	19000359
		E-3C-2 ANINE REBOILER	19808359 19808359
	- 00 0424-SRUC-I-L103C2 - 00 0424-SRUC-I-L104C	TIC BOTTOM LEVEL	19888359
	00 8424-SRUC-I-L105C	D2C REFLUX DRUM LEVEL	19000359
	00 0424-SRUC-1-L107C1	E-AC-1 ANIME REBOILER	19000359
	00 0424-SRUC-1-L107C2	E-4G-2 ANINE REBOILER	19000359
	- 00 0424-SRUC-1-L114C1	E-2C-1 AHINE REBOILER	19000359
	- 00 0424-SRUC-1-L114C2	E-2C-2 ANINE REBOILER	19000359
	0 0424-SRUC-1-L117	TK-10 FRESH ANINE TANK	19000359
	0 8424-SRUC-I-L131C	DIOC AMINE FEED DRUM	19000359
	- 00 0424-SRUC-1-L132C	TIC STRIP BOTTOMS	19000359
	- 00 0424-SRUC-1-L133C	D-2C AMINE REFLUX DRUM	19000359
	□ 0424-SRUC-1-L134C	D-2C HIGH LEVEL PRE S/D	19000359
	M 0424-SRUC-1-L135C	D-2C ANINE REFLUX DRUM	19000359
	0 0424-SRUC-1-L136C	DIOC ANINE FEED DRUH LEVEL	19000359
	0 0424-SRUC-1-L138C	D1 ANINE FEED DRUM LEVEL	19000359
	─	TC1 STRIP BOTTONS	19000359
	- 0 0424-SRUC-I-L165C1	COHO POT FOR E-4C-1 ANIHE RE	19000359

49. Failure and repair codes: The reporting capability of the CMMS should provide good failure trending and support analysis of the failure information that is entered from completed work orders. Improving reliability requires good information that helps to pinpoint root causes of failure.



50. Maintenance standard task database: Developing the maintenance standard task database (or standard repair procedures and detailed job packages) for recurring jobs is an important part of a planner's job function. This allows for determining scope of work, special tools and equipment, and for estimating repair times. Once a standard repair procedure is established, it can then be used as a template for other similar jobs, resulting in less time for developing additional repair procedures. This database is an excellent source of benchmark jobs for review by the ACE team discussed in Chapter 16, Developing Improved Repair Methods plus Reliable Maintenance Planning Times with the ACE Team Process<sup>TM</sup>.

Summary: Developing a "Class A" CMMS installation requires the combination of good system functionality and improved maintenance practices. The CMMS team should begin very early during implementation with how it will measure the success of the installation. The recommendations provided here for using the CMMS Benchmarking System can help your organization achieve maximum return on its CMMS investment.

Understand the power of CMMS/EAM to support potential savings: The evaluation of your CMMS using the CMMS Benchmarking System will identify improvement opportunities that translate into direct savings. It is important that these areas be highlighted and that the future process for performance measurement is focused upon these specific areas that may have been used initially for CMMS/EAM capital project justification. The opportunities to realize both quantifiable and qualifiable benefits are numerous. Maintenance must be given the best practice tools, the people resources, and capital investments to address the improvement opportunities, and in turn are held accountable for results. As summarized in Part 2, there are 12 key areas where direct savings, cost avoidances, and gained value can be established and documented. Effective CMMS/EAM will contribute to all of them and help to increase:

- 1. Value of asset/equipment uptime providing increased capacity and throughput
- 2. Value of increased quality and service levels due to maintenance

- 3. Value of facility availability or cost avoidance from being nonavailable
- 4. Value of increased direct labor utilization (production operations)
- 5. Gained value from increased craft labor utilization/effectiveness via gains in wrench time
- 6. Gained value from increased craft labor performance/efficiency
- 7. Gained value of clerical time for supervisors, planners, engineering, and administrative staff
- 8. Value of MRO materials and parts inventory reduction
- 9. Value of overall MRO materials management improvement
- 10. Value of overall maintenance costs reductions with equal or greater service levels
- 11. Value of increased facility and equipment life and net life cycle cost reduction
- 12. Other manufacturing and maintenance operational benefits, including improved reliability and other reduced costs

Use CMMS to develop your maintenance operation as a profit center: A fully utilized CMMS is your business management system to support the business of maintenance. It is a mission-essential information technology tool, and effective physical asset management and maintenance is also mission essential and a core requirement for success. Often we see the CMMS being purchased as "the solution" and never really integrated with the business system, or the necessary basic best practices are not initiated to really make the IT investment work. Often maintenance is only viewed as a "necessary evil" and not as a valid "profit center" and internal business. Many times the maintenance leaders cannot sell management on doing maintenance the right way or able to convince them that the right thing to do is to shut down for preventive maintenance. Conversely, when maintenance is viewed as a "profit center," the opportunities to realize both quantifiable and quantifiable benefits are numerous. In turn, maintenance support to the profit optimization process continues when CMMS is used

effectively to develop your maintenance operation as a profit center.

-

9

# Defining Maintenance Strategies for Critical Equipment With Reliability-Centered Maintenance (RCM)

-

#### **Abstract**

This chapter is specifically included to expose the planner/scheduler to the concept of reliability-centered maintenance RCM and the fundamental RCM concepts and the seven key elements. The process is used to determine the maintenance requirements of any physical asset in its operating context. In addition, it provides a detailed process to answer the question: What must be done to ensure that any physical asset continues to do whatever its users want it to do in its present operating context?

#### **Keywords**

Bathtub curves; Default actions; Defining functions; Failure consequences; Failure effects; Failure modes; FMEA; Functional failure; Functions; Operating context; Performance standards; P–F interval; Proactive maintenance; Proactive tasks; RCM Decision Diagram; Reliability-centered Maintenance

#### (RCM); Task intervals

This chapter is included to expose the planner/scheduler to the concept of reliability-centered maintenance (RCM). Some professionals believe that the so-called classical RCM has been made much more complicated than it needs to be. Nonetheless, RCM was first introduced in the field of commercial aviation. It made its way to the nuclear industry in the mid-1980s, then spread to other organizations. In all, it is been estimated that more than 60% of all RCM programs initiated have failed to be successfully implemented. According to Neil Bloom (2005) in his book Reliability Centered Maintenance— Implementation Made Simple, RCM became overly complicated in its transfer from the airlines and history. Also, it is his belief that the successful application of the process is inversely proportional to the complexity it has acquired. Bloom also stated that some consultants employ an elixir of obfuscation to allow them sole possession of understanding the process, and hence a continued income stream.

Bloom (2005) clearly stated that RCM is not a preventive maintenance (PM) reduction program. It is a reliability program. RCM will indeed identify those unnecessary PMs that may become candidates for deletion. RCM is almost always described as a process of identifying critical components whose failure would result in an unwanted consequence to one's facility. As a planner, your organization may have experienced some of the following reasons for lack of success or it may have a successful. You may be what is needed to get the RCM analysis on the right track. Many times, one or more of the following occurrances cause a lack of success:

- 1. Lost of in-house control
- 2. An incorrect mix of personnel performing the analysis
- 3. Unnecessary and costly administrative burdens
- 4. Fundamental RCM concepts are not understood

- 5. Confusion determining system functions
- 6. Confusion concerning system boundaries and interface
- 7. Divergent expectations
- 8. Confusion regarding convention
- 9. Misunderstanding hidden failures and redundancy
- 10. Misunderstanding run-to-failure
- 11. Inappropriate component classifications
- 12. Instruments were not included as part of the RCM analysis

My goal for this chapter is for the planner/scheduler to understand item 4—the fundamental RCM concepts. Let us start with a definition and then a question. First, RCM can be defined as a process that is used to determine the maintenance requirements of any physical asset in its operating context. It provides a detailed process to answer this question: What must be done to ensure that any physical asset continues to do whatever its users want it to do in its present operating state?

RCM can be defined as the seven key elements as shown in Figures 9.1–9.17.

## The 7 Key Elements of RCM

7. Default Actions

What should be done
if a suitable
proactive task
cannot be found?

6. Proactive Tasks & Task Intervals

What should be done to predict or prevent each failure?

5. Failure
Consequences
In what way does
each failure matter?

1. Functions

What are the functions and associated desired standards of performance of the asset in its present operating context? 2. Functional Failures

In what ways can it fail to fulfil its functions?

What causes

each functional failure ?

3. Failure Modes

- RELIABILITY CENTERED MAINTENANCE
- 4. Failure Effects

What happens when each failure occurs?

Figure 9.1 The seven key elements of RCM.

## Reliability-Centered Maintenance (RCM)

#### The principles which define and characterize RCM are:

- ✓ A focus on the preservation of system function
- ✓ The identification of specific failure modes to define loss of function or functional failure
- √ The prioritization of the importance of the failure modes, because not all functions or functional failures are equal and
- ✓ The identification of effective and applicable PM/PdM tasks for the appropriate failure modes
  - ✓ Applicable means that the task will prevent, mitigate, detect the onset of, or discover the failure mode
  - ✓ Effective means that among competing candidates the selected PM/PdM task is the most cost-effective option

Figure 9.2 The principles that define and characterize RCM.

### Reliability-Centered Maintenance (RCM)

# These RCM principles, in turn, are typically implemented in a seven step process:

- The objectives of maintenance with respect to any particular item/asset are defined by the <u>functions</u> of the asset and its associated desired <u>performance standards</u>.
- Functional failure (the inability of an item/asset to meet a desired standard of performance) is identified. This can only be identified after the functions and performance standards of the asset have been defined.
- 3. Failure modes (what causes each functional failure) are identified.
- Failure effects (describing what will happen if any of the failure modes occur) are documented. (Consequences of failures)

Figure 9.3 RCM is typically implemented in seven steps.

### Reliability-Centered Maintenance (RCM)

- 5. Failure consequences are quantified to identify the criticality of failure. RCM not only recognizes the importance of the failure consequences but also classifies these into four groups:
  - √ Hidden failure
  - ✓ Safety and environmental
  - ✓ Operational
  - √ Non-operational
- Functions, functional failures, failure modes are criticality analyzed to identify opportunities for improving performance and/or safety.
- Proactive tasks are established which may include:
  - ✓ Scheduled on-condition tasks (which employ condition-based or predictive maintenance)
  - √ Scheduled restoration/overhaul
  - ✓ Scheduled discard tasks/replacement

Figure 9.4 RCM is typically implemented in seven steps.

#### 1. Functions and Performance Standards

What are the functions and associated performance standards of the asset in its present operating context?

Defining the Operating Context: The type of process is the most important feature of the "operating context". It must be very clear before starting the RCM process.

- √ Continuous processing
  - √Failure may stop entire plant
  - √ Failure could significantly reduce output
- √ Batch processing or discrete manufacturing

#### Other factors related to operating context of the asset:

✓ Redundancy

- ✓ Quality standards
- ✓ Environmental standard
- √ Safety hazards
- ✓ Shift arrangements
- ✓ Work in process

√ Repair time

- √ Spares
- ✓ Market demand
- √ Raw material supply

Figure 9.5 Functions and performance standards.

#### 2. Functional Failures

#### In what way does the asset fail to fulfill its function?

Functional Failure: A functional failure is defined as the inability of any asset to fulfill a function to a standard of performance which is acceptable to the user.

- ✓ More accurate to define failure in terms of a specific function rather than the asset as a whole.
- √ Categories of functional failures
  - ✓ Partial and total failure
  - ✓ Upper and lower limits
  - √ Gauges and indicators
  - √ The operating context
- ✓ The RCM process looks to define/record all functional failures with each function.

Figure 9.6 Functional failures.

#### Functions and Performance Standards

Defining Functions: A function statement should consist of a verb, object and a desired standard of performance; "To pump water from Tank X to Tank Y at not less than 300 gallons per minute"

Performance Standards: Can be defined in two ways:

- ✓ Desired Performance: What the user wants the asset to do.
- ✓ Design Capability: What the asset can do.

Function statements may include different types of performance standards depending on the asset:

- ✓ Multiple ✓ Quantitative
- ✓ Qualitative ✓ Absolute
- √ Variable 
  ✓ Upper and lower limits

Figure 9.7 Functional failures.

#### 3. Failure Modes

#### What causes each functional failure?

Failure Mode: A failure mode is any event that causes a functional failure. How we deal with this defines our options for a maintenance strategy

- Reactive Maintenance: Dealing with failure events after they occur
- Proactive Maintenance: Dealing with events before they occur or deciding how they should be dealt with if they occur

#### Failure Mode Categories:

- Capability falls below desired performance
- 2. Desired performance rises above capability
- 3. Asset not capable from the start

Figure 9.8 Failure modes.

#### 4. Failure Effects

#### What happens when each failure occurs?

Functional Effects: Failure effects are not the same as failure consequences. Failure effects answer the question, "what happens", whereas failure consequences answers the question "how does it matter?"

Describing the effects of a failure strives to answer these questions: What evidence is there that the failure occurred?

- ✓ In what way did the failure pose a threat to safety & the environment?
- ✓ In what ways did the failure affect production or operations?
- √ What physical damage is caused by the failure?
- √ What must be done to repair the failure?

Items #1 to #4 all lead now to completing the Failure Modes and Effects
Analysis (FMEA)

Figure 9.9 Failure effects.

System: SMW Gas Turbine	Sub-System: Exhaust System	EXAMPLE: FAILU	EXAMPLE: FAILURE MODES AND EFFECTS ANALYSIS (FMEA)					
FUNCTION	FUNCTIONAL FAIL (Loss of Function		FAILURE EFFECT What happens when it fails?					
<ol> <li>To channel all the hot turbine air without restriction to a fixed point</li> </ol>	Unable to chann at all.	el gas 1. Silencer mountings corroded away.	Silencer assembly collapses and falls to bottom of stack. Back pressure causes the turbine to surge violently and shut down on high exhaust gas temperature. Downtime to replace silence up to four weeks.					
10m above the roof of the turbine building.		falls off due to fatigue.	Depending on the nature of blockage, exhaust temperature may rise to where it shuts down the turbine. Debris could damage parts of the turbine. Downtime to repair silencer up to four weeks.					
	C. Fails to maintain gas.	1. Hole in flexible joint from corrosion.	The joint is inside turbine hood, so leaking exhaust gases would be extracted by the hood extraction system. Fire and gas detection equipment inside hood is unlikely to detect an exhaust gas leak, and temperatures are unlikely to rise enoug to trigger the fire wire. A severe leak may cause gas demister to overheat, and may melt also melt control wires near the lea with upredictable effects. Pressure balance inside the hood ar such that little or no gas is likely to escape from a small leak, a small leak is unlikely to be detected by smell or hearing. Downtime to replace joint is 3 days.					
		Gasket in ducting improperly fitted.	Gas escapes into turbine hood and ambient temperature rise: Building ventilation system would expel gases through louven to atmosphere. So concentration of gases is unlikely to reach noxious levels. A small leak at this point would be audible. Downtime to repair up to 4 days.					
		Hole in upper bellows due to corrosion.	The upper bellows are outside the turbine building, so a leak here discharges to the atmosphere, Ambient noise levels may rise. Downtime to repair, a few days to several weeks.					
2. To reduce exhau noise to ISO Rating 30 at 50m	A. Noise level exce	equipment mesh retaining	Most of the material would be blown out, but some might fail the bottom of the stack and obstruct the turbine outlet causing high EGT and possible turbine shutdown. Noise levels would rise gradually. Downtime to repair about 2 weeks.					

Figure 9.10 Failure modes and effects analysis (FMEA).

### 5. Failure Consequences

#### In what way does each failure matter?

Failure Consequences: Failure consequences answers the question "how does it matter". They're many consequences of failure:

- √ Impact on output, quality and customer service
- ✓ Personal safety and environmental issues
- ✓ Increase in operating cost, energy consumption

Nature and severity of effects govern whether users of the asset really believe that a failure matters

The focus on consequences starts the RCM process of task selection

- ✓ Assessment of the effects of each failure mode
- ✓ Classifying into 4 basic categories of consequences
  - 1. Safety and environmental consequences
  - 2. Operational consequences
  - 3. Non-operational consequences
  - 4. Hidden failure consequences

Figure 9.11 Failure consequences.

### Evaluating Consequences with an RCM Decision Diagram

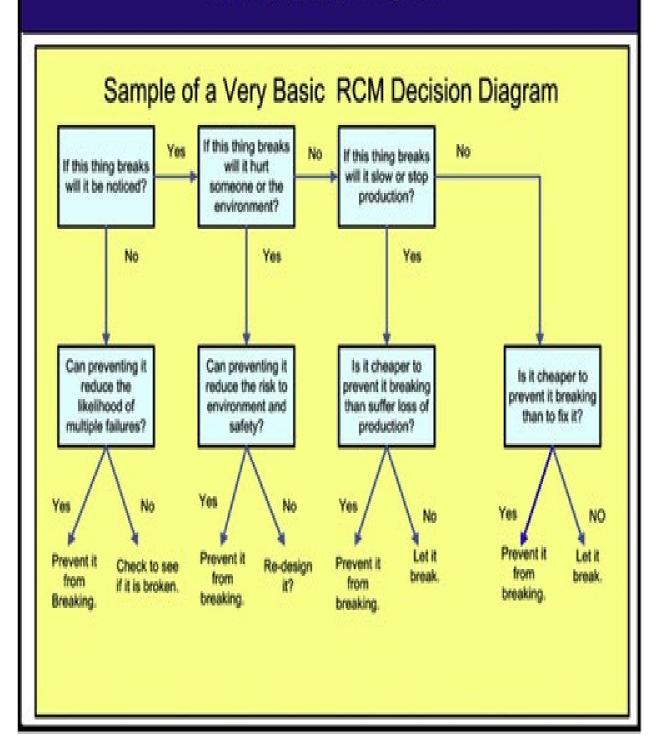


Figure 9.12 Evaluating consequences with an RCM decision diagram.

### 6. Proactive Maintenance

Step 6 in the RCM process strives to make the best failure management decision by considering:

- ✓ Age-related failures
- √ Non-age related failures (operator error)
- √ Cost factors for scheduled restoration/overhaul
- ✓ Cost factors for scheduled discard/replacement
- ✓ Identifying potential failures and the P-F Interval which is:
  - √ The time that a potential failure begins and
  - ✓ The time that a functional failure actually occurs
  - ✓ Is the P-F interval enough time to deal with failure/consequences?
  - ✓ Condition monitoring options?

Figure 9.13 Proactive maintenance.

#### 6. Proactive Maintenance

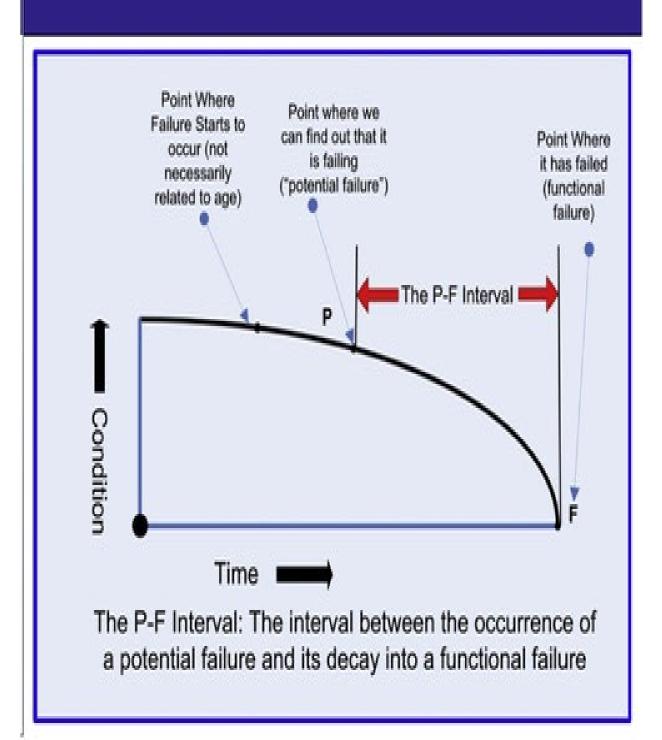


Figure 9.14 The P–F Interval.

Figure 9.15 Areas of the "bathtub curve"

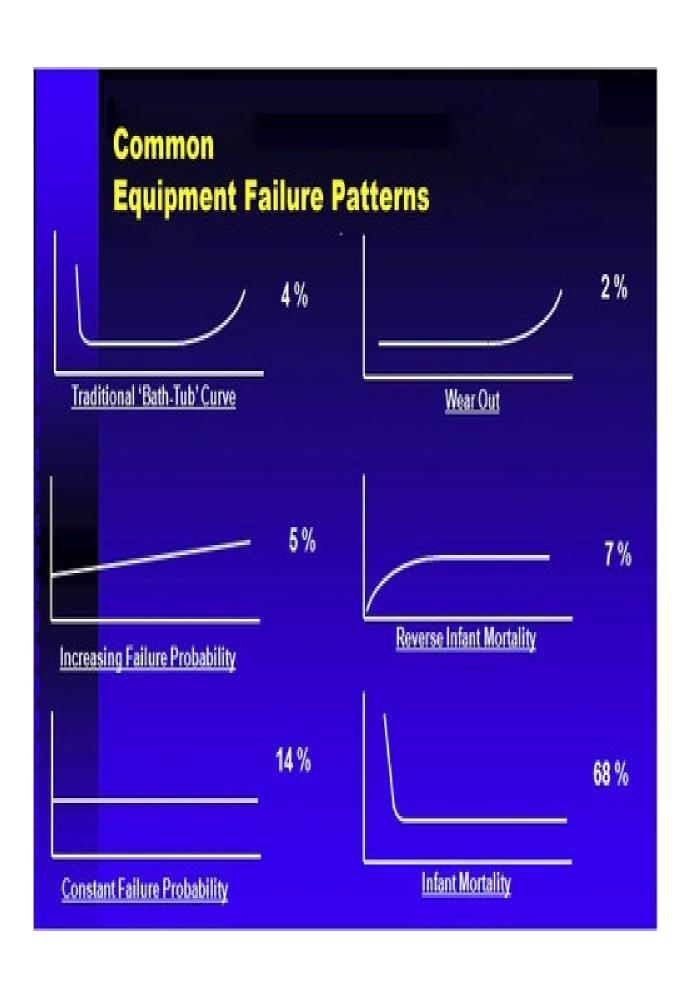


Figure 9.16 Common equipment failure patterns.

#### 7. Default Actions

# What should be done if a suitable proactive task cannot be found?

- ✓ For hidden functions that cause multiple failures look for a possible failure finding task; if one is not available maybe redesign?
- ✓ If safety or environmental issue cannot be resolved by proactive task; redesign or change the process.
- ✓ For operational consequences, if no proactive tasks available and costs are less then no scheduled maintenance (run to failure). Look to redesign if costs too high.
- ✓ For non-operational consequences (same as above)

#### Figure 9.17 Default actions.

#### **Further Reading**

Bloom Neil B. Reliability Centered Maintenance; Implementation Made Simple. McGraw-Hill Companies Inc; 2005.

Moubray John. Reliability-centered Maintenance. Industrial Press; 1997.

Smith Anthony M, Hinchcliffe Glenn. RCM-gateway to World Class Maintenance. Elsevier-Butterworth-Heinemann; 2004.

## Defining Total Maintenance Requirements and Backlog

\_

#### **Abstract**

This chapter looks at some of the items connected to the "How Much Work?" question as related to our total maintenance requirements and our current backlog. Trying to manage maintenance without managing the backlog can be a losing situation. A certain level of backlog is needed in order to plan and schedule work. Backlog gives us a picture of resources and whether we are capable of accomplishing work with in-house staff, overtime, staff additions, or outsourcing to contract maintenance providers. Backlog in its simplest terms is work that has not yet been completed.

#### **Keywords**

Backlog; Backlog integrity; Backlog management; Backlog relief; Job status codes; Priority systems; Ready backlog; RIME System; Total backlog; Total maintenance requirements

This book strives to answer many important questions, including the who, what, when, where, why, and "how to" of effective planning, estimating, and scheduling. So far, I have tried to answer some of these questions in previous

chapters and appendices.

- 1. Why? Chapters 1, Chapter 2, and 6.
- 2. Who? Appendix C.
- 3. What? Chapter 7.
- 4. When? Generally, you apply reliable maintenance planning estimating scheduling (RMPES) when there is a desire to move from reactive, firefighting-type maintenance to a proactive, planned maintenance strategy.
- 5. Where? This book focuses on the oil, gas, and petrochemical sectors, but much of the information is applicable to all types of operations.
- 6. How much? Chapter 10.
- 7. How to? Chapters 3, 4, 5, 8, and 9, and Appendix A.

In this chapter, we look at some of the items related to the "how much?" question regarding total maintenance requirements (TMR) and current backlog. In the simplest terms, backlog is the work that has not yet been completed. Trying to manage maintenance without managing the backlog can be a losing situation. However, you must have a certain level of backlog in order to plan and schedule work. Backlog provides a picture of resources and whether it is possible to achieve work with in-house staff, overtime, staff additions, or outsourcing to contract maintenance providers.

As a work request is generated and becomes a work order, it contains key information, of which one is a priority code. In this way, the planner can determine when the job will be planned, scheduled, and performed in relation to other jobs being requested. As a planner completes all the planning functions for each work order, the job then becomes available to schedule. If the planner and scheduler are two positions, the scheduler then receives the available planned job. Likewise, if the planning process is not completed, the job is not ready for the schedule and is unavailable. This may be due to a number of reasons, such as awaiting parts because of out-of-stock items or nonstocked items that must be purchased.

I have always considered TMR as one of the key items that a maintenance

leader, supported by the planner/scheduler, should always be ready to review with top leaders. We can think of TMR as all of the work required during a period of time, such as on an annual basis. TMR includes everything that needs to be done, including (most importantly) the identified deferred maintenance, which can cost more if not repaired in a reasonable timeframe. TMR also can be minor project work that maintenance typically is staffed to perform and has done in the past.

When the maintenance leader requires additional staff resources, a valid estimation of TMR plus the validation of current craft productivity (OCE) is available. In this case, using these current facts on workload increases the chance that a request using documented needs will be successful. If not successful, then the maintenance leader will have provided due diligence by informing top leaders of critical deferred maintenance. TMR also includes the equivalent staffing needed to achieve 100% preventive maintenance compliance.

In most cases, the planner may have this information in a master plan, broken down into two areas:

- 1. Total backlog, which includes work waiting to be scheduled (unavailable) due to a number of reasons.
- 2. Ready backlog, which is work that is ready to go on to a schedule, with all parts and materials being ready (available).

In this case, what I call total maintenance requirements is the total backlog plus ready backlog. TMR includes measured labor hours required and translated into labor weeks. The labor hours that the work is estimated to take are the available resource. The normal range for backlog is typically based on 80–90% of jobs being planned. Most companies set their own criteria for total backlog.

- Ready available backlog is equal to 2–4 weeks of labor hours.
- Total backlog.
- TMR—the total backlog (unavailable) plus the ready backlog (available)—for the schedule Total backlog is equal to 4-6 weeks of labor hours.

Backlog "is what it is," so to speak, if maintenance is clearly working at a documented high level of productivity and deferred maintenance is clearly being

reported correctly to top leaders.

Now, we will take a look at some of the formats for joining backlog, coding backlog, and computing weeks of backlog. Again, all of this is a critical role and responsibility of the planner/scheduler. First, as a minimum, the planner should maintain a continuous TMR list of total backlog plus ready backlog, with the following items summarized in an end-of-the-month report:

- Total weeks of total backlog and ready backlog.
- Total TMR jobs/labor hours for all open work orders.
- Total backlog jobs/labor hours for work orders unavailable to be scheduled.
- Total ready backlog job/labor hours ready to be scheduled.
- Backlog aging
- <1 month
- <1–2 months
- <3–6 months
- >6 months
- Total backlog summary by reason code for being unavailable.
- Trend charts
- Total labor hours completed versus number of work orders completed.
- Total available labor hours.
- Total scheduled overtime hours. (Figures 10.1–10.6).

### **Backlog Management**

- Types of Backlog
  - -Ready Backlog: Jobs Ready to Go
  - Total Backlog = Ready Backlog + Other open work orders
  - -Ready Backlog: 2 to 4 Weeks
  - Total Backlog: 4 to 8 Weeks
- Establish a Valid Priority System
- Establish Valid Job Status Codes
- Maintain Backlog Integrity. It must be;
  - Complete
  - -Current
  - -Pure
  - -Reliable

Figure 10.1 Key elements of backlog management.

### Valid Priority System

- Numerical
  - 1= An immediate true emergency, a life safety or regulatory issue
  - 2= Required within 24 hours
  - 3= Required in 2-5 days
  - 4= Required in 1-2 weeks
  - 5= Required in over 2 weeks
- RIME System
  - Ranking Index for Maintenance Expenditures (RIME)
  - Based on Criticality of the Asset/Equipment
  - Based on Criticality of the Work Type

Figure 10.2 Two types of priority systems.

# RIME System

# RIME System: Ranking Index for Maintenance Expenditures and Calculated by:

Criticality of the Asset/Equipment (Rated 10 down to 1)

X

Criticality of the Work Type (Rated 10 down to 1)

= RIME Number for the Work Order

Figure 10.3 The Ranking Index for Maintenance Expenditures (RIME) system.

# RIME System Example (Distribution Center)

Work Type Priority  Asset Criticality		Safety & True Emergency (SAF)	Preventive and Predictive Maintenance (PM) (PDM)	Project Work (PRJ)	and Warranty Work (CMM)	Operations Service (OPS)	Routine Normal Safety (RNS)	Tenant Improvement (TIM)	Inspections (INS)	Miscellaneous (MIS)	Housekeeping (HSK)
Occurs	40	10	9	8	7	6	5	4	3	2	1
SORTER	10	100	90	80	70	60	50	40	30	20	10
Conveyor	9	90	81	72	63	54	45	36	27	18	9
Utilities	8	80	72	64	56	48	40	32	24	16	8
Turret Truck	7	70	63	56	49	42	35	28	21	14	7
Lift Truck	6	60	54	48	42	36	30	24	18	12	6
Stock Picker	5	50	45	40	35	30	25	20	15	10	5
Miscellaneous Mobile Equipment	4	40	36	32	28	24	20	16	12	8	4
Office Facilities	3	30	27	24	21	18	15	12	9	6	3
Miscellaneous support To Other Asset	2	20	18	16	14	12	10	8	6	4	2
Buildings, Roads and Grounds	1	10	9	8	7	6	5	4	3	2	1

Figure 10.4 Example of Ranking Index for Maintenance Expenditures (RIME) system.

RIME Equipment Code	Maintenance Work Code												
		Breakdown or critical sufety hazard	Operating Maint	РМ	CM &	Shudown	Normal Sched. Moint.	Process improve- erent	Cost Reduction	Facility Maint	Sanitation & hockpg.		
		2000000514	COLUMN TO STATE OF	depotency.	Distriction of the last of the	*******	*****	ORNAMOS.	GONGSON,	*	SOMEONS.		
Utilities	30	200000			11015157	60	80	47	20	20	server.		
Key Production Eq.	盔.	555 (0000)			- 64	64	46		27	18			
Multiple Production Eq.	20	CONTROL OF		Sec. 27.5	- 4	- 4	40	3.2	24	16			
Secondary Production Eq.	7	1000000	63	61	44	CONTRACT AND	26	27	21	14			
in Plant Mobile Equipment	3	1 40	E E	4	- 4	Harris M	16		15	12	91100		
Non-Production Eq./Not Span		/ "	- 41		16		25	20	16	10			
Non-Production Eq./Spamd	27	4	34		1	24	50	16	12	ALC: U	2000		
Wisc. Eq	œ.	30	27	24	21	18	15	12	REAL PROPERTY.		distributed.		
Roads and Grounda	h	20	- 11	14	16	12	10	0300000		Same of	The state of		
Buildings and Grounds	40			NEED THE PERSON	NAME OF TAXABLE PARTY.	CALCULATION	TOTAL PROPERTY.		(\$22525000		ACCORDED		

Din Work Convenience Work

 $\underline{\mathbf{Or}}$ 

### RIME Chart

RIME  Equipment Code	Maintenance Work Code												
	Breakdown or critical outsty hazard		eritical wy	Operating Maint.	PN	CM &	Situations: work	Normal Bahad. Maint.	Process improve- ment	Cost Raduction	Facility Veint.	Sentation A heatpy	
			MARKET.	Street,	<b>GENERAL</b>	. Hattachte	, tentences.	Michigan .	SHIRANE.	SHORE.	300002	HARME	
Julies	31	100				O STOCKERS	- 4	- 14 - S	4		2	100000	
Key Production Eq.	3						5	- 4		17		100 0000	
Wultiple Production Eq.	鰀	nn			100000	H 6	4	- 4	1	34	- 6	THE RESERVE	
Secondary Production Eq.		刨			3	96 4	Dia 40			1	- 4	200000	
In Plant Mobile Expopreme	3		1.5		4 .	0 9	1	- 4	24	- 1			
Non-Production Eq. Not Spanid			1.			. /		35	x		10		
Non-Production Eq/Spaned			1 4	3	4	2 2	20	26	16	0.00	RECEEDED		
Misc, Eq			1			2				(COOK 1917)	The same		
Poseds and Grounds	ij,		21	1	100.0	1				STREET, STREET,		6250433	
C. C. Street,		-	- 1	-	DESCRIPTION OF	OF STREET, STR	0.0000000000000000000000000000000000000	BOYES, IV		11133503			

Priority 1

Priority 2 & 3 - planned and scheduled

Convenience Work

Figure 10.5 Two examples of "do it now" (DIN) work and convenience work.

### Benefits of the RIME System

- Adds objectivity and professionalism into the planning and scheduling process
- Does not eliminate the need to apply individual judgment for final priorities for scheduling
- Lessens the impact of the "squeaky wheel"
- Provides better understanding about maintenance to the customers.
- Criticality of assets is determined in asset database
- · Criticality of work types is established

### Figure 10.6 Benefits of the Ranking Index for Maintenance Expenditures (RIME) system.

One advantage of using the Ranking Index for Maintenance Expenditures (RIME) system is that it provides another level of professionalism for the planning process. In other words, if the operations team understands that it is based on criticality of equipment and criticality of the work type, then the acceptance of work to be scheduled increases. The RIME system can also be used by the planner as a validation tool in determining the validity of a job priority assigned by the originator. Most often, the job priority is self-evident and validation by the planner is seldom required. It is been said that "the squeaky wheel gets the most grease," such as a persistent operations person who wants to get work done immediately. However, if there is a question about job priority assignments, the planner must always direct questions back to the work order approving authority for resolution. For a refinery unit, this authority may be granted to the unit maintenance coordinator, unit manager, or the maintenance leader. If procedures state that operations must approve all scheduled breaks, then the unit manager must sign off on work that changes the schedule significantly.

One of the things I distinctly remember about the scoreboard assessment at the Marathon Ashland Petroleum refinery in Robinson, Illinois (the 1999 North American Maintenance Excellence (NAME) Award winner) was a comment by their senior planner. He stated, "We have a very hard-and-fast rule about classifying work as an emergency work here at our refinery" Now here we are within a site with all types of critical failure consequences, but they wanted to be proactive and plan work to be as safe as possible. Not a bad idea! So let us consider what Kister and Hawkins defined as emergency ("E") work, which all companies should adapt:

"Emergency—Must be performed immediately. Higher priority than scheduled work, critical machinery down or in danger of going down until requested work is complete. 'E' to be used only if production loss, delivery performance, personnel safety (new and eminent), and equipment damage or material loss are involved and no bypass is available. Start immediately and work expeditiously and continuously to completion, including the use of overtime without specific

further approval. Only personnel authorized to approve overtime can assign 'E' to work orders. Emergency work order reports will be sent to the plant manager for review."(Figures 10.7–10.13).

Maintaining an accurate backlog is an important responsibility of the maintenance planner. From this document, schedules based on priorities are created. This document in terms of TMR defines staffing needs for the valuable resource of craftspeople. It is a means to define the facts of workload to top leaders. In turn, the backlog must have accurate estimates of the time required for as many jobs as possible. It must also have reliable estimates of jobs that have not been completed through the planning process. Every company site is different, and requirements for backlog levels may vary. One constant is that there must be control of the backlog, regardless of what has been accrued. Backlog is necessary for having planned work to develop effective scheduling. In Chapters 11–18, we will review the five key areas of the planning process:

## Planner Must Monitor Backlog

- By Planner Responsible for Area, Trade or Job
- By Job Status Codes (Reviewed Previously)
- By Crew or By Supervisor
- By Customer/Originator of Work request
- By Age of Work Order
- By Due Date

Figure 10.7 Areas where the planner should monitor backlog.

## Maintaining Backlog Integrity: How Does Your Backlog Compare

 Jobs completed, but nobody has closed them out

Duplicate jobs under different names

 Jobs over 6 months old (No one has reviewed & purged old work orders

 Jobs when no one recognizes the originator or why the job needed in the first place

Figure 10.8 Maintaining backlog integrity.

### Maintaining Backlog Integrity: How Does Your Backlog Compare

- A poorly described job (no one can figure out what to do to what)
- Job status not filled in and nobody know status
  - Were parts required?
  - Were parts ordered?
  - Were they delivered-where are they now?
- Jobs that need to be done but not on the backlog

Figure 10.9 Maintaining backlog integrity.

# Balancing Maintenance Resources with the Maintenance Workload Must;

- Ensure that expectations for backlog relief (reduction) are realistic
- Make allowances for all commitments to indirect activity
- Clarify the craft time to be allocated to true emergency work
- Clearly define labor hours for PM/PdM requirements

Figure 10.10 Balancing the maintenance resources with the backlog.

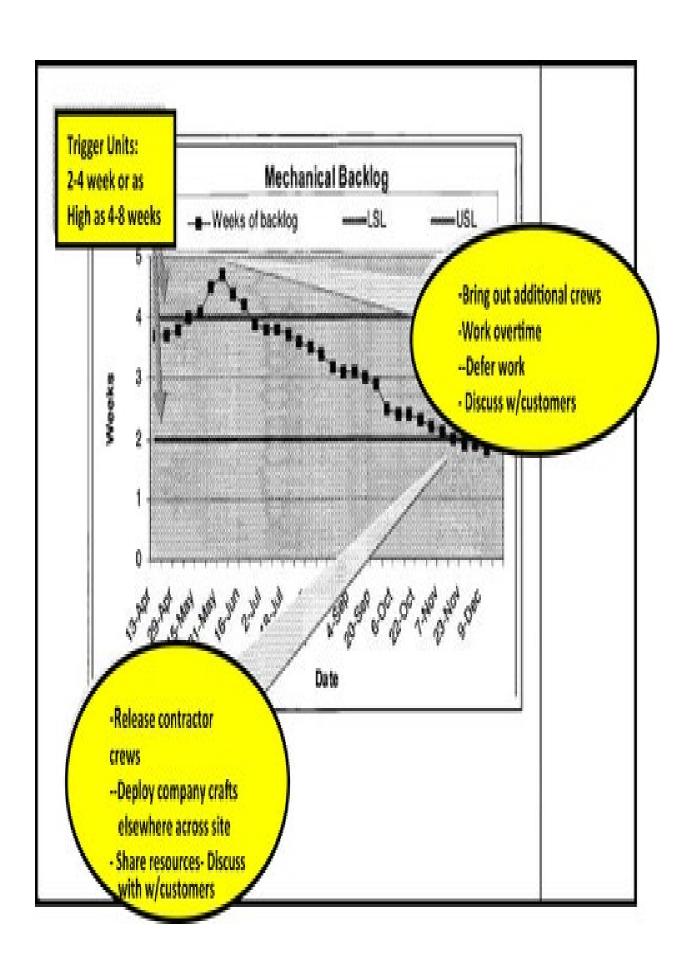


Figure 10.11 Monitoring backlog trends.

## **Backlog Job Status Codes**

Status Code	Status Code Description	Type of Backlog
AP	Awaiting Planning	Total
AE	Awaiting Engineering Review	Total
AA	Awaiting Approval	Total
PF	Pending Funding	Total
DF	Deferred-Funding	Total
PO	Waiting PO to be Issued	Total
AM	Awaiting Receipt of Material	Total
FP	Further Planning Required	Total
DP	Requires Downtime-Programmed Shutdown	Total
PW	Requires downtime- Weekend	Ready
DS	Requires downtime-Not Scheduled	Ready
DO	Requires downtime- Await Window of Opportunity	Ready
R	Ready to be scheduled	Ready
FI	Ready for Fill In Assignment	Ready
S	On the current schedule	Not in Backlog
СО	All maintenance work complete	Not in Backlog
CM	WO pending material close out	Not in Backlog
CH	Closed to Equipment History	Not in Backlog
CP	Print Revision not received	Not in Backlog

Figure 10.12 Backlog status code examples.

# Example: Maintenance Work Program to Address Backlog Relief (Reduction)

Work Program for Backlog Relief				
Available Resources- Crew Size = 20 Crafts				
Straight Time Man-hours Available Per Week				
Planned Overtime Per Weel		800 96		
Man-Hours Contracted or Borrowed Per Week		0		
	Total Man-Hours Available Per Week	896		
	Less Indirect Commitment (Average)			
Lunch (if paid)				
	Vacation	120		
	Absence	34		
	Training	56		
	Meetings	40		
	Special Assignments	40		
Average Man-Hours Loaned to Other Areas		40		
Average man-nours coaried to Other Indirect		10		
	Total Indirect Hours Projected Per Week	330		
Yotal	Hours Available Per Week for Direct Work (Wrench Time)	566		
Commitments Other Than Backlog Relief				
Emergency/Urgent (Unschedulable)				
	Routine PM/PdM	100 120		
Other Fixed Routine Assignment		0		
	Sub Total	220		
1	Net Resource Available for Backlog Relief	346		
The residence of the second				
Backlog Data Current	Backlog Weeks Current	Target		
Man Hours in 3200	Ready 9.2 Weeks	2 to 4		
Ready Status	Backlog	Weeks		
Total Man-Hours 4800 Of Backlog	Total 13,9 Weeks Backlog	4 to 6		

## Figure 10.13 Calculating weeks of backlog.

- 1. Planning
- 2. Estimating
- 3. Scheduling
- 4. Monitoring
- 5. Controlling

# Overview of a Reliable Planning-Estimating-Scheduling-Monitoring-Controlling Process

\_

### **Abstract**

This chapter looks at the overall range of planning and scheduling, which has five key phases: planning, estimating, scheduling, monitoring, and controlling. The maintenance function must do a better job in defining staffing needs by defining total maintenance requirements and showing maximum craft labor productivity. It also identifies areas contributing to increased maintenance costs and greater staffing needs. A key area is what ineffective planning looks like to the organization, and this can be turned into benefits of effective planning. This chapter looks at selling this best practice to maintenance and how to improve craft productivity to equal 5+ equivalent crafts positions.

## **Keywords**

Contractor management; Engineering support; Maintenance challenges; Maintenance supervisor; Planner needs; Planner responsibilities; Process mapping; Purchasing benefits; Selling benefits; Storeroom benefits; Work control When we consider the overall range of planning and scheduling, there are five key phases:

- 1. Planning
- 2. Scheduling
- 3. Estimating
- 4. Monitoring
- 5. Controlling

As we discussed previously, the planner begins with a reliable backlog of total maintenance requirements (TMR). From that baseline, labor resources are considered. During annual budgeting, one of the main questions asked by top leaders is how many staff positions are required. Measurement of TMR provides the definition of inherent workload. It is the staff required to preserve an asset related to its size, replacement value, and usage. Without this investment, the asset will inevitably deteriorate. In many cases, there is a shortfall between what is needed and what gets accomplished, thereby creating deferred maintenance. Deferred maintenance is a key element for which the maintenance leader must clearly show that short-term savings will create higher long-term costs.

The maintenance function must do a better job in defining staffing needs. That is why I always say (1) define total maintenance requirements and (2) show maximum craft labor productivity. If you have done this, you have done due diligence in regard to your current state of maintenance. Chapter 10, Defining Total Maintenance Requirements and Backlog, is a very important part of the planner's job and one that can help directly define staff requirements. Without solid evidence and facts, relying on vague evidence and indirect measures of increased in work (such as rising customer complaints, increasing downtime, growing use of contractors, etc.) may be inadequate justification for additional staff. Other areas contributing to maintenance costs and staffing are the shown in Figure 11.1.

A good book for your maintenance library is Maintenance Planning, Scheduling and Coordination by Don Nyman and Joel Levitt. Monitoring and controlling is much like their term coordination that is shown in Figure 11.2.

One last illustration concept from their book is Figure 11.3, which illustrates a steady state of parts maintenance (PM) work and backlog relief work that is planned work. In addition, we see urgent response work, deferred maintenance work, plus capital program requirements across time periods showing a reduction in urgent response/emergency work. This in turn allows for deferred maintenance to be accomplished. All of this occurs when we have a complete shift from an environment that is reactive to a maintenance strategy that is proactive and well -planned.

- · Processes and equipment used
- Frequency of process improvements or changes
- Frequency is set up and product changeover
- Is purchasing based on life cycle cost and quality?
- Are contracts awarded to the low bidder i.e. and at time the high cost of low bid buying
- Policy and procedures for purchasing, engineering and quality
- Customer service measured by percent uptime, schedule compliance, delivery, safety and other measures
- · Scope of asset utilization
- The maintenance staff's knowledge and skill levels and dedication
- Expectations of internal customers as well as skills expected and dedication
- · Availability of spare parts and vendors
- Availability of qualified contractors located near the site
- Size of the capital budget in relation to the overall replacement asset value (RAV)
- Organizational change such as turnover within maintenance, operations and support staff
- · Business competition

- · Single or multi-shift operation
- · The product mix
- · Sector within the industry
- · Small, medium or large operation
- · The expectation for maintenance
- · History of the site
- Location of the site, unit and whether indoor/outdoor
- Is this a new Greenfield, recently commissioned operation or an aging facility?
- Age of processing equipment and control systems
- Type of equipment installation, materials and workmanship of facilities and equipment
- Quality of process design; latest technology applications?
- Accessibility to the equipment performing maintenance
- Size of the facility, layout and operating context
- · Products and processes
- Hours of operation, one, two or three shift operation and weekends and 24/7
- Regulated industries such as refining, nuclear, pharmaceutical etc.
- ISO 55000 compliance goal?

Figure 11.1 Areas contributing to maintenance costs and staffing.

# Monitoring Controlling

Coordination

#### Figure 11.2 Monitoring and controlling is coordination.

Appendix E – Case Study: Process Mapping for a Refinery – Work Initiation to Completed Work Reliability Improvement Analysis is a very detailed process mapping within a refinery. Figure 11.4 illustrates the planning, estimating, and scheduling work process flow. Key to this illustration is the center block containing coordination and communication. I often call it the three C's: coordination, cooperation, and communication.

Let us now review how management can better understand the symptoms of ineffective planning in Figure 11.5, Figure 11.6, and Figure 11.7.

As it has been said before, "Nothing happens until somebody sells something!" This too applies to planning/scheduling, which we touched on in Chapter 1, Profit and Customer-centered Benefits of Planning and Scheduling. Figure 11.8, Figure 11.9, and Figure 11.10 provide areas where we must strive to sell the benefits of planning and scheduling.

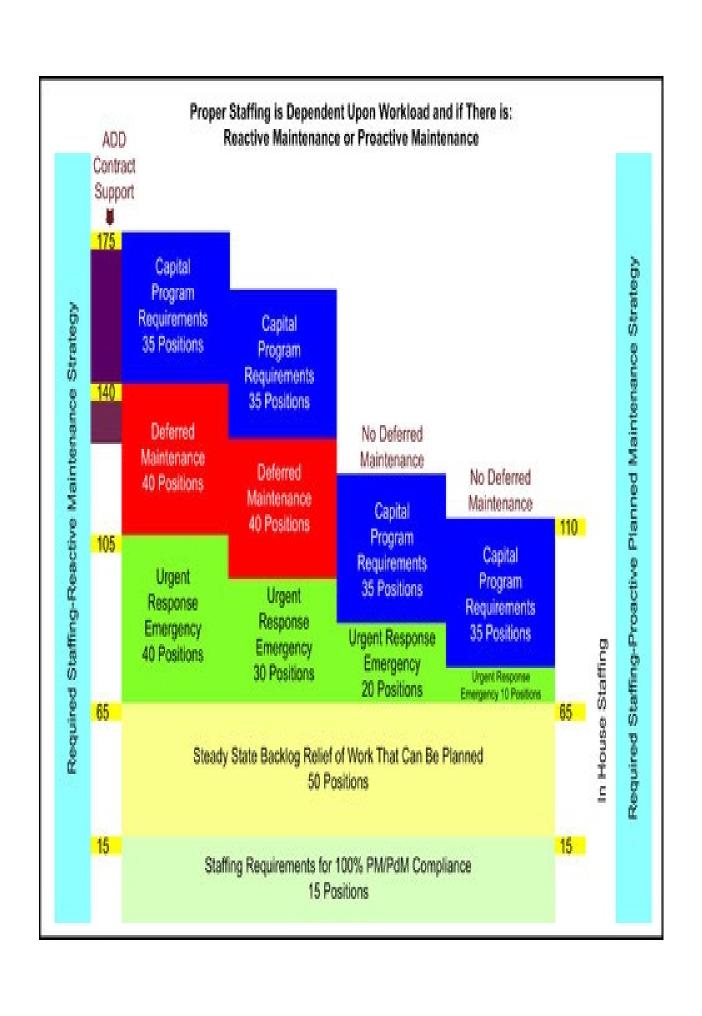


Figure 11.3 Illustrates a steady state of PM work and planned backlog relief work with reduction in urgent response/emergency work, which in turn allows for deferred maintenance to be accomplished.

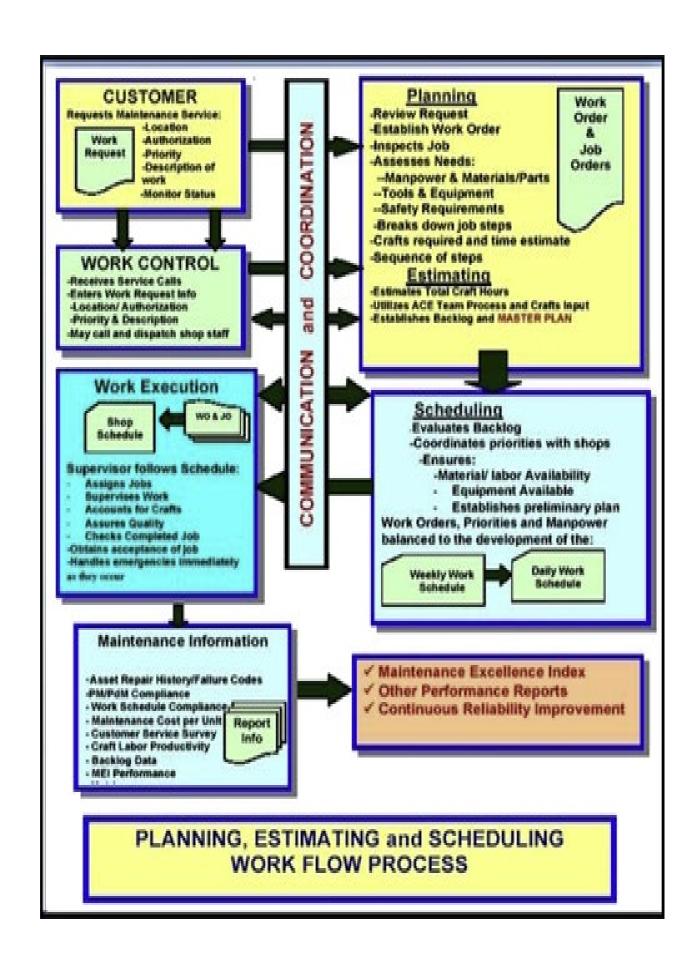


Figure 11.4 Illustrates the planning, estimating and scheduling work process integrated coordination and communication.

# Management Must Understand Symptoms of Ineffective Job Planning

- Delays encountered by our most valuable resources, the craft work force
  - Gaining information about the job
  - Obtaining permits
  - Identifying and obtaining parts and materials
  - Identifying blue prints, tools and skills needed
  - Getting all of above to the job site
  - Waiting for required parts not in stock
- Crafts waiting at job site for supervisor or operations to clarify work to be done

Figure 11.5 Examples of ineffective planning #1.

# Management Must Understand Symptoms of Ineffective Job Planning

- Delays or drop in productivity when operations request work without sufficient planning
- Equipment is not ready, even if on a schedule
- Number of crafts does not match scope of work
- Coordination of support crafts; not the right skill, come too late or early and stand around watching

Figure 11.6 Examples of ineffective planning #2.

# Management Must Understand Symptoms of Ineffective Job Planning

- Crafts have no prior knowledge of job tasks or parts
- Crafts leave job site for parts, go to storeroom or wait for delivery
- If parts to be ordered, job is left disassembled and crafts go to next job
- Many jobs in process awaiting parts
- Crafts can not develop work rhythms due to start/stops and going from crisis to crisis
- Supervisors become dispatcher for emergencies

Figure 11.7 Examples of ineffective planning #3.

# Selling the Benefits of Planning and Scheduling to Management

- Provides central source of equipment condition, workload & resources available to perform it
- Improves employee safety & regulatory compliance
- Helps achieve optimal level of maintenance in support of long and short-term operational needs
- Challenges work request of questionable value

Figure 11.8 Selling the benefits of planning and scheduling to management #1.

# Selling the Benefits of Planning and Scheduling to Management

- Provides forecast of labor and material needs
- Permits recognition of labor shortages and allows for leveling of peak workloads
- Establishes expectations for what is to be accomplished each week and variation from the schedule are visible

Figure 11.9 Selling the benefits of planning and scheduling to management #2.

# Selling the Benefits of Planning and Scheduling to Management

- Improves productivity by anticipating needs and avoiding delays
- Increases productivity of both operations & maintenance
- Provides factual data; performance measurement, cost variations
- Provides info to identify problems that need focused attention

## Figure 11.10 Selling the benefits of planning and scheduling to management #3.

Selling benefits of planning and scheduling to operations is essential. As they are the customers, they are the service receivers, and they are focused on production with the process that provides plant throughput to create profit. Within refineries, for example, it is important to understand the integration of complex processes and types of output that are possible. Figure 11.11 illustrates common processes found in a refinery.

Within operations shown in Figures 11.11–11.13 are many complex and hazardous maintenance challenges. They can be summarized as four major challenges in Figures 11.14 and 11.15.

Therefore, we must sell planning and scheduling to the operations management staff and operators. They must be trained in the CMMS/EAM as to information required for creating a work request. If a modern CMMS/EAM in place, they can do this electronically while monitoring their own backlog of work, schedule, and status of work in progress. Figures 11.16 and 11.7 define key benefits to the operations/production customers.

Just remember, the planner you must be a salesman too as shown in Figure 11.18! Many times this will be selling benefits to your own maintenance organization. Sometimes this can be very difficult if a planner is not well trained, respected, and viewed as a valuable asset supporting the maintenance mission (Figures 11.19–11.24).

Figure 11.25 illustrates most all of the "right things" that planner/scheduler must get right in terms of planning a maintenance job (Figure 11.26).

Figure 11.27 (from Maintenance Planning, Scheduling and Coordination by Don Nyman and Joel Levitt) shows how small reductions in all areas of nonproductive time can increase direct wrench time available from 35% up to 65%. Figures 11.28 and 11.29 include two case study examples. Figure 11.30 is a very good way to see the scope of possible gained value in your operation. First, provide a good estimate of true wrench time. This totals hours working directly on a job (tool time) compared to total labor hours paid. Second, estimate your

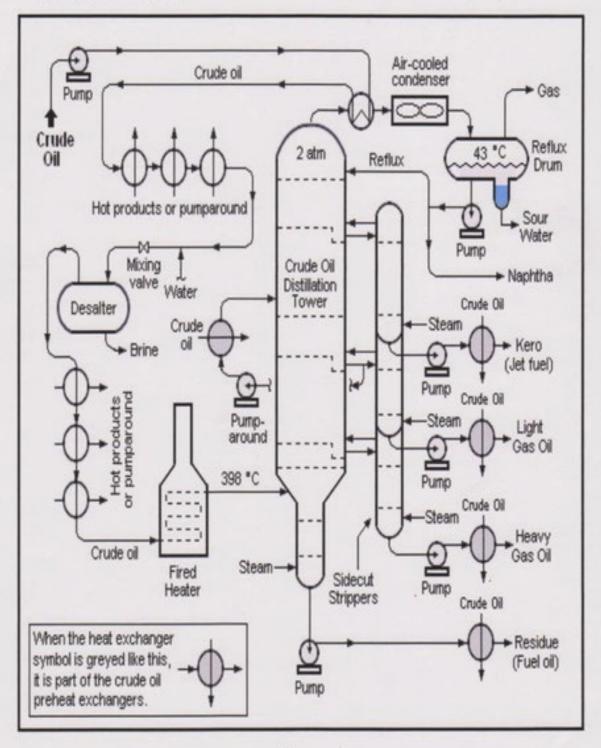
goal for improving the craft utilization factor of OCE (overall craft effectiveness), which is wrench time. Then do the simple math based on number of pure crafts people and average annual wages (Figures 11.31 and 11.32).

Now is an appropriate time to discuss where the maintenance storeroom is included within the total operation. There are three main options: (1) it reports to maintenance, (2) it is part of finance/purchasing, and (3) it could be a contracted storeroom in Figures 11.33–11.36.

When we organize the planning process it should report directly to the maintenance leader and be structured so that there is open and cooperative communication with the operational side of the business. That type of organization is shown in Figure 11.37 and of course depends as much on relationships between planners, maintenance supervisors, and operational staff as much as any other factor. Figure 11.37 strives to illustrate a closed-loop-type organization with actions clearly displaying a service-oriented approach to operations. This relationship is further enhanced when production planning can also work hand in hand with maintenance planning. In contrast to Figure 11.38, this could be viewed as indirect liaison with planner reporting primarily to the maintenance leader.

#### Common Process Units Found in a Refinery

Schematic flow diagram of a typical crude oil distillation unit as used in petroleum crude oil refineries is shown below.



### Figure 11.11 Illustrates common processes found in a refinery #1.

The maintenance supervisor is a key maintenance leader. In Figures 11.39–11.42 we will cover the important role played by the supervisor who supports the execution of work from the schedule and also the monitoring and controlling areas of the five steps in the overall planning process (Figures 11.43–11.55).

Now to add to Chapter 7, What to Look for When Hiring a Reliable Planner-Scheduler, we will see that good planning starts with a good planner having qualities as shown in Figure 11.56 and Figure 11.57. As a special note, I personally recommend having at least one backup planner, designated and trained to support an existing planner during time off and possibly during major shutdown, turnaround, or outage (STO) periods.

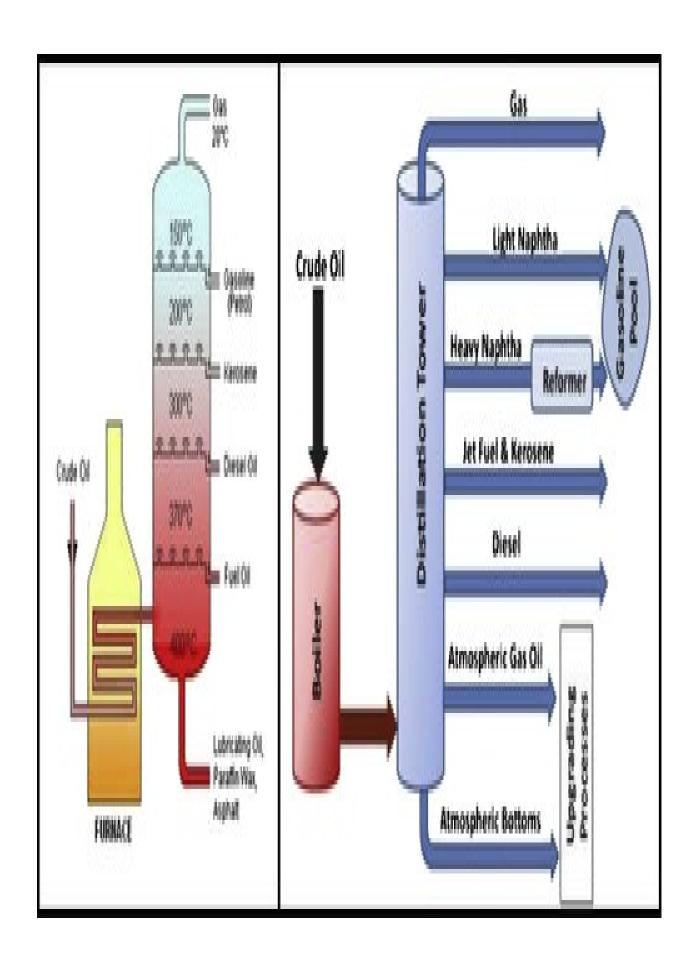


Figure 11.12 Illustrates common processes found in a refinery #2.

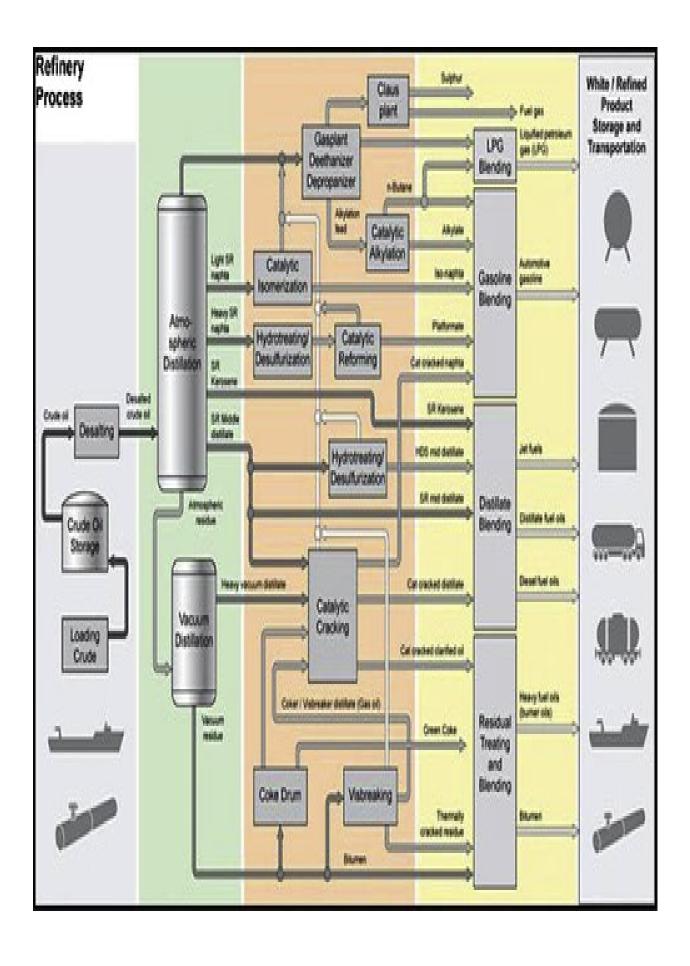


Figure 11.13 Refinery process flow #3.

#### Today's Very Real Challenges

Challenge One: Maintain existing facilities and equipment in safe and sound conditions.

Challenge Two: Improve, enhance and then maintain existing physical assets to achieve environmental, regulatory life safety/security standards & energy best practices.

Figure 11.14 Challenges #1 and #2.

#### Today's Very Real Challenges

Challenge Three: Enhance, renovate and add to existing physical assets using capital funds and then maintain the additions.

Challenge Four: Commission new physical assets and assume increased scope of work to maintain plus more work from Challenges One, Two and Three as assets get older and older.

Figure 11.15 Challenges #3 and #4.

#### Selling the Benefits of Planning and Scheduling to Operations

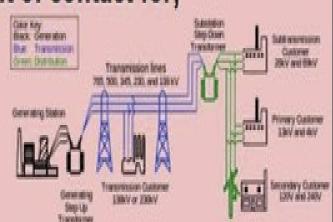
- Provides orderly process for requesting, preparing, executing and closing out maintenance work
- Facilitates anticipating required repairs before emergency breakdowns
  - Great benefits to storeroom
  - Great benefits to MRO procurement
- Provides close and continual coordination between operations and maintenance

Figure 11.16 Key benefits to the operations/production customers #1.

# Selling the Benefits of Planning and Scheduling to Operations

Provides single point of contact for;

- Work pending
- Work in-process
- Work completed



- Accurate backlog status; very important
- Applies technical knowledge and analysis of each planned job
- Increases equipment availability
- Minimizes downtime and interruptions

Figure 11.17 Key benefits to the operations/production customers #2.

#### Remember You Must be a Salesman Too!

# "Remember That Nothing Happens Until Somebody Sells Something!"

Mr. Red Motley Said This a Long Time Ago

Figure 11.18 Selling benefits to your own maintenance organization.

#### Selling the Benefits of Planning and Scheduling to Maintenance

- Defines and measures workload
- Permits advance determination of staffing by area, work unit or by type of craft skill
- Establishes realistic priorities
- Identifies best methods and procedures
- Identifies risks and all HSSE factors
- Anticipates bottlenecks and interruptions

Figure 11.19 Benefits to the maintenance organization #1.

# Selling the Benefits of Planning and Scheduling to Maintenance

- Coordinates manpower, material and equipment to include;
  - —Craft labor
  - —Parts and materials
  - -Special tools and equipment
  - —Shop and other support
  - —Off-site job preparation to minimize downtime
  - -Equipment access; internal & external rentals

Figure 11.20 Benefits to the maintenance organization #2.

#### Selling the Benefits of Planning and Scheduling to Maintenance

- Provides accurate promises that can be fulfilled
- Increases craft productivity & quality of output
- Helps control overtime
- Helps monitor job status
- Provides supervisor more time for direct job supervision and leadership

Figure 11.21 Benefits to the maintenance organization #3.

# Selling the Benefits of Planning and Scheduling to Purchasing and Stores

- Maintenance does "the real work" when ordering parts not in the storeroom
  - Remove components, parts and find specifications
  - Obtain part number, manufacturer, source
  - Look for prime vendor/alternate vendor in some cases
  - Define specific quality requirements
  - "We must avoid the high cost of low bid buying"
- Provides advance notice to storeroom & MRO Purchasing
- Improves accountability for all parts & material
- Improves accountability for contractors

<b>Figure 11.22</b>	Benefits to the storeroom and	purchasing organization #1.
---------------------	-------------------------------	-----------------------------

## Selling the Benefits of Planning and Scheduling to Purchasing and Stores

- Helps insure parts ordering with more lead time to
  - Reduce number of emergency purchase\$
  - Reduce cost of expre\$\$ freight
  - Reduce Fedex, UPS, DHL emergency shipping cost
- Helps optimize maintenance inventory
  - Note: Modernizing Your Maintenance Storeroom
  - Your storeroom: One Cornerstone for Maintenance Excellence
- Improves information for equipment specifications to include;
  - "Part Where Used"
  - Parts list by asset/equipment

<b>Figure 11.23</b>	Benefits to the storeroom and	purchasing organization #2.
---------------------	-------------------------------	-----------------------------

## INVENTORY ACCURACY CAN ELIMINATE THIS!



How much do you spend expediting parts & materials?

Figure 11.24 Benefits to the bottom line.

**Right Parts Materials** Right Tools & Right People Special **And Skills** Equipment The Follow-Up & Maintenance Continuous Right Job Reliability Information Improvement Right Right Timing & Equipment **Priority for** Available Scheduling For Repair The Planner/Scheduler's Role

Figure 11.25 Illustrates the "right things" that planner/scheduler must get right.

# Maintenance Planning, Estimating and Scheduling

#### Planner/Schedulers:

1. You Have the Capability to Effect
Change, to Get Things
Implemented/Repaired/Built/Rebuilt
and To Help

"Make Things Happen".

2. You can Provide a 5 to 1 Return on Investment from Your Position

Figure 11.26 Planner/scheduler must make things happen.

## Maintenance Planning, Estimating and Scheduling Provides Gained Value

Typical Maintenance Worker's Day	Reactive No Planning	Proactive Planned
Receiving Job Instructions	5%	3%
Obtaining Tools and materials	12%	5%
Travel To and From Job (Both with and without tools & materials)	15%	10%
Coordination Delays	8%	3%
Idle at Job Site	5%	2%
Late Starts and Early Quits	5%	1%
Authorized Breaks and Relief	10%	10%
Excess Personal Time (Extra breaks, phone calls, smoke breaks, slow return from breaks/lunch)	5%	1%
Subtotal Non-Productive Time	65%	35%
Direct Wrench Time Available for Work	35%	65%

Figure 11.27 Typical workday: reactive versus proactive planned work.

### Productivity Improvement for a Central Maintenance Operation

Central Maintenance Without Planning	Central Maintenance With Planning
0 Planner	1 Planner
30 Total Crafts	29 Total Crafts
35% Wrench Time	65% Wrench Time
11 Equivalent Full Time	19 Equivalent Full Time Workers
Net Gain of 8 Eq	uivalent Craft Positions
Net Gain in C	Craft Capacity = 73%
	5/Hr Avg. x 40 Hrs/Wk x 52 Wks/Yr = O Gained Value



Wrench time improvement of 30% from an estimated baseline of 35% to 65% is very realistic with an effective planning and scheduling process in place.

#### Figure 11.28 Example: 1 planner equals an additional 8 equivalent crafts positions.

CATEGORY 9: Work Management and Control: Maintenance and Repair and CATEGORY 11: Shop Level Reliable Planning, Estimating and Scheduling from the Scoreboard for Maintenance Excellence<sup>TM</sup> in Figure 11.58 and Figure 11.59.

#### What is the Possible Gained Value of Increased Wrench Time Across GRIDCO?

Practical Exercise: Gained Value			
Without Effective Planning, & Scheduling		With Effective Planning & Scheduling	
Total Crafts	600	600	
Wrench Time Estimate	X <u>.35</u> %	X <u>,55</u> %	
Equivalent Crafts	210	330	NET GAIN CRAFTS 120
Potential Gained Value	Net Gain Crafts x	Annual Salary \$54,000 c/yr	TOTAL GAINED VALUE 6,480,000 cedi = \$3,000,000 USD

Figure 11.29 Example: gained value of 120 equivalent crafts positions.

### What is the Possible Gained Value of Increased Wrench Time in Your Operation?

Practical Exercise: Gained Value			
Without Effective Planning, & Scheduling		With Effective Planning & Scheduling	
Total Crafts			
Wrench Time Estimate	x%	X%	
Equivalent Crafts			NET GAIN CRAFTS
Potential Gained Value	Net Gain Crafts x	Annual Salary \$	TOTAL GAINED VALUE

#### Figure 11.30 What is possible gained value of increased wrench time in your operation?

Category 10: Work Management and Control: Shutdowns, Turnarounds and Outages (STO), Category 12: STO and Major Maintenance Planning/Scheduling with Project Management, and Category 13: Contractor Management from The Scoreboard for Maintenance Excellence<sup>TM</sup> are included as Figure 11.60, Figure 11.61, and Figure 11.62. Contractor work planning during a major shutdown, turnaround, or outage (STO) will be an important part of the total work package of an STO.

# Ensuring Your Maintenance Storeroom Supports the Planning Process

## Planner/Schedulers:

# Must understand storeroom and inventory management best practices



Figure 11.31 Ensure your storeroom promotes the planning process.

## Ensuring Your Maintenance Storeroom Supports the Planning Process

Team Discussions: How well do these three operations work together in your operations?

Maintenance

Does Maintenance get the customer service from the Storeroom and Purchasing that it needs?

Planning, Estimating & Scheduling

**Purchasing** 

 What about Purchasing and the customer service to your storeroom and to maintenance?

Storeroom

 What about your Storeroom and the customer service to maintenance?

Figure 11.32 Ensure maintenance, the storeroom, and purchasing work well together.

## Types of Maintenance & Storeroom Organizations

#### The Three Major Options

- 1. Storerooms Reporting to Maintenance
- 2. Storerooms Reporting to Finance or Purchasing
- 3. Storerooms are Contracted Services





Figure 11.33 Three major options.

# Storerooms Reporting to Finance/Purchasing

# **Key Points**

- 1. Finance may not understand true maintenance needs
- 2. Also requires best practices, leadership and collaboration
- Also requires total accountability by maintenance for all costs
- Financial side must balance inventory \$'s with cost of downtime
- May create a "We versus They" culture.

Figure 11.34 Reporting to finance or purchasing.

# Storerooms Reporting to Maintenance

# **Key Points**

- Recommended structure: Maintenance directly responsible
- 2. Requires best practices and strong leadership
- 3. Requires total accountability by maintenance for all costs
- Financial side must monitor accountability
- Allows maintenance to operate as a "business"

Figure 11.35 Reporting to maintenance (recommended).

# Being Successful Regardless of Organization

## **Key Points**

- Contracted Stores has "Pros" and "Cons"
- Finance must understand true maintenance needs
- 3. Requires best practices, leadership and collaboration
- 4. Requires total accountability by maintenance for all costs
- Financial side must balance inventory \$'s with cost of downtime
- Must be "Team Effort" and not a "We versus They" culture.

Figure 11.36 Keys to successful storeroom regardless of organizational position.

#### Organizing, Managing and Leading the Maintenance Planning, Estimating and Scheduling Process

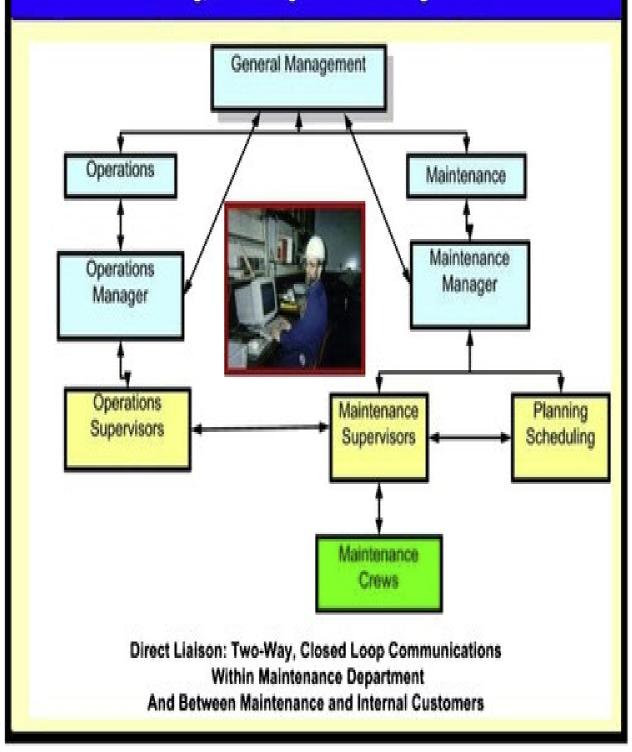


Figure 11.37 Illustrates a closed-loop-type organization.

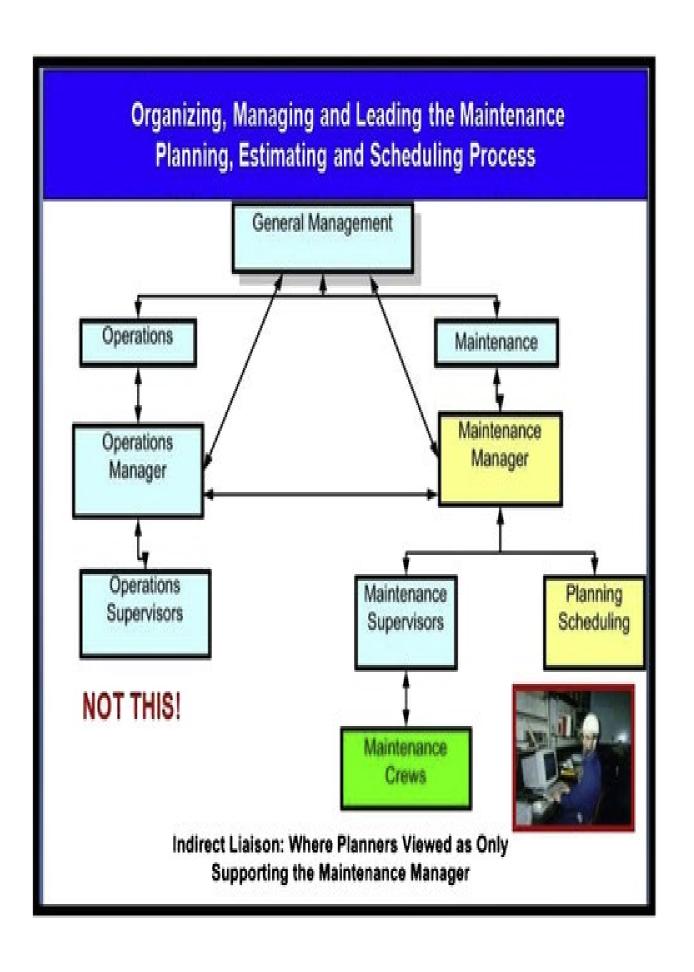


Figure 11.38 This organization is viewed as indirect liaison with planner reporting to the maintenance leader.

## Responsibility to lead, control and follow up to;

- Ensure proper, safe and efficient execution of maintenance work
- Assign jobs to the right craft person or crew having the correct skills
- · Refine and finalize labor, parts, priorities and methods
- Monitor job quality, duration, cost and thoroughness of the completed job
- Control time lost between jobs, at breaks and at lunch

Figure 11.39 The important role of the maintenance supervisor #1.

## Responsibility to lead, control and follow up to;

- ✓ Control overruns and interruptions
- √ Always have the next job ready and assigned to each crafts person (KAHADA)
- ✓ Make tactical decisions to remain on schedule
- ✓ Make changes during job to meet the promised scheduled date and time
- ✓ Communications with operations, planner, engineering as much as possible

Figure 11.40 The important role of the maintenance supervisor #2.

## To Exercise Responsibilities, Supervisor's MUST:

- Balance motivation and discipline by interfacing with crafts at least twice daily
- Follow up on significant jobs 2-3 times daily
- Give time and attention to formal and on-thejob training of the team
- Never neglect development of each team member

Figure 11.41 The important role of the maintenance supervisor #3.

## To Exercise Responsibilities, Supervisor's MUST:

- Lead the crafts skills training; Identify training needed
- Act upon requests for support
- Prompt and fair handling of grievances
- Control of tardiness, absenteeism and vacation

Figure 11.42 The important role of the maintenance supervisor #4.

# **Engineering Support to Maintenance**

## Responsibilities for;

- Actively supporting design for maintainability
- Design, monitor and refine PM/PdM including
  - √ Proper operation and care of equipment
  - √ Comprehensive lube program
  - ✓ Inspections, adjustment, parts replacement and overhauls for selected equipment
  - √ Vibration and other predictive analyses
- Leading the Maintenance & Reliability Excellence
   Process

Figure 11.43 Engineering support to maintenance #1.

# **Engineering Support to Maintenance**

## Maintenance Leadership Responsibilities for;

- ✓ Maintainability of new installations, documentation information
- ✓ Identification and correction of chronic, costly and dangerous equipment problems
- ✓ Maintaining/analyzing equipment data and history records to predict maintenance needs

Figure 11.44 Engineering support to maintenance #2.

## Responsibilities for;

- Logistical support to remove all barriers for results
- Customer liaison on all planned work
- Creating job plans and reliable estimates of partsmaterial, labor and equipment
- Ensure all logistics are identified and provided for
- Coordination of manpower, parts, materials & equipment
- Also coordinate equipment access in preparation for effective job execution and schedule compliance

Figure 11.45 Responsibilities of the planner/scheduler #1.

## Responsibilities for;

- Cooperative & coordinated scheduling of jobs in order of agreed upon priorities
- Planning a full days work for each crafts person
- Monitoring and coordinating with both the storeroom and purchasing on incoming parts
- Arranging parts delivery to the job site where possible
- Ensuring low priority jobs are accomplished ?????
- Maintains performance records as compared to goals by way of The Reliable Maintenance Excellence Index
- And MORE!

Figure 11.46 Responsibilities of the planner/scheduler #2.

## To be effective, maintenance planners need;

- To be recognized as an important contributor to the maintenance mission!
- Resources that be continuously balanced with the workload/backlog
- Clear definition of their relationships with:
  - ✓ Maintenance Manager
  - √ Maintenance Supervisors
  - **√Operations**
  - √Craft work force
- Work requests by customer via Call Center with;
  - √Adequate identification of work to be done
  - ✓ Descriptive information details
  - ✓ Sufficient lead-time to plan properly & schedule work

Figure 11.47 Responsibilities of the planner/scheduler #3.

## To be effective, maintenance planners need;

- Proper computer support to develop comprehensive planning database
- Effective support from storeroom and purchasing and timely status info on availability
- Effective storeroom where planner provides required withdrawals/requisitions & does not become an expeditor
- Purchasing support where planner does not have to do all sourcing, prepare PO's, track and expedite deliveries
- Receiving support that alerts planner when critical items are received

Figure 11.48 Planner/scheduler needs for effectiveness #1.

#### Maintenance Planner/Scheduler

## To be effective, maintenance planners need;

- Commitment from maintenance & operations to
  - √ Hold structured weekly coordinating and scheduling sessions
  - ✓ Establish daily, weekly and down day priorities
  - √ Major outage or project work priorities
- Cooperation in effectively using planned job packages from maintenance/operations supervisors and crafts
- Adequate maintenance engineering support
  - ✓ So planners do not have to develop standard operating and safety procedures
  - ✓ So planners do not have to devote engineering attention to solving recurring problems

Figure 11.49 Planner/scheduler needs for effectiveness #2.

## Maintenance Planner/Scheduler

## To be effective, maintenance planners need;

- Feedback on planned job packages to improve future planning processes
- Feedback from maintenance supervisors regarding compliance with and exceptions to the weekly schedule
- Recognition that planners are not supervisors
- A proper work station

Figure 11.50 Planner/scheduler needs for effectiveness #3.

## Good Planning Starts With A Good Planner

## The Maintenance Planner

#### Number of Planners:

- Highly variable depending on operation\*
  - ✓ Operational, Day to Day Work Planners
  - ✓ Minor & Major Project Planners
  - √ Operational + Projects
- 20-25 craftsmen per planner
- Must consider equivalent number of crafts
- Type of equipment maintained

Figure 11.51 Defining number of planner/schedulers required.

Worksheet for Ratio of Crafts to Planners	
	Points Assigned
Planning and Scheduling Structure	100
Separate from material coordination (vertical structure)-1 Point	
Combined (Horizontal structure)-2 points	
Number of Crafts Coordinated	
One-1 Point	
Two- 2 Points	
Three-3 Points	
Four-4 points	
Level of Planning	
Craft and general description with schedule -1 Point	
Graft, general description, special tools and major materials with schedule -3 Points	
Craft, general instructions, tools, materials, prints and schedule - 5 Points	
All of the above plus work methods described - 7 Points	
Level of Estimating	
Estimates or historical averages 1 Point	
Slotting against past jobs in labor library -3 Points	
ACE Team-analytical estimating- 5 Points	
Inappropriate Responsibilities (Additive)	
Sourcing -1 Point	
Procuring -1 Point	
Expediting -1 Point	
Receiving -1 Point	
Stocking -1 Point	
Picking and kiting -1 Point	
Staging and securing- 1 Point	
Delivery to scheduled job site -1 Point	
Total Points	

Figure 11.52 Worksheet for ratio of crafts to planners. From Maintenance Planning, Scheduling and Coordination by Don Nyman and Joel Levitt.

Co	nversion Table
Total	Crafts to Planner Ratio
Points	
4-7	30:1
8-12	25:1
13-17	20:1
18-22	15:1
23-26	12:1
27-30	10:1

Figure 11.53 Conversion table for worksheet: total points on worksheet for ratio of crafts to planners.

# Factors Influencing Number of Planners (Planner to Craft Ratio)

- Number of crafts performing planned/scheduled work
- Current state of maintenance management organization
- Complexity of craft structure in place
- Level of planning/scheduling needed
- Method of estimating used
- Current state of planner support system (labor and material libraries, CMMS etc

Figure 11.54 Factors influencing number of planners #1.

## Factors Influencing Number of Planners (Planner to Craft Ratio)

- Complexity of the operations supported by maintenance
- Level of liaison and coordination required by planners
- Structure of the planning and scheduling organization
- Other support available:
  - ✓ Maint Engineering
  - √ Clerical support
  - **✓ PM Coordinator**
  - √ Material coordinators
  - ✓ Maintenance Planning Coordinator etc.

Figure 11.55 Factors influencing number of planners #2.

## Good Planning Starts With A Good Planner

## Selection of a Planner:

### **Qualities Desired:**

- · Has craft skills
- Knows the facility
- Multi-craft knowledgeable
- Possesses math and print reading skills
- · Has respect of peers
- Embraces proactive maintenance
- Possesses interpersonal skills
- Can communicate well

Figure 11.56 Qualities desired in a planner/scheduler #1.

## Good Planning Starts With A Good Planner

## Selection of a Planner

#### **Qualities Desired:**

- · Has leadership skills
- Self motivated
- · Has follow-up abilities
- · Can cope in a staff position
- Reliable
- Computer literate
- Adaptable
- Reasonable "thick skin"

Figure 11.57 Qualities desired in a planner/scheduler #2.

#### CATEGORY 9. WORK MANAGEMENT AND CONTROL: MAINTENANCE AND REPAIR (M/R)

ITEM #	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5	RATING
l.	A work management function is established within the maintenance operation generally crafted along functionality of the CMMS.	
2.	Written work management procedures which governs work management and control per the current CMMS is available.	
3.	A printed or electronic work order form is used to capture key planning, cost, performance, and job priority information. 10=Bar coded assets, parts and work order.	
4.	A written procedure which governs the origination, authorization, and processing of all work orders is available and understood by all in maintenance and operations.	
5.	The responsibility for screening and processing of work orders is assigned and clearly defined.	
6.	Work orders are classified by type, e.g. emergency, planned equipment repairs, building systems, PM/PdM, project type work, planned work created from PM/PdM's.	
7.	Reasonable "date-required" is included on each work order with restrictions against "ASAP", etc.	
8.	The originating departments are required to indicate equipment location and number, work center number, and other applicable information on the work orders.	
9.	A well-defined procedure for determining the priority of repair work is established based on the criticality of the work and the criticality of equipment, safety factors, cost of downtime, etc.	
10.	Work orders are given a priority classification based on an established priority system.	
II.	Work orders provide complete description of repairs performed, type labor and parts used and coding to track causes of failure.	
12.	Work management system provides info back to customer; backlogs, work orders in progress, work completed, work schedules and actual cost charge backs to customer. 10= real time system	
	9. Work Management and Control: Maintenance and Repair SUBTOTAL SCORE POSSIBLE:	120

Figure 11.58 CATEGORY 9: Work management and control: maintenance and repair.

#### CATEGORY 11. SHOP LEVEL RELIABLE PLANNING, ESTIMATING AND SCHEDULING (M/R)

ITEM#	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less	RATING
I.	A formal maintenance planning function has been established and staffed with qualified planners in an approximate ratio of 1 planner to 20-25 crafts people.	
2.	The screening of work orders, reliable estimating of repair times, coordinating of repair parts and planning of repair work is performed as a support service to the supervisor.	
	Planner/Schedulers realize their primary scope and role of planning and scheduling is to improve craft labor productivity and quality through the elimination of unforeseen obstacles such as potential delays coronation parts machine time and available resources.	
	Planner/Schedulers clearly understand the scope of their defined roles and responsibilities within your organization and are in an organization structure that promotes close coordination, cooperation and communications with their customer in operations.	
3.	The planner uses the priority system in combination with parts and craft labor availability to develop a start date for each planned job to be scheduled	
4.	A daily or weekly maintenance work schedule is available to the supervisor who schedules and assigns work to crafts personnel with multiple week "look a heads" if required.	
5.	The maintenance planner develops reliable and well accepted estimated times for planned repair work and includes on work order for each craft to allow performance reporting, backload levels and even documentation of work competency for selected jobs.	
6	A day's planned work is available for each crafts person with at least a keeping a half a day ahead (KAHADA) during the working day known in advance.	
7.	A master plan for all repairs is available indicating planned start date, duration, completion date, and type crafts required to define "total maintenance requirements".	
8.	The master plan is reviewed and updated by maintenance, operations, and engineering as required with project type work expected from maintenance. Care is taken not to overload maintenance with project work that causes PM/PdM and other work to be neglected,	
9.	Total maintenance requirements are a total of Total Backlog + Ready Backlog that has all resources (except labor or equipment availability) available to be scheduled.	
10.	A firm rule of thumb is never to put anything on the schedule without parts in house. But have contingency plan if needed parts arrive for critical equipment.	

II.	When parts arrive for critical equipment and can be inserted to the current schedule this is very proactive maintenance cooperation with operations.	
12.	Scheduling/progress meetings are held periodically with operations to ensure understanding, agreement and coordination of planned work, backlogs, and problem areas.	
13.	Operations cooperate with and support maintenance to accomplish repair and PM schedules.	
14.	Operations staff signs off the agreed upon schedule and are responsible to approve change in schedules and are accountable to TOP Leaders for adverse results.	
15.	Set-ups and changeovers are coordinated with maintenance to allow scheduling of selected maintenance repairs,  PM inspections, and lubrication services during scheduled downtime or unexpected "windows of opportunity" to insert Ready Backlog jobs into the schedule.	
16.	Planned repairs are scheduled by a valid priority system, completed on time and in line with completion dates promised to operations and measured accordingly.	
17.	Deferred maintenance is clearly defined on the master plan and increased costs are identified to management as too the impact of deferring critical repairs, overhauls, etc.	
18.	Maintenance planners and production planners work closely to support planned repairs, to adjust schedules and to ensure schedule compliance in a mutual goal.	
19.	The planning process directly supports the supervisor and provides means for effective scheduling of work, direct assignment of crafts and monitoring of work in progress by the supervisor.	
20.	Planners training has included formal training in planning/scheduling techniques, super user training on the CMMS, report generating software or via Excel and on the job training to include developing realistic planning times for craft work being planned. Understand use of MS Project or the company's larger project management system such as Primavera 6.	

	11. Shop Level Reliable Planning, Estimating and Scheduling M/R SUBTOTAL SCORE POSSIBLE:	300
30.	Planners help ensure that warranted parts or equipment is denoted in the equipment file and that work orders for warranted parts or equipment are flagged during the planning process to document supplier reimbursements.	
29.	Planners see what is repetitively coming up for non-stock item purchasing as well as what is being repaired over and over again, Are your planners active in this area can support improving reliability and uptime.	
27	Planners are in an excellent position to ensure critical spares by asset are accounted for as well as to recommend items to consider for including within the storeroom as critical spares.	
26.	If planned work orders involve participation by several shops or functional crews they are crossed over to a planner in that area. However a single planner/scheduler must plan and then coordinate various functional crews with the respective supervisors during the scheduling process.	
25.	If issues and of any nature arise and are not readily resolved by the planner and operations, the maintenance leader should be the next step that the planner/scheduler takes for resolution.	
24	If a maintenance coordinator is assigned within a unit of a large refinery or any production the planner will coordinate with that person about the job request, location within the unit, the problems to be repaired and related risks. In many cases this is an engineer or experienced operator who should be able to define complete requirements or a work request and in some case prepare a risk assessment for the planner to use for the job.	
23.	A reasonable number of backup planner/schedulers are selected and properly trained and used to cover for the full time staff. The number is based on the size and type work being planned. Ideally just like the full time planner should have good shop experience and sound technical experience.	
22.	Planning and scheduling procedures have been established defining work management and control procedures, the planning/scheduling process, the priority system, etc.	
21.	Benefits of planning/scheduling investments are being validated by various metrics that document areas such as reduced emergency work, improved craft productivity, improved schedule compliance, reduced cost and improved customer service.	

Figure 11.59 CATEGORY 11: Shop level reliable planning, estimating, and scheduling.

TEM#	Rating: Excellent - 10, Very Good - 9, Good - 8, Average - 7, Below Average - 6, Poor - 5 or less	RATIN
1.	Work management and control is established for major overhaul repairs, shutdowns, turnarounds and outages	
	(STO) and includes effective work management and control by in house staff and contracted resources.	
2	Work management and control of major projects provide means for monitoring project costs, schedule compliance and performance of both in house and contracted resources with a robust project management system.	
3.	Work orders are used to provide key planning info, labor/material costs and performance info for major all STO and overhaul work.	
(4)	Equipment history is updated with info from work orders generated from major overhaul regains, and SATO work.	
5.	The responsibility for screening and processing of work orders for major repairs is assigned to one person or unit.	
6.	Change order procedures and control are clear to all and approved at the appropriate level based on company requirements.	
7.	Change orders are reviewed by planners just as they review all jobs; scope of work, key job steps, equipment required and total additional cost and impact on total STO duration and appropriate approvals received before work execution.	
8.	Work orders for major repairs, shutdown, and overhauls are monitored for schedule compliance, overall costs and performance info including both in house staff and contracted services.	
9.	Cost variances are measured at key milestone with cost variance info so extreme variance can be investigated sooner than later when it is too late. A 5%-10% variance is set as maximum with clear reason for increased scope of work.	
10.	Has the current level of plant maintenance asset management achieved the desired reliability to make to make an STO a) needed at longer timeframe than normal bineeded at a shorter timeframe or c) needed the appropriate period based on age and state of asset capabilities in their operation context.? a)= 10,9,8; b)=5; c=7,6	
11.	The organization has the capability to manage the turnaround program and be cost effective as compared to the best in the sector, has a strategy for reducing costs in the face of an ageing plant and rising manpower and material costs and where can we get high level technical advice?	
12.	The organization knows what manpower is available in-house, the competence levels where to get additional resources, who will lead the site team, who will do the work plus the cross functional team to design, monitor and control the event organization?	
13.	Have STO's received significant level of attention companies, have a history of tolerating higher than necessary downtime have older age of plants, see STO as a "necessary evil" are striving to lengthen the STO intervals from	
14.	12 – 24 months and even4, 5 and sometimes 8 years. The organization's history of planning & preparation for STO's has been: carried out more carefully, alignment of capital programs, has been scrutinizing and challenging scope of work.	
15.	A process of assessing plant equipment deterioration is in place, the likely impact on reliability is known, the planning stocks and safeguarded, and has partnering with major plant overhaul engineering contractors and have a learning organization from past history to manage STO's effectively	
16,	The plant-beginning an STO has personnel available when required and capable of performing-design specifications economically and a) safely for life of plant, b) knows sum of activities performed to protect reliability of the plant, c) helps provide consistent means of production, d) help generate profit all with e) reducing the Total Cost of Ownership (TOC)	
17.	Top Leaders clearly understand that STO is a significant maintenance and engineering event during which new plant is installed, existing plant overhauled, and redundant plant removed which has a direct connection between successful accomplishment and the company's profitability	
18.	The company includes profit lost during period of STO is considered part of turnaround cost because they know the total true cost of event and the real impact can be assessed	
19.	All involved with STO's realize the potential hazard to plant reliability or can diminish or destroy reliability if not :properly planned, prepared, executed, poor decisions by managers and engineers, bad workmanship, use of incorrect materials and damage done while plant is being shut down, overhauled, restarted	
20.	Technical uncertainty due to occurrence of unforeseen problems can be accurately reported, knowing when cost estimates are being exceeded, event's duration must be extended, how both cost and duration increases be justified. Are reasonable cost and time contingencies built into an STO plan with accurate loss of revenue/profit considered.	
21.	Have Top Leaders created their business strategy to manage the STO basic objectives to eliminate STO's all together unless proven it is absolutely necessary.	
22.	If an STO is proven to be necessary, the Top Leader ensures that it will align with maintenance objectives, production requirements, business goals.	
23.	When beginning as STO the Top Leader has formed a chartered leadership driven, self-managed (not a committee) forming a cross functional staff to help a committed company get the best STO value.	
24.	The STO team has senior managers , responsible for long-term strategy and meet at regular intervals throughout year to review current performance and formulate high-level strategies for management of events such as a long-	
25.	term STO program  Is an STO truly aligned to overall business strategy which include an evolution of asset management's driven search for change to preventive/predictive maintenance, being driven by technical considerations and a	
26.	philosophy of maintenance prevention and continuous reliability improvement.  STO's are driven by business needs and question every maintenance practice to determine if it can be eliminated by addressing cause that generated the need and examines the largest maintenance initiatives first during an STO.	
	10. Work Management and Control: Shutdowns, Turnarounds and Outages (STO)	260

Figure 11.60 Category 10: Work management and control: shutdowns, turnarounds, and outages (STO).

ITEM #	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5 or less	RATING
Ï.	The planning and scheduling function includes major repairs, overhauls and shutdown, turnaround and outage (STO) type work not considered as part of normal maintenance work and any work requiring an STO event,	
2.	The planner team is a resource (or member) for the STO team of senior managers and the Maintenance Leader.  Planners should meet at regular intervals to review current jobs awaiting a planned STO event.	
3,	Are your Total Backlog jobs coded and planned effectively to await an STO event. In large plants and refineries planners support the plant schedulers with normally detailed job packages for estimates of all required resources for an STO job	
4.	Schedulers from Item #3 coordinate parts/materials develop daily or weekly schedules, monitor status of work along with onsite observations, from the supervisor input and from a planner's job package which could include several crews, defined job steps and estimated time for each step. With real time reporting to a project management system or CMMS status including costs can be readily determined from progress reporting.	
5,	Current planning/scheduling manpower is available with the competency levels needed to support the site team during an STO.	
6.	All planners and schedulers involved with STO's must realize the potential hazard to plant reliability or can diminish or destroy reliability if not: properly planned, prepared and execute.	
7.	There may be even poor decisions by managers and engineers, bad workmanship, use of incorrect materials and damage done while plant is being shut down, overhauled or restarted. Planners realize that properly planned, well prepared work and work executed to all HSSE requirements is essential.	
8.	The use of work orders, estimating of repair times, coordinating and staging of repair parts/materials and planning/scheduling of internal resources and contractor support is also included for major work and STO work not considered day to day maintenance and repair	
9.	A project work schedule or formal project management system is used to manage status and cost variance for STO work.	
10.	The current CMMS is integrated and linked to the project management system in real time when STO work orders or a change order work is approved.	
11.	Estimated labor and materials are established prior to project start using work orders with effective labor and material reporting to track overall cost, work progress, schedule compliance, etc.	
12.	The master plan for all major STO repairs, overhauls and new installation is available indicating planned start date, duration, completion date, and type crafts required.	
13.	Resources required for day to day maintenance work are not compromised by having to perform major repair type work, installation, modifications etc, consuming in house resources required for PM's and other day to day type work.	
14.	Scheduling/progress meetings are held periodically with operations to ensure understanding, agreement and coordination of major work and problem areas such as asset being ready for scheduled work.	
15.	Major work performed by contractors is preplanned, scheduled and includes measuring performance of contracted services.	
16.	Planning and scheduling procedures have been established for project type work.	
	12. STO and Major Maintenance Planning/Scheduling with Project Management SUBTOTAL SCORE POSSIBLE:	160

Figure 11.61 Category 12: STO and major maintenance planning/scheduling with project management.

TEM#	Rating: Excellent – 10, Very Good – 9, Good – 8, Average – 7, Below Average – 6, Poor – 5	RATIN
1.	Contracted work is clearly defined because the better the definition at the early stages the better the job will go.	
2.	Loose specifications for both materials and work to be done are avoided	
3.	Communication of your ideas to a contractor is included in the Scope of Work and make sure they understand	
***	with meeting of the minds at kick off and status update meetings.	
4.	Ensure that the contractor understands the quality of materials needed from clear specifications.	
5.	Negotiation and award of the contract has had key due diligence by the key owner's representative.	
6.	For larger jobs, owners may check-out finances, credit, insurance, and staff.	
7.	Owners may visit other jobs to see contractor quality of work and call references.	
8.	Maintain at shop level a copy of the contract documents and keep a fair and complete set of contract info	
***	including requests for changes of scope.	
9,	Be aware of and avoid, if possible, low ball bids and negotiate a schedule of extras if applicable (i.e. "the high cost of low bid buying")	
10.	Avoid a common ploy where low balling the bid to get the job and floods the company with small extras.	
11.	Always add in for clauses like "all extras not included in the original price have to be agreed to in writing prior to	
	the commencement of the work."	
12.	Are deduction clauses in the contract that spell out what you will charge back and when you will charge it?	
	Examples would be debris removal, clean-up, missing firm completion dates.	
13.	Negotiate cancellation clauses and spell out how and why you can cancel the contract. Otherwise you could find	
	yourself with a mechanic's lien against you over an inadequate job after you did not pay the final payment.	
14.	For ongoing service bids avoid both too short of a contract term and too long of a contract term for two reasons:	
	If the term is too short then the contractor will charge excessively for mobilization costs.	
	2. If the term is too long you might be stuck with a barely adequate vendor with no easy way to improve the	
	situation.	
15.	Is the contract as clear as possible about responsibilities on, who supplies what, where to unload, site rules (safety,	
	owner contact, clean-up, security, keys, etc.)?	
16.	Are there statements about how the site is to be left at the end of each work day?	
17.	Ensure who is responsible for locking up, barricades, traffic management, cleaning, and debris removal.	
18.	Does the agreement also include who is responsible for municipal permits, job plans, and all health, safety,	
	security and environmental (HSSE) issues?	
19.	Are contractor's insurance policies reviewed with an agreement about what happens when (if) the contractor	
3376	damages your property?	
20.	Damage to a neighbor's property that then might sue you or might spoil a good relationship is included as required.	
21.	Is all Insurance certificates up to date covering: General liability, Casualty (property damage), Workmen's compensation, Auto liability	
22.	If the contractor did a design build then Malpractice and Errors & Omissions is included.	
23.	Define performance as to what would a good job look like.	
24.	Add clause like "all work is expected to be done in a professional and workmanship manner and all work will be in	
10001010	compliance with applicable codes".	
25.	Owners should prepare the area to be worked on and remove as much as possible to avoid breakage/theft and	
	isolate area so contractors have no reason to wander around the plant or a large multi-operational site such as	
	refinery.	
26.	Does the owner manage the contractor and keep a record of the job/project as it unfolds & provides feedback?	
27.	Does owner perform frequent inspections and document results with a functional planned schedule and compare	
	progress to projections with problems being identified as early as possible for resolution?	
28.	Clear agreements have been made about when and amounts of progress or final payments are to be made, etc.	
29.	To avoid sloppy record keeping all contractor work is documented on the owner on their CMMS/EAM.	
30.	Owner requires copy of paid receipts to prove subcontractors and material vendors have been paid.	
31.	Owner should get a "release of all liens form" signed before last payment because:	
1000	a) You could have paid off the general contractor and still be hit with liens from unpaid jobs	
	<ul> <li>b) Consult with your legal department about lien laws in your state or country and be sure you are covered</li> </ul>	
	13. Contractor Management SUBTOTAL SCORE POSSIBLE:	310

Figure 11.62 Category13: Contractor management.

## Why the Work Order Is a Prime Source for Reliability Information

\_

#### **Abstract**

The work order is the single most important document within maintenance. Beginning as a work request, it becomes a description of work to be accomplished. If maintenance was operating as a business, it would in essence be the invoice given to the customer with total costs of labor, parts, and materials used. Crafts people understand that the work order must be accurate and correctly document work that was performed. Work orders may come in many formats. This process allows the planner to have a continuing picture of equipment problems of all types and magnitude. From the analysis of work orders, the planner and others can play a very important role within a strategy of continuous reliability improvement.

#### **Keywords**

## Cause of failure; Detailed planning; Job plan; Job plan database; Repetitive jobs; Scope of work; Total cost of ownership; Troubleshooting; Work order

The work order is the single most important document within maintenance. Beginning as a work request, it becomes a description of work to be

accomplished. The work order would be viewed as the main document if maintenance was operating as a business; in essence, it would be the invoice given to the customer with total costs of labor, parts, and materials used. We strive to have our craftspeople understand this analogy so that the work order is accurate and correctly documents the work that was performed.

Work orders may come in many formats, as shown by the examples in Figures 12.1–12.4.

A beneficial job plan requires that a logical step-by-step process be followed. Job planning encompasses verification of all aspects of the job, as well as resources such as material manpower and equipment required to complete the work in an orderly manner and at optimum costs.

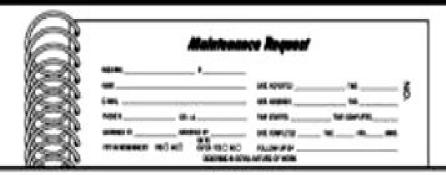
The job objectives and scope must be defined and described by the planner while listing the steps to be performed, thus defining what is to be done. There may have been a similar job performed in the past with a job plan already developed, which would be in the planner's database for job plans. In a case where the planner is not familiar with the job, a visit to the jobsite may be necessary for discussion with the requester as a possible next step. At this point, the planner may not have experience in the trade that will be required for the repair. Nonetheless, the planner must try to identify the cause of the failure and possible consequences of the failure. In some cases, plan troubleshooting may be necessary to get the full details of the repair job and the extent of repair parts required.

On the occasions where troubleshooting is required and disassembly is needed, we are in a good position to define the cause of the problem. The planner and the craftsperson involved with this event should be concerned with why the failure occurred. At times like this, a member of maintenance engineering, plant engineering, or reliability engineering may be called to the scene to give their analysis of the condition. Planners should never allow these types of events to pass without documenting the cause of failure, whether it is the operator or wear-and-tear of a system component.

To complete the work order correctly, a number of important criteria should be established. These criteria are included in Figure 12.5.

Two key questions are: (1) What work orders should be planned? (2) How much

planning is enough? Here, we are talking about the approximate degree of detail to which jobs should be planned. During the early installation phases of planning and scheduling, there may be insufficient planning capacity to plan all jobs. Therefore, as proactive maintenance replaces firefighting, the organization plant will settle down into more capability for planning more jobs as planning and scheduling matures. So, the level of detail is less during the early phases of implementation than in the later phases.



### **Maintenance Request**

wr			DATE REPORTED		TME	
EMAL			EATE ASSAUNED		196	
HOIE #	CELL	٠	THE STATED	TME	COMPLETED_	
KSSOMED TO	AS90	ON TO	EAST COMPLETED	twt	145	_ MNS.
PET IN RESIDENCE?	YES (I NO II	ENTER: YES CI NO CI	FOLLOW UP BY IL NATURE OF WORK			
TET IN RESIDENCE?	YES () NO ()	ENTER: YES CI NO CI				
NET IN PRESIDENCE?	YES O MOD	ENTER: YES CI NO CI				
PET IN PESIDENCE?	0000	ENTER: YES CI NO CI				
	0000	ENTER: YES CI NO CI		ERSON_		



### Figure 12.1 Work request example #1.

- In general, large jobs are planned first. Larger jobs are usually accompanied by delays and conflicts, therefore giving greater opportunity for benefits from planning.
- Cutoffs of 4–8 h may initially be established for the magnitude of jobs to be planned.
- The selected cutoff point should be progressively reduced as the planning process matures.
- Delays encountered in smaller jobs have a more dramatic percentage impact, but planning coverage should ultimately include all jobs that can benefit.
- Detailed planning of large jobs requires much more effort than what is justified on simple jobs.
- The usual tendency is to underplan large jobs and overplan small jobs.
- Smaller jobs require less planning.
- However, a 1-h job that is missing essential materials can cause much wasted time due to unnecessary travel.
- Also, a small job will have a greater unproductive time as a percentage of total time than a larger job.
- Focusing on repetitive jobs is important during early stages of planning and scheduling.
- As the planner's library/database of plan job packages increases, this leads to reduced work.

# MAINTENANCE WORK REQUEST FORM Date of Request: Location: Please be specific Building, Room #, etc. Description of Work required: Requested by: Extension No: Completed by: Leave maintenance request in our malbox, fax: 768-8112, inner-office mail, or email to MAINTENANCE via outlook.... If the problem is an Emergency, call extension 171, but don't forget to turn in a maintenance request form after the phone call. Hours are fr. Bam-3:30pm. MAINTENANCE WORK REQUEST FORM Date of Request: Location: Please be specific Building, Room N. etc. Description of Work required: Requested by: Extension No:

Leave maintenance request in our mailbox, fax: 768-8112, inner-office mail, or email to MAINTENANCE via outlook.... If the problem is an Emergency, call extension 171, but don't forget to turn in a maintenance request form after the phone call. Hours are fr. 8am-3:30pm.

Completed by:

### Figure 12.2 Work request example #2.

- These benefits are a prime reason to provide ample planning capacities (such as a backup planner) to have sufficient planning capacity during the early phases of program installation.
- We must remember the Pareto principle during early phases of installation, whereby 80% of the benefits are derived from 20% of the effort.

The planning process should cover 80% or more of the available man-hours. The remaining 20%, which constitutes emergencies and unplanned work for one reason or another, falls upon the supervisor and his team to execute effectively with as much productivity as possible. Chapter 16 focused on scheduling, we will talk about when the planner does not plan for emergency work. However, the planner can plan for emergency work. In this case, selected craftspeople are designated to lower priority planned jobs, but they can leave that job and do it now (DIN, as part of a DIN squad) as emergencies emerge. In this case, the planner knows the percent of emergency work versus planned work and can have the supervisor's scheduled staff loaded accordingly.

OADER NO			YES NO	STRUCTI	For	ain Part (5) C y. ward balance Plant Service	of set intact	MJO NO. EST. START	EST.	COMPLETED
260100 100	2000/02		0.00			not write in sh				
EQUIPMEN	T DESCRIPTIO	)N				LOCATION GULDING NO	. FLOOR	COL NO. PROP	ERTY IDENT.	OR FR. NO.
YE CETEL WAY SE OF SHOW YE EJECTIVE SE THE LINE LAND SECOND SECON				JOB PRIORITY (CHECK ONE)						
DATE	TIME		DATE	1	IME		URS 🗌	STEWEEK -	POSSIBLE	D REXYS
WORK RE	QUESTED									25 11 970 97
-						_				
ORIGINATE	D BY	- 550	ORG. NO.	PHONE	MAIL ST	OP DATE	APPRO	VED BY (SUPE	RVISION)	DATE
				CRGINA	TOR - DO NOT	WRITE BELOW				
ERMITS A	EQUIRED:		FRE		ENTRY	SULT	EQUIPMENT COUPED			
EO C	RAFT			WORK DE	SCRIPTION	-		NO. OF MEN	EST:MATED	ACTUAL M
-								-	MANHOURS	HOURS
								T		
+-		_			_			-	-	-
+	-		-					-		-
$\pm$										
+						_				
	_					_				
ABOR CAL	CULATION	TOTAL	MANHOUR	S X BA	SE RATE	- TOTAL	ABOR COS	T TOTAL MIH		
		TOTAL	MANHOURS	S X BA		- TOTAL		T TOTAL M/H	ESTIMATED	D AGTUAL C
	.CULATION SCURCE		MANHOURS	5 X BA				T TOTAL M/H	4	D AGTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D ACTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D ACTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	AGTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D AGTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D AGTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D ACTUAL C
		MAT'L	MANHOURS	S X BA				T TOTAL M/H	ESTIMATED	D AGTUAL C
		MAT'L			MATERIA	L DESCRIPT		T TOTAL M/H	ESTIMATED	D AGTUAL C
		MAT'L				L DESCRIPT	TON		ESTIMATE COST.	ST TOTAL MAP
TYUNIT	SCURCE	MAT'L	MATERU	NL AVAILAS	MATERIA BILITY NOT	L DESCRIPT	ICA ICA	HARGE	ESTIMATED	
D	SCURCE ISTRIBUTION Sen, Marri Coord	MATU	MATERI CLOSE OU	NL AVAILAS	MATERIA	L DESCRIPT	ICA ICA		TOTAL MAPL E	ST TOTAL MAP
D	SCURCE	MATU	MATERU	L AVALAI	MATERIA BILITY NOT	ES CORD.	ICA ICA	HARGE	ESTIMATE COST.	ST TOTAL MAP

#### Figure 12.3 Work order example #1.

When working with the Facilities Management Division for Raleigh, North Carolina state government facilities, we received numerous hot/cold calls and calls to unstop drains, sinks, etc. We solved this challenge by having one repair van plus typically used parts and one plumber assigned to take all so-called emergency calls that were dispatched by our central call center. This was back in the "good old days" of papers work orders and fat files of completed work orders. We did have an estimator for jobs with other Raleigh state government agencies, and they paid our department for the work.

WORK OR 192		work or		2500 - 100			ATE 3/86	
PRIORI		SCHEDULED DATE: 05	/03/	86 COMPLE	TION DAT	E: /	7	
REQUEST	R: D. BLANN							
DESCRIP	TION: REPLAC	ED BEARINGS						
EQUIPMEN	¥T #: 2010-R	M EQUI		T NAME: RE		FIN TU		
		LABOR	Politic					
Craft								
Crart			698300			Reg	l	
1 10	1 RI	PLACE MAIN MOTOR BEARINGS				1.0		
 }		AND BUSHES						
· · · · · · · · · · · · · · · · · · ·								
7								
REMARKSI				FT/MAN 1	101	1.0		
		1/10/10/10/10	500000	FT/MAN 2				
				FT/MAN 3				
				F1/MAN 3				
		TOTA	MLS:		HRS	1.0	L	
		MATERIALS			С	ODES		
QTY	STOCK #	DESCRIPTION	1	COST, \$ REI		PAIR TYPE		
1	SET	BEARINGS		\$ 30.00				
2	B-93	BRUSHES		\$ 2.95				
			\$			ACCOUNT NUMBERS		
				 \$	LABI			
						MAT:		
!		<u> </u>		<u></u>	men i			
		TOTAL MATERIA	LSI	\$ 35.90	SUB:			

Figure 12.4 Work order example #2.

- There is a need shown by the work order, work request or other documentation defining the content and scope of the job
- An inquiry has asked the questions a) should the job be done b) what priority should be given c) have expenditures been approved?
- Conduct a thorough analysis which breaks down the job into smaller subtasks. From this the planner can;
  - √ identify required skills
  - ✓ make a reliable estimate of repairtime(total labor hours and Job duration)
  - √ determine parts and material needs
  - ensure parts and materials are available before the job to scheduled
  - ✓ determine any special tools that may be needed, rented or reserved
  - ✓ determine if selected specifications, drawings repair manuals
    and other documents are provided for
  - ensure that all safety and legal permissions are provided for
- identify all processes that may have to be rerouted shutdown or back to and notify the affected owner/customer
- list and coordinate all preparatory and estart activities that are needed regardless of whether they are theresponsibilities of maintenance or operations

#### Figure 12.5 Important criteria to be established for selected work order.

So, Why is the Work Order the Prime Source for Reliability Info? The work order provides the most comprehensive description of work accomplished, repairs parts used, reasons for failure, and causes of failure. Over the life of the equipment, the work order tracks total cost of ownership and life cycle cost as they accrue over time, allowing replacements or major repair decisions to be made at the most economical point in time. As work orders are completed and signed off by the supervisor, the planner makes one final review before the work order is closed in maintenance. This process allows the planner to have a continuing picture of equipment problems of all types and magnitude. From this pure observation of work orders plus the analysis of work orders, the planner can play a very important role within a strategy of continuous reliability improvement. As we will see in Chapter 15, the planner/scheduler is a key member of an A Consensus of Experts (ACE) team that reviews basic job plans, large and small, for key steps and wrench time for each step and the total job. Teams established by maintenance engineers or reliability engineers have their ideal team member in the planner position.

# Detailed Planning with a Reliable Scope of Work and a Complete Job Package

\_

### **Abstract**

This chapter looks at detailed planning with a reliable scope of work so that a complete job package or job plan can be developed based upon the scope of work. When there is sufficient planning capacity, "all jobs that can benefit" should be planned. Planners should avoid getting involved with emergency work; nonetheless, they should know the percentage of man-hours normally required for emergency work. With repetitive jobs the planner can invest more time because the details of planning these jobs will have a positive impact in reducing planning time in the future. The planner can also use the "building block of time" approach where previously planned work is often applicable as a portion of a new job package.

### **Keywords**

ACE Team Process; Detailed planning; Equipment records; Labor estimates; Labor estimating; Labor library; Maintenance technical library; Material library; Planned job packages; Planner worksheet; Refinery work flow; Scope of work; Standard

### operating procedures

When there is sufficient planning capacity, "all jobs that can benefit" should be planned. We mentioned that planners should avoid getting involved with emergency work, but nonetheless they should know the percentage of man-hours normally required for emergency work. Then as I said before, "they can plan for emergency work," and factor this into the available hours for planned work. With repetitive jobs, the planner can invest more time because the details of planning these jobs will have a positive impact in reducing planning time in the future.

The planner can also use the "building block of time" approach where previously planned work is often applicable as a portion of a new job package example. Figure 13.1 illustrates the building block approach.

In Figure 13.1, tasks 1, 2, 3, or 4 maybe repetitive-type jobs serving as templates for equivalent work content that can be used over and over again by the planner. There are many conditions that support the maturing stage s of s planning program. Some of these are listed in Figure 13.2.

One of the most important sources of information is from within the maintenance technical library. This is where information such as equipment history, equipment manuals, parts manuals, parts lists, and assembly drawings can be found along with site drawings of equipment that is in place. This should be a controlled area with Internet access, drawing files, large reference tables, and proper shelving for books and catalogs. Here there may be parts catalogs for specific equipment or suppliers of specific components. This is the one place that should have ease of accessibility yet be controlled consistently. It should not be like the example shown in Figure 13.3.

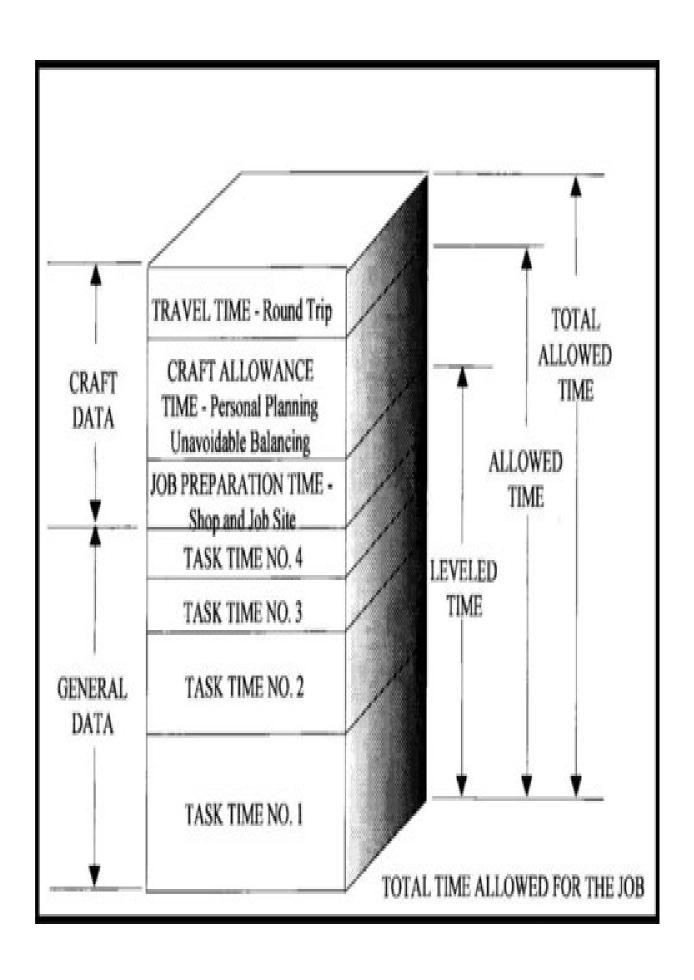
There are many benefits for a planner to have a well-organized library of the documents that are catalogs and the computer network established with Internet. These benefits include:

- the planner's job is simplified, accelerated and more productive
- the planner can maintain job plans that are more consistent and with good quality

- this library becomes the universal resource for other groups, such as maintenance engineering defining specifications and problem solving
- and this foundation can be good for further computer assistance via electronic document management systems.

Key records and the maintenance technical library are very important and should include:

Equipment records: These contain all the pertinent data for the equipment and subsystems such as installation data, make model, vendor capacity for service, and parts support. One important item is the original asset capacity and specifications, not to be confused with equipment history of all repairs performed on the equipment.



#### Figure 13.1 Building blocks of time.

Equipment history: This captures all the work order history of repairs performed on the equipment.

Library of planning aids: There are a number of means to simplify the planning process for machine repair and overhaul by classifying the debacle groups of machines and then building libraries of preplanned work element sequences along with the bill of materials. This concept establishes and documents the work sequence news for each type of equipment, class by clients. Here the documentation records the procedure needed to take the equipment completely apart and then put it back together with replacement parts as needed. In this case, when the ACE Team Process is used a number of individual benchmark jobs can be developed from the disassembly part of the job as well as the assembly part of the job.

Labor libraries: Labor libraries should be filed so that document retrieval is as convenient as possible. This might be by unit equipment specific type of skill required or by the job code. Having a labor library supports development of job steps sequences and labor resource requirements listings:

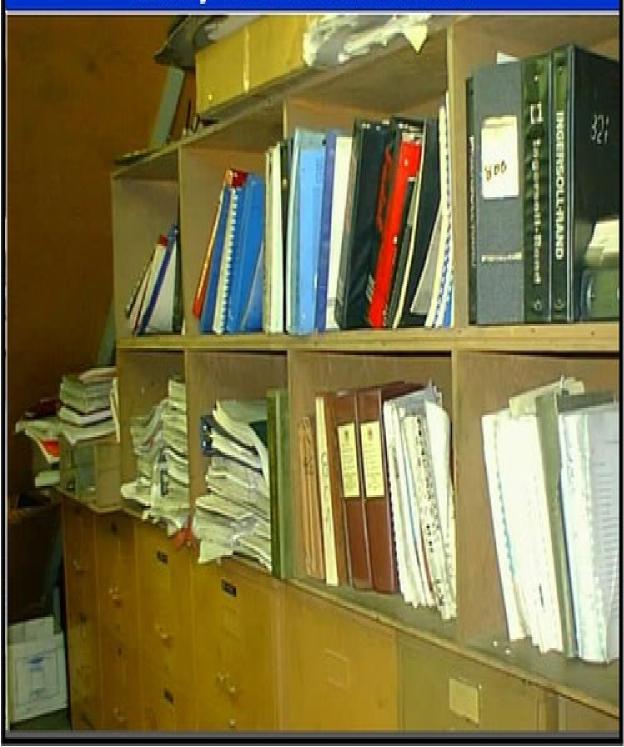
- Crew size by skill
- Job duration
- Man-hours by skill

Labor estimating: Having the term estimating within the actual title of this book strives to emphasize the importance that estimating plays in so many areas of planning and scheduling. There is an old saying that "what gets measured gets done." This ranges from maintenance strategy goals to personal goal setting down to work at the shop floor level. Even where a labor library is in place, some form of reliable estimating is required to extend it to as much work as possible. Later we will discuss some methodologies along with the ACE Team Benchmarking Process for the task level work content shown previously in Figure 13.1.

- The RCM process the best maintenance strategy/plan has developed for the equipment. The maintenance plan may include PM., PdM, remove and rebuild, remove and replace, or even run to failure.
- Potential problems are reported by operations in a timely manner to provide lead time for planning
- There is a maintenance technical library, controlled and updated as new equipment is placed into the operation. In some cases this may be an electronic document management system with all site drawings and related documents.
- Over time the planner has built a good library of planned job packages, easily retrieved via an electronic system in some cases.
- For utilization of an existing CMMS system is present with functionalities needed by the planner for areas such as scheduling which often is a weak link.
- The planner receives good feedback on completed jobs. From the supervisors and craft employees
- Within the equipment master file there is good repair history to include failure codes and causes of failure
- PM/PdM task descriptions are such that anyone new can perform the inspection
- Within the organization and there is dedicated resources to failure analysis supported by the maintenance planner, supervisors and crafts people
- Equipment vendors and parts of vendors provide good support to plant staff when needed
- New technologies for repair are reviewed for site applications
- There is open dialogue on equipment problems from the operators
- Engineering is capable of providing qualified support to major problem areas
- Overhaul and rebuild capabilities are available either in-house or via contracted services
- Crafts personnel provide good workmanship and display PRIDE in Maintenance

Figure 13.2 Signs of a maturing planning process.

# Develop a Stores Parts Catalog and Technical Library That the Crafts Can Use



#### Figure 13.3 Invest in a good area for the maintenance technical library.

Material library: For critical units of equipment, this library should include parts lists and bills of materials. The material library supports identification of materials or parts requirements for jobs to be planned, including:

- the parts involved
- stockroom number of each item
- manufacturing ID for each part
- storeroom location
- unit of issue

Purchasing/Stores: These catalogs can be in hard copy or electronic format and are essential for all parties. They contain much the same information that is in the material libraries used by the planner. So some form of storeroom catalog or vendor catalog is used to develop material libraries. We can sort these catalogs by:

- component description
- assets where used
- stock number
- vendor serial number

If searching a computerized parts inventory, we can search by keywords and perform many types of analysis such as doing an ABC analysis, looking at parts usage, or identifying obsolete items.

Planned job packages: This library of planned job packages is very important to the planner. When completed and reviewed, job plans become viable templates to save the planner much time when the same job is

planned again. In addition, job plans within major job packages can become jobs that the ACE Team uses for benchmark job analysis.

Other references: The library would include services and any other information from experienced supervisors, crafts people, as well the planner. One of the things that can be done is to take a video of critical repair jobs as they are being performed by an SME. This could be an SME nearing retirement and he is the "go to guy" for a specific repair. Therefore, he becomes the star of his own personal training film.

Standard operating procedures: Within complex operations such as refineries, these SOPs are included for lockout tag out, safety, risk assessment, and management of change compliance etc. Figures 13.4–13.12 illustrate work flow within a refinery unit where (1) operators can do some repair or help crafts person, (2) the unit has an asset coordinator, and (3) work is carefully reviewed when job has been completed. This was a standard operating procedure for this refinery.

Job packages: When planning work within a refinery you are faced with large and complex equipment that is physically linked to form the process. When planning work within this environment, many factors are involved and plan job packages are often the best approach. Especially during shutdown turnaround and outage planning, all jobs must be detailed with a job package, which is all of the documentation from the planning efforts. In most cases, job packages are reviewed with the supervisor and the person making the requested work. They are also reviewed between a supervisor and the craftsperson who will be assigned the work.

During the verbal exchange between the maintenance supervisor and the requester clarification of work to be performed is confirmed between strategic planning phase and the tactical execution phase as a work is being completed. Figures 13.13 and 13.14 summarizes a list of items typically included in a job package:

# Work ID to Post-Job Completion



Figure 13.4 Work ID to job completion–refinery.

# WORK IDENTIFICATION / WORK ORDER PROCESSING

### **Identify Work**

### Everyone



- Everyone is responsible to ID work (early)
- Early work ID is safer and less costly

### Operator Performs Maintenance Investigate Problem

#### Operator



- Operator performs Maintenance if possible
- If not, go to next step

### Identifier



- Gather problem information then contact supervisor
- What is the problem/opportunity?
- Where is it (asset location/identifier)?
- When does it occur (related process operation, etc.)?
- How much is it occurring (minor vibration, large rate of drip, leak, break, etc.)?
- How often (all the time, sometimes, rarely)?
- Note: If it is suspected an Emergency condition, go directly to next step

### Determine Urgency

### Shift Supervisor



- Shift supervisor responsible for declaring Emergency/Urgent status
- Troubleshoot with team
- Determine if work is required

### Can Operator Perform Work?

### Operator and Supervisor



- Operator
  Performs
  Maintenance
  If not, record all
  relevant
  information for
- information for quality notification input

Figure 13.5 Work ID. Work order processing–refinery #1.

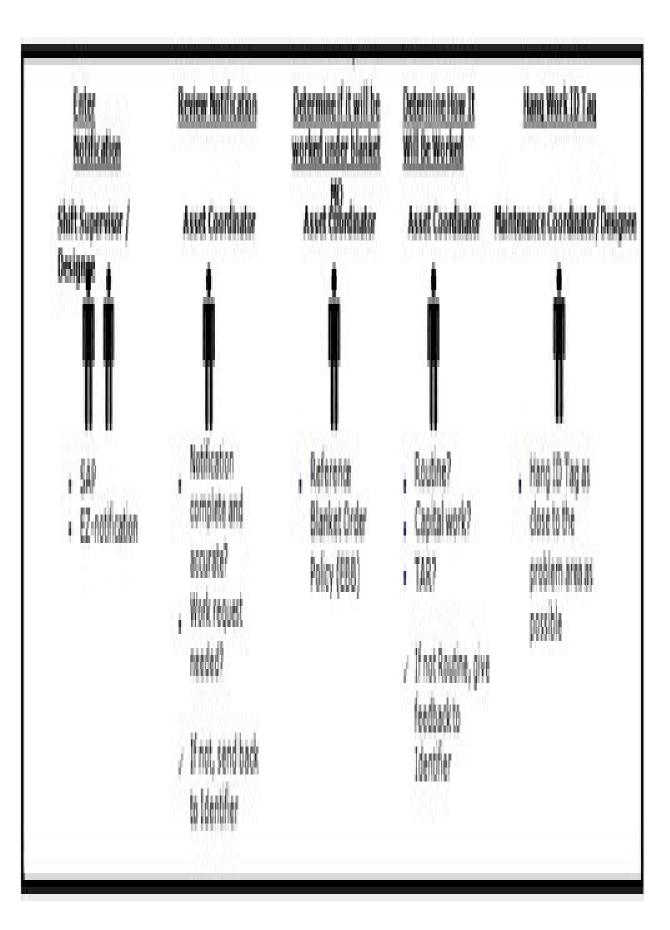


Figure 13.6 Work ID. Work order processing–refinery #2.

# ROUTINE MAINTENANCE WORK PLANNING PROCESS

### Notification in SAP

Minimum 2-3 days prior to allow for detailed planning.



- Planner reviews new approved notifications in SAP.
- Assures job description is adequate.
- Create M.O. with planner group 0

### Field Scope Job

Planner/Supervisor

Planner/Supervisor/UNE

Planner works

with Supervisor

to determine job

contacts the Unit

Maintenance

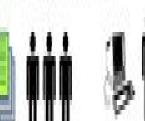
Engineer to

reeded.

create job note if

note need

. The Planner



- Planner visits work site to assemble information for plan.
   Materials, tools, equipment, and craft resources needed
- by Supervisors/Job Reps may also be asked to review job
- Safety requirements must be observed

# Job Note Request

Plan The Job



- Search SAP database to find existing job template if available. Plan as new if not available
- The Planner copies the template into the new maintenance order
- The maintenance order can be updated with additional details, job steps, etc.
- Update status to planner oroup 1

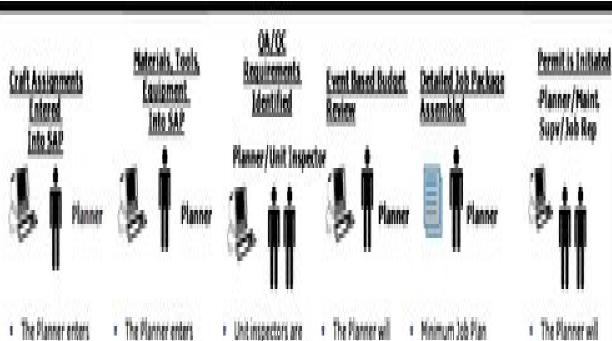
### Determine Who Will Perform Job



Planner Supervisor

- Non-core work is tasked to contractor
- The Planner and Supervisor determine if contractors will be needed to perform the work

Figure 13.7 Routine maintenance work planning process–refinery #1.



- detailed tacks into SAP with correct work deilters
- . Work centers are used in SAP to determine what crafts will work. each task
- Kultpletanks are entered for operators as well as crafts

- stock and non-stock materials into the plan
- Procurement. Coordinators are asked to help produre materials when needed
- · Planner will use the VAN (Vendor Agreement Karagement) tool when buying non-stock tems

- · Unit repettors are notified when work will be performed
- · The Harner will include steps for inspection and quality control in the estimate
- determine if the work is budgeted

before releasing

the order for work,

· If the work is Not

in the budget, a

variance will need

to be created and

approved.

Kelesse materal

requisitors.

- Mnimum Job Plan Requirements
  - Complete SAP printed NO.
  - Frimary & secondary oris
  - · Labor estimates
  - Description of job steps
  - Status of materials & ecations
  - OA/OC requirements
  - Reser specifiations
  - · Location of work
  - · Maintain ready to schedule
  - · Update status to planner group 2

- nicate permits for all tasks on the order that require one
- The Planner will contact the correct Name. Supy. / Job Rep. to begin the risk BSBS7eft
- · Acordorate level drsk assessment and permit creation bccurs.

Figure 13.8 Routine maintenance work planning process–refinery #2.

## ROUTINE MAINTENANCE WORK - DAILY SCHEDULING PROCESS

### Update Current Day's Schedule

### Preparation for Unit Daily Scheduling Meeting

### Conduct Unit Daily Scheduling Meeting

### Permit Creation











- Planner reviews current day schedule with completed work and work that will carry over to the next day
- Updates are made in the current tools
- Scheduler,
  Maintenance
  Supervisor, and
  Planner provide the
  Asset Coord, with MO
  status information in
  preparation for the Unit
  Daily Scheduling
  Meeting
- Mandatory attendees:
   Asset Coordinator (Team Leader), Maintenance
   Supervisor, Planner,
   Maintenance Coordinator,
   Operations Supervisor
- Attendees as appropriate:

   Unit Engineer,
   Inspections, Capital
   Project Reps, Job Rep's etc.
- Operations and Maintenance
   Supv./Job Rep. verify permit readiness by reviewing risk assessment, initiated ATW and associated permits

Figure 13.9 Routine maintenance work daily scheduling process–refinery #1.

### Ready to Work Backlog



 Planner sends a copy of the RTW backlog to the unit team members

### Weekly Scheduling Meeting

Planner, Maint, Supe, Main, & Count, SNM Supe, Asset Count,



- Select jobs for weekly schedule that meet the unit requirements for safe optimal operation
- Considerations for selection:
   LOTO
   Priority
   Equip. Availability
   Carry over work
   Crocal trips & alarms
   PM's
   Budget
   Backlog
   Updated RIME priorities
- Planner codes scheduled Maint, Orders in SAP by 2:30 cm

### Scheduler Creates Schedule



- Scheduler downloads coded Maint. Orders from SAP into P3e draft schedule
- Scheduler incorporates TAR, Tank TAR, infrastructure, and capital projects schedules into the P3e draft schedule

### Resource Validation & Update

Schabeler, Flancer, Asset Coordinator



- Scheduler levels resources noting any conflicts because of resource or CoW issues
- Scheduler contacts unit planner where resource restrictions are found
- Planner contacts asset coordinator for review
- Asset Coordinator prepares to discuss issues around resource allocation

### Site Wide Scheduling Meeting

Planning Schaduling Supt. /Asset Counts, TAX and Routine Planning & Schaduling Leads, Shift Director, Schadulars



- Planning Superntendert facilitates a high level review to gain consensus on what will be worked on at a high level
- Attendees commit to schedules

### Finalize Schedule





- Scheduler makes changes to schedule resulting from the weekly meeting
- Scheduler makes schedule available on the website no later than Thursday at 4:00 pm

Figure 13.10 Routine maintenance work daily scheduling process—refinery #2.

# ROUTINE MAINTENANCE WORK EXECUTION AND ACCEPTANCE PROCESS

### Start of the Day

### Received from the Planning Day before the job starts And Scheduling Process

Operator / Maint. Coord. Job Rep. / Ops. Supv

- Job Packages Daily Schedules
- Hazard Assessment (training in progress



- · Operator verifies that the area is clean and ready for maintenance
- Maintenance coordinator communicates with nearby units as needed
- Maintenance coordinator verifies that critical jobs are ready to be worked
- Night Operations finalizes equipment preparation for maintenance

Haint, Supv.



- · Maint, Supv. or Job Rep. renews job package for completeness
- · Maint, Supy. / Job Rep. holds maintenance safety meeting/contractor lineup
- · Ops. Shift Supy holds operations pre-shift meeting
- · Ops Shift Suov approves any hot work or confined space entry permits

### Job Start-up

Operator Craftsman Job Rep



- · Alpersonnel entering unit must sign in at the control room
- Operator, craftsmen and Job Rep. walk the job on new jobs, verifying that isolation LOTO, etc have been completed
- Verify equipment is energy free

### Job Start-up (con't)

Operator Craftsman Job Rep.



- Operator, contractor crew rep and job rep (contractor work) sign the ATM
- Work Crew Rep or job rep (contractor) work) or responsible operator review the Permit Pack and conducts pre-job safety review with everyone in the work crew. Work Crew Dedaration signed by all
- · New work crew member needs the prejob safety review prior to work and needs to sign the ATW
- Operator and contractor crew representative walk the job on continuation work each shift to revalidate permits

Figure 13.11 Routine maintenance work execution and acceptance process—refinery #1.

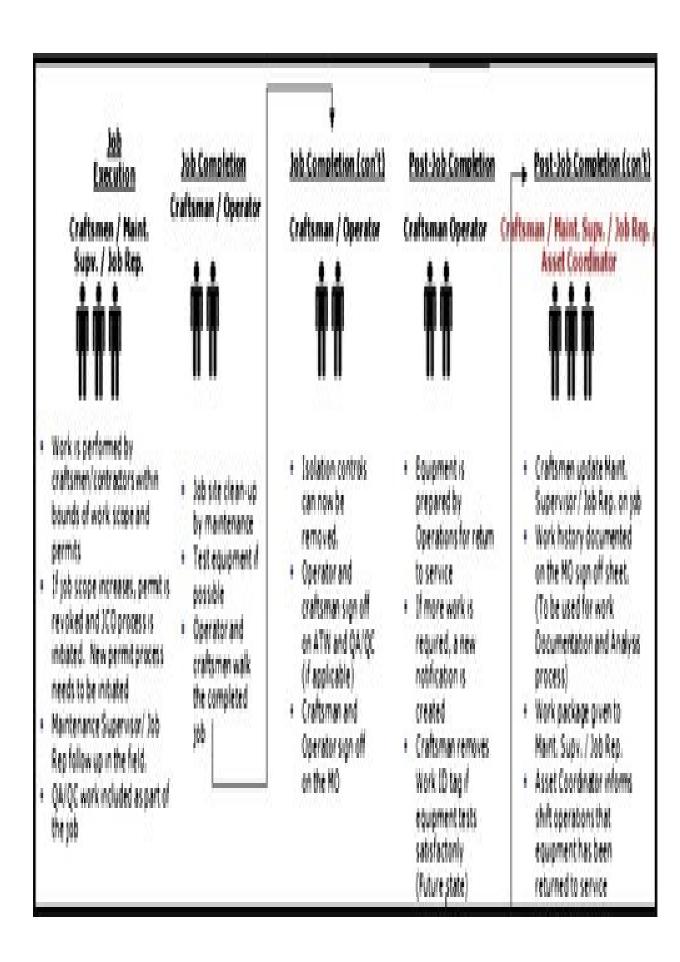


Figure 13.12 Routine maintenance work execution and acceptance process–refinery #2.

- The work order that has initiated and been approved for the work to be accomplished
- ✓ A work planning sheet as a basic checklist (See Figure 13.13)
- ✓ The job plan with details for each task and the step-by-step sequence
- ✓ A labor deployment plan by craft and skill including labor hour estimates. This should also include duration and consider contract as well as in-house resources.
- ✓ If the job is complex and requires multiple crews is then the use of a GANNT bar chart might be needed to help plan task sequencing to assign crews
- ✓ For a pre-shutdown fabrication or other preparation this should be completed in advance so as to minimize equipment being out of service
- ✓ Bill of materials: here a list of all materials needed for the job is developed along with an acquisition plan for major items. We need to determine if the material is authorized inventory or a direct purchase item. The planning package should include spares reservation and stage location. However, wiping out stock levels of critical spares should be avoided.
- ✓ Develop a requisition and purchase order reference list
- Provide estimated time this step/task summarized by resource group and for the total job
- Provide a set down plan as to where everything used for major tear down will go
- ✓ A copy of all required permits clearances and tag outs
- ensure that contractors bring qualified people and have knowledge of all site safety requirements
- ✓ and for job packages are number of things that can be supplied; prints, sketches, digital pictures, specifications, special procedures and any references that the assigned crew is likely to need

Figure 13.13 List of items typically included in a job package.

#### PLANNING WORKSHEET PLANT LOCATION DATE COST CENTER \_\_\_\_\_\_ PLANNER WORK ORDER# CRAFTSMAN TOTAL EST HRS. COMPLETION DATE DESCR OF WORK MATERIALS REQ'D SPECIAL TOOLS PROCEDURES \_\_10\_\_\_\_ \_\_\_\_12\_\_\_\_ \_\_\_\_13 \_\_\_\_\_\_\_ 15.\_\_\_ \_\_\_\_16.\_\_\_\_\_ \_\_\_\_18.\_\_\_\_ TOTAL CRAFT ESTIMATED SUGGESTIONS \_\_ ADDITIONAL WORK PERFORMED DELAYS:

Figure 13.14 Planner worksheet example.

# Understanding Risk-Based Maintenance by Using Risked-Based Planning with Risk-Based Inspections

\_

#### **Abstract**

This chapter is to ensure that planning/scheduling always considers safety and all HSSE factors when developing small job plans or large job packages. In refineries extreme care is needed to make sure that work is properly identified, accepted for quality, and all mitigations for risk related to the job have been considered. Risk-based maintenance is something that a planner must understand within their special work environment. This chapter strives to introduce the key concepts of risk-based maintenance and how it can help define risk-based inspections. Risk is calculated as the product of the probability of failure and the consequence associated with a failure: Risk = Probability of Failure x Consequence of Failure.

#### Keywords

Asset criticality; Health, safety, security, and environmental (HSSE); Operating context; Risk matrix; Risk ranking; Risk-based inspection (RBI); Risk-based maintenance (RBM)

#### **Basic Overview**

1

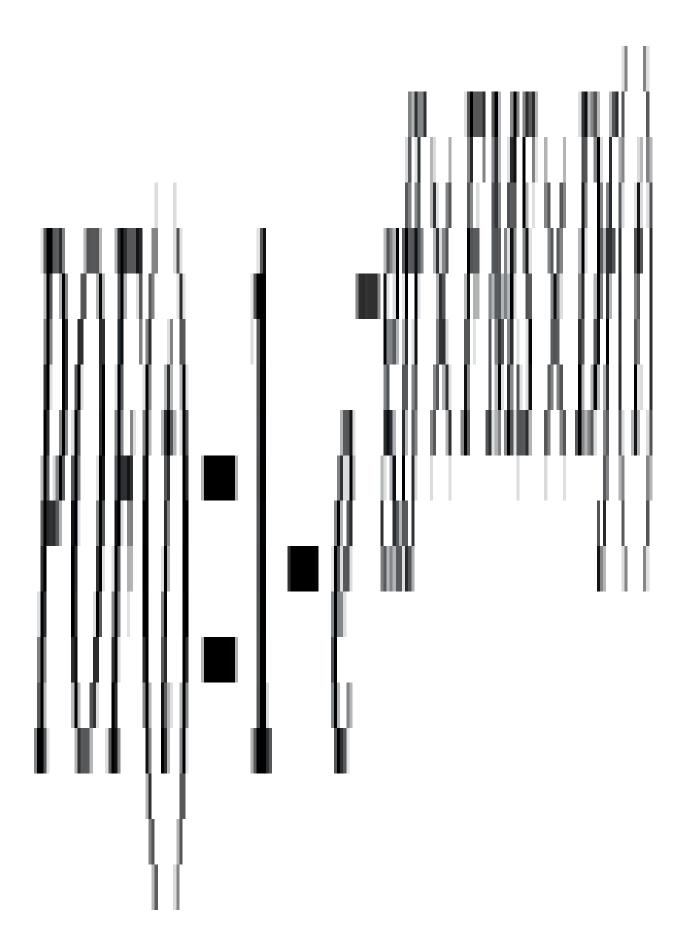
In RBI analysis, risk is calculated as the product of the probability of failure and the consequence associated with a failure. Planning must always consider safety and all health, safety, security & environmental (HSSE) factors when developing small job plans or large job packages. In refineries as we saw in the work process flow process Chapter 14, there is extreme care in making sure that work is properly identified, accepted for quality, and all mitigation for risk related to the job has been considered. So risk-based maintenance (RBM) is something that a planner must understand within their special work environment. This chapter strives to introduce the key concepts of RBM and how selected software systems can help define risk-based inspections (RBI). First, let us define what risk is and how it is calculated. And, as I always say, it is like gambling with maintenance costs and equipment conditions that are deferred to a later date.

Risk is calculated as the product of the probability of failure and the consequence associated with a failure:

Risk = Probability of Failure × Consequence of Failure

Risk is usually considered a better measure for prioritization than either the probability of failure alone or the consequence of failure alone, because it is more descriptive of the actual damage/loss caused. As an example, if you need to prioritize two assets where one asset has a high probability of failure but low consequence of failure, and the other asset has a low probability of failure but a high consequence of failure, the analysis would yield completely opposite results if you considered only one factor or the other. The use of risk eliminates this ambiguity.

The probability of failure (POF) is determined using applicable damage factors (mechanisms), a generic failure frequency, and a management system factor:

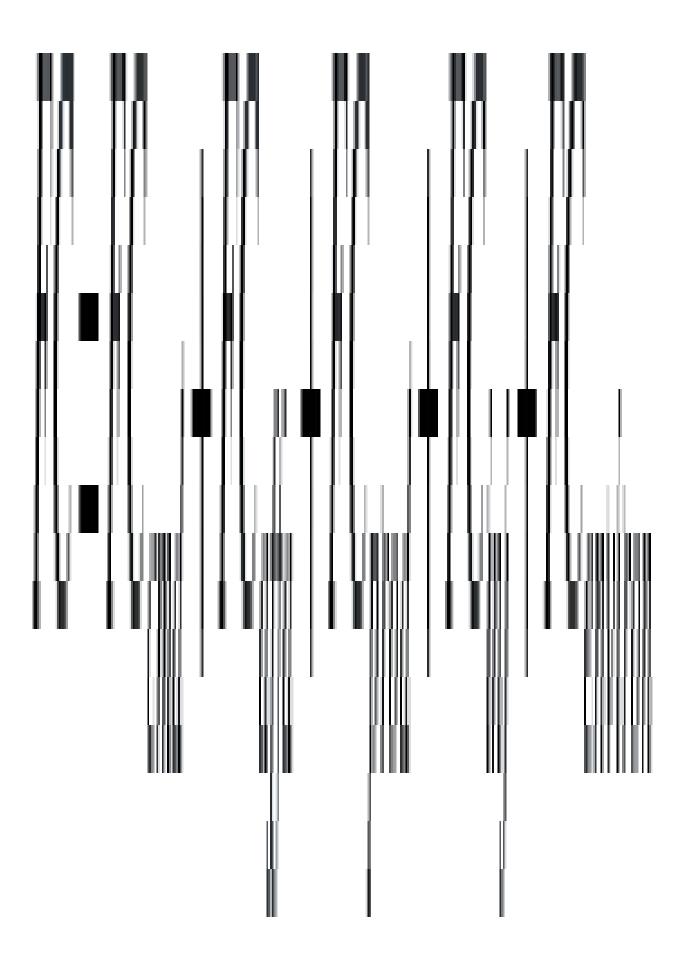


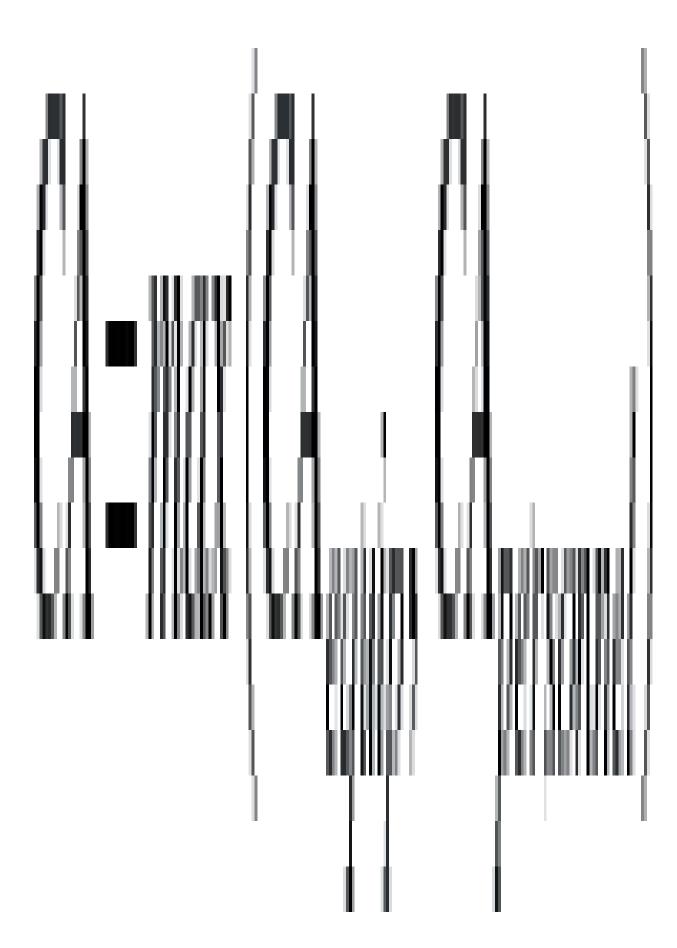
#### where:

- gff is the generic failure frequency
- FMS is the management system factor
- Df(t) is the overall damage factor

The generic failure frequency is based on industry averages of equipment failure. The management system factor is a measure of how well the management and labor force of the plant are trained to handle both the day-to-day activities of the plant and any emergencies that may arise due to an accident. The overall damage factor is the combination of the various damage factors that are applicable to the particular piece of equipment being analyzed.

The consequence of failure is calculated as the combined values of the consequences for damage to the failed equipment, damage to the surrounding equipment, loss of production, the cost due to personnel injury, and the damage to the environment. The consequence of failure can include both a financial consequence (FC) and an area (safety) consequence (CA):





- FCcmd is the financial consequence to failed equipment
- FCaffa is the financial consequence to surrounding equipment
- FCprod is the financial consequence due to production downtime
- FCinj is the financial consequence due to personnel injury
- FCenviron is the financial consequence due to environmental damage/cleanup
- CAequip is the area consequence to surrounding equipment
- CApersonnel is the area consequence to nearby personnel

For further detail on calculating probability of failure and/or consequence of failure, please consult API RP 581.

## **Evolution of Maintenance Strategies to Create Transition Between ReliaSoft**

Since the 1950s, maintenance strategies have evolved through an event-based response, time based, condition based, reliability based, and then risk based. Figure 14.1 illustrate development of these maintenance strategies. RBM is extremely important within large complex operations like refineries. In addition, as you will see, the analysis for risk leads to what we call RBI (Figures 14.2–14.10).

There are a number of software systems that can support the analysis of reliability data and in turn support RBM with defining the best RBI plan. The following will describe such a system that is available from ReliaSoft. This material is reprinted with permission from ReliaSoft Corporation based on "Introduction to Risk Based Inspection (RBI)," Reliability HotWire, Issue 151 (September 2013). For more information about the RBI software tool, visit http://www.ReliaSoft.com/rbi/.

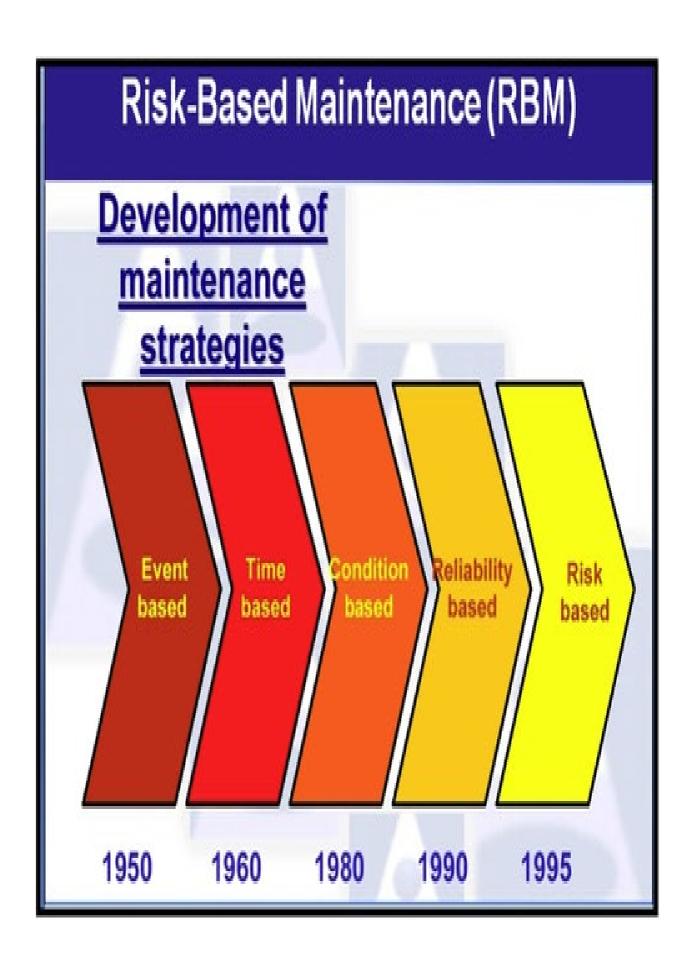


Figure 14.1 Development of maintenance strategies.

#### Concepts

- Managing Risk = finding the right balance
- Asset Risk concepts familiar to most
  - Probability of event X consequence of event
  - Most approaches only look at technical side
  - Don't consider implementation risk
- Solutions are often simple technically

Figure 14.2 The concept of risk-based management (RBM).

### Outline of RBM Methodology

- Delineate process units, establish boundaries and interfaces.
- Identify critical assets within each unit.
- Generate equipment asset register.
- Identify factors affecting consequences of failure for these assets.
- Conduct failure likelihood assessments (failure mechanism, assessed corrosion rate, residual corrosion allowance, and residual remaining life).



Figure 14.3 Outline of risk-based maintenence (RBM) methodology (Part 1).

## Outline of RBM Methodology

- Assess the consequence of failure (safety, operational, environmental)
- Assess the ease of detection or otherwise of failure.
- Review the risk ranking (criticality) and assign weighting factors.
- Identify the appropriate maintenance strategy for the assets.
- Populate the RBM database.
- Generate Risk Based Maintenance Plans.

Figure 14.4 Outline of risk-based maintenence (RBM) methodology (Part 2).

#### RCM Analysis Flowchart With Risk Based Maintenance in Steps 8, 9 & 10

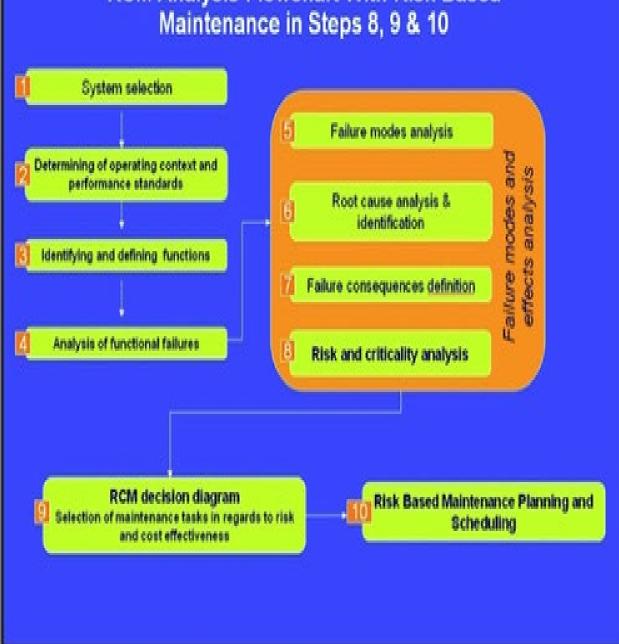


Figure 14.5 Risk-based maintenence (RBM) methodology leads to RBM planning and scheduling.

## Risk matrix - modification of risk

Consequence of failure

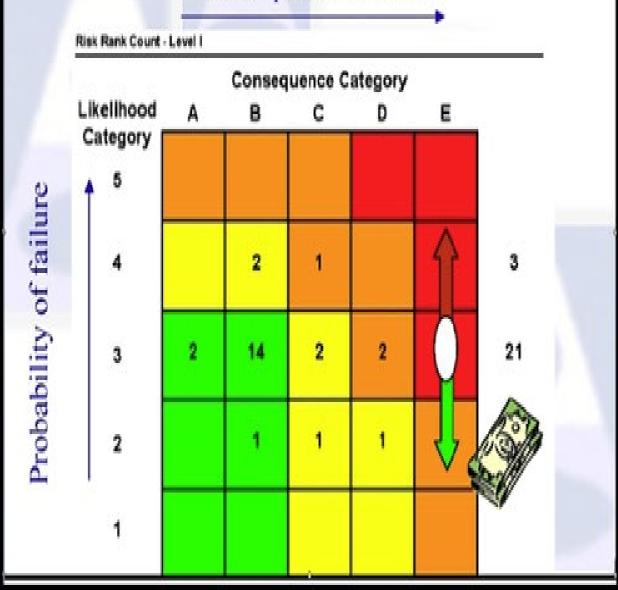


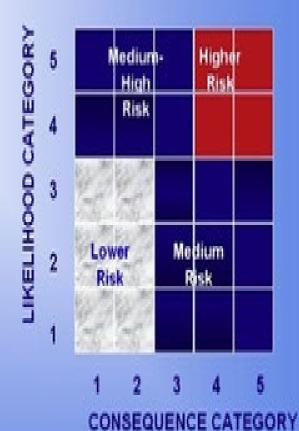
Figure 14.6 Risk-based maintenence (RBM) risk matrix.

## Overview of Risk Based Maintenance

Evaluate Failure Mechanisms Such As:

- Corrosion (H2S, CO2, Water, and other factors)
- Cracking
- Heat Exchangers and Heaters
- Desalters, separators, critical piping, etc.

Prioritize Facilities
Equipment Inspection
and Revamp based
on greatest risk.



Flammability, toxicity or chemical hazard, business interruption, environmental.

Figure 14.7 Overview of risk-based maintenance (RBM).

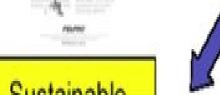
## **Factors for Implementation**

- Size of prize and rate of return depend on start point
- Most problems have many possible solutions

Asset Risk



Solution Risk



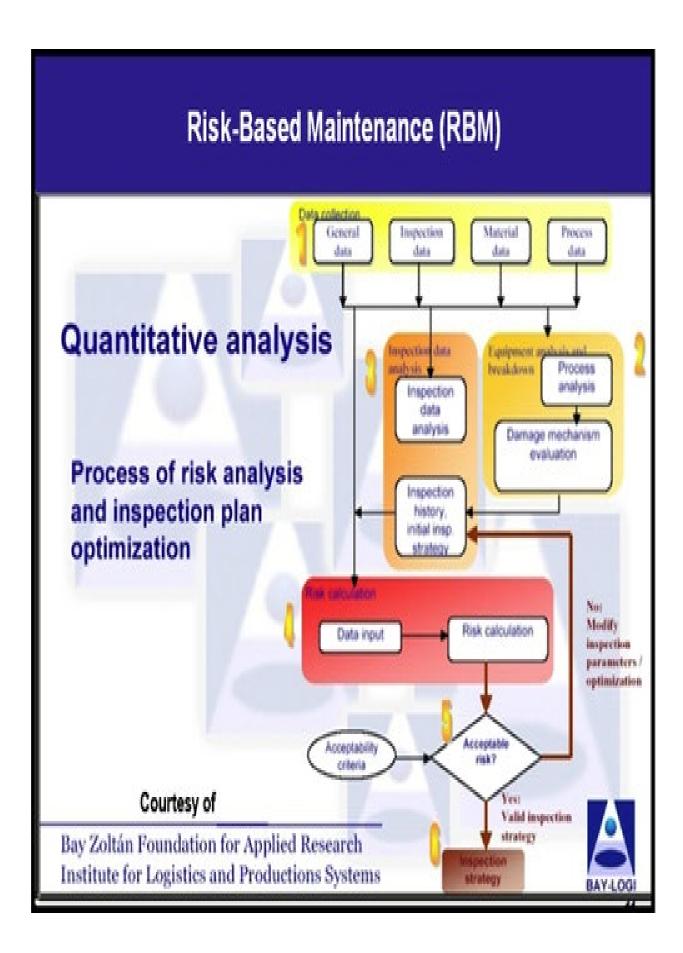
Sustainable

Implementation

Figure 14.8 Factors for risk-based maintenance (RBM) implementation.

#### **Local Conditions** Climate, Exposure Parts/Skills Physical Protection data location/proximity **Equipment Process Data** Set Points Relief Rate Duty Availability performance Pressure, Temperature Composition/Properties Demand rate Flow rate **Operating Context** Alarm and Trip Schedule **Equipment Mechanical Data** Alarm Set Points Dimensions, Materials Trip Set Points Corrosion Details, Insulation Loop Register Performance (curves, powers) Failure Consequence **Design Conditions** Instrument Range

Figure 14.9 Remember the "operating context" of the asset.



<b>Figure 14.10</b>	Process of risk analysis and inspection plan optimization

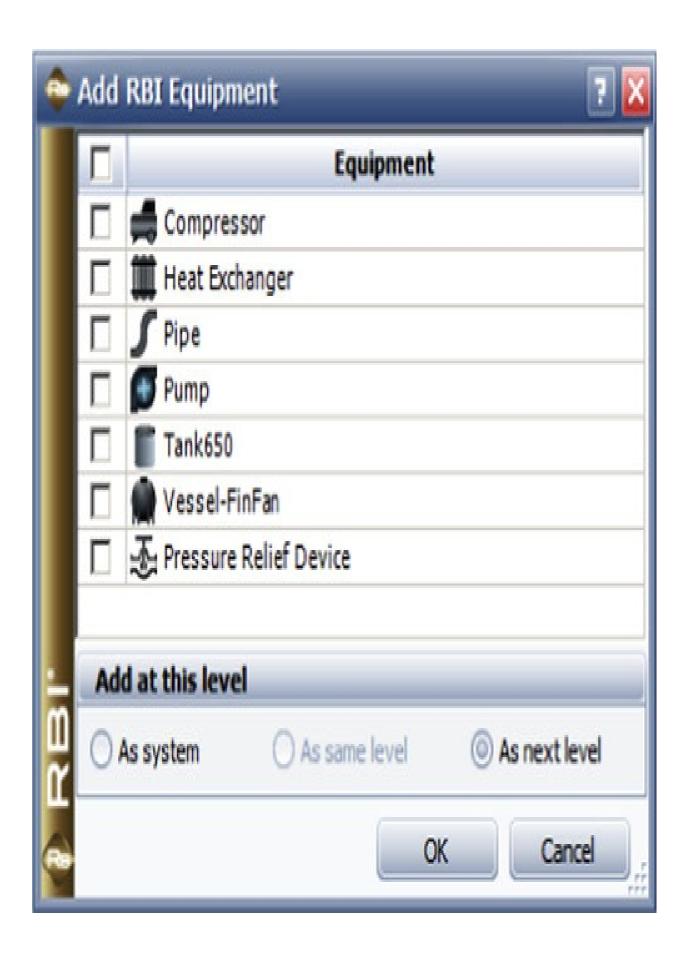
# Introduction to the RBI Software from ReliaSoft Corporation

ReliaSoft's new RBI software tool facilitates RBI analysis for oil and gas, chemical, and power plants in adherence to the principles and guidelines presented in the American Petroleum Institute's recommendations in the API RP 580 and RP 581 publications, as well as the American Society of Mechanical Engineers' recommendations in the ASME PCC-3-2007 publication. RBI also includes all of the standard features available in RCM++, a software tool that is widely used for Failure Modes and Effects Analysis (FMEA) and Reliability Centered Maintenance (RCM).

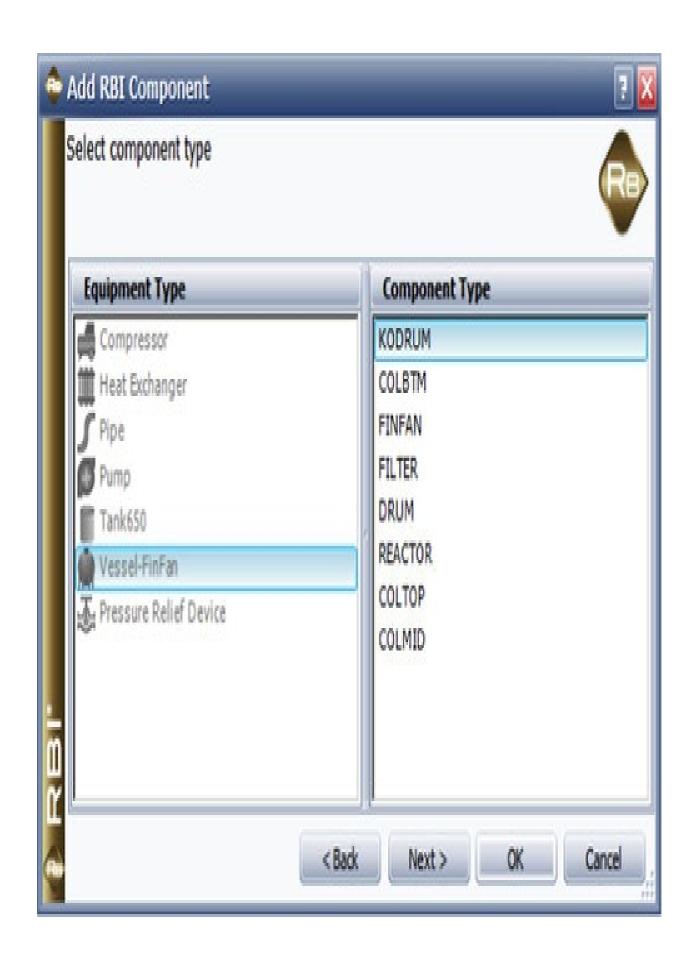
The RBI interface is identical to RCM++, with the addition of RBI specific options on the System Hierarchy tab.

li i	W		*	
	ı	•		
			alw	

The equipment and component types that are available for RBI analysis are currently limited to those addressed API RP 581. The equipment and component types that are available for RBI analysis are currently limited to those addressed in API RP 581.



Each equipment type also has associated components. For example, the Vessel-FinFan equipment has the specific components shown below available for analysis.



While the system hierarchy can contain items that are not RBI related, those items will be ignored when performing an RBI analysis. For example, in the following picture the system is the hydrogen generation unit, which has several items that receive RBI analysis and several that do not.



Once you create the assets, you must answer questions and fill out the relevant properties for the asset to be analyzed. All of these inputs are used to create a failure model that determines the probability of failure, and calculates the consequences of failure. The results also include the recommended inspections, if any, that should be performed to keep the asset under the maximum allowable risk.

### **Case Study Example**

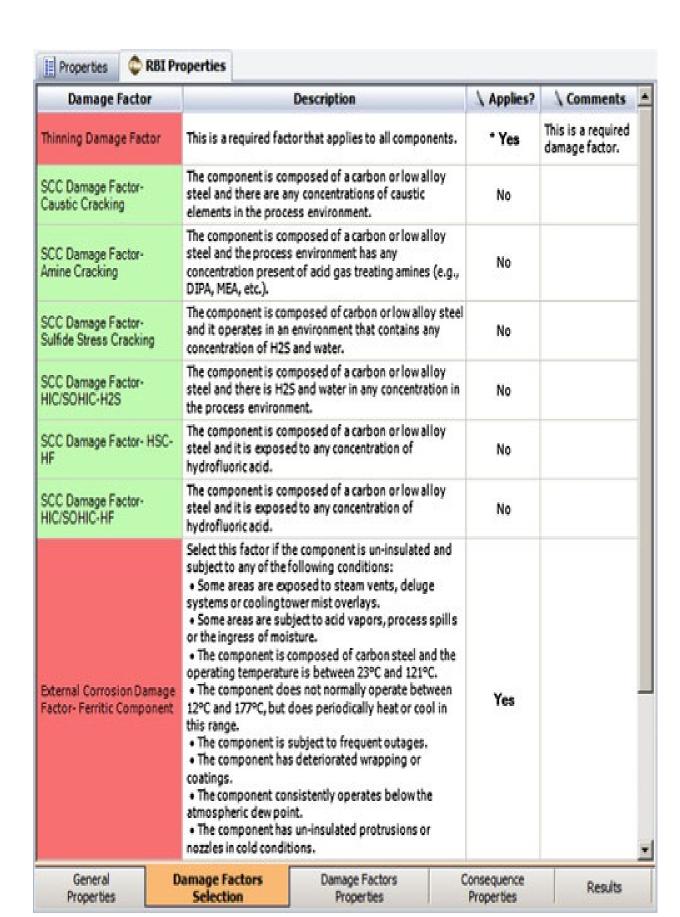
A small town wants to do a risk analysis on a proposed high-pressure 24-inch pipe carrying crude oil for which the oil transportation company is willing to pay a rent of \$500,000 in advance for the next 20 years. The company will also perform an inspection on the pipe halfway through the rental period. Since the city is self-insured and is not willing to take any financial chances, the city council would like to know if the \$500,000 offsets the possible risk associated with the pipe. The city has requested the required information from the oil transportation company to conduct its own RBI analysis of the pipe. The pipe is composed of carbon steel. The heavy crude, which contains 100 ppm H2S, is being pumped through at an operating temperature of 25 °C with a pressure of 4.5 MPa.



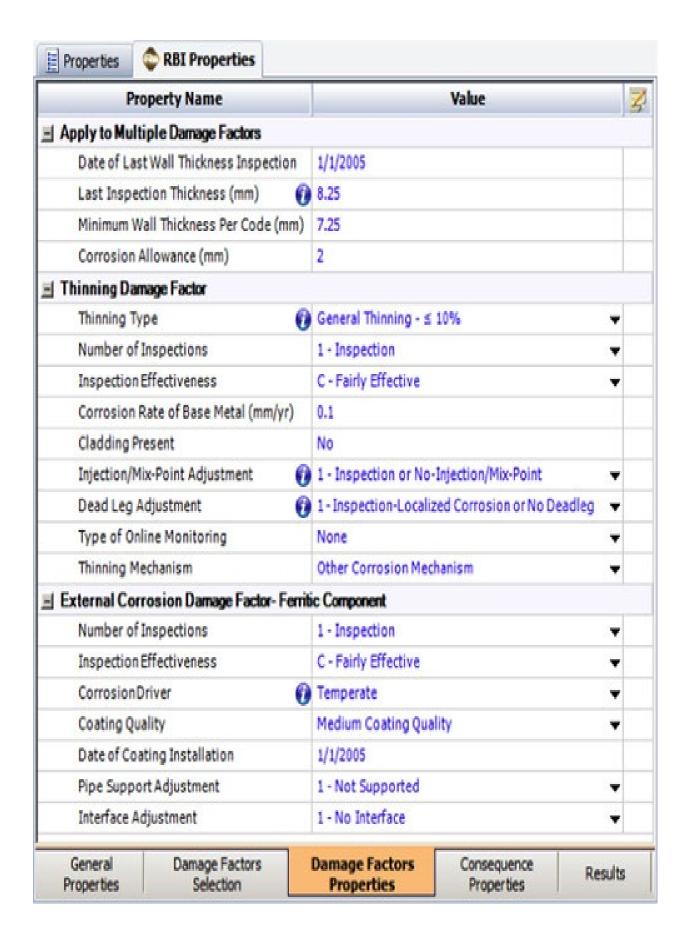
Property Name	Value	
Material of Construction	Carbon or Low Alloy	•
Lining Present	No	
Insulation Present	No	
Exposed to Chloride and Water	No	
Processed Fluid Type		•
Operating Temperature (°C)	25	
Operating Pressure (Pa)	4500000	
pH of the Process Fluid > 7.5	No	
Date of Component Installation	1/1/1995	
Plan Date	1/1/2015	

General Properties	Damage Factors Selection	Damage Factors	Consequence	Results
Properties	Selection	Properties	Properties	

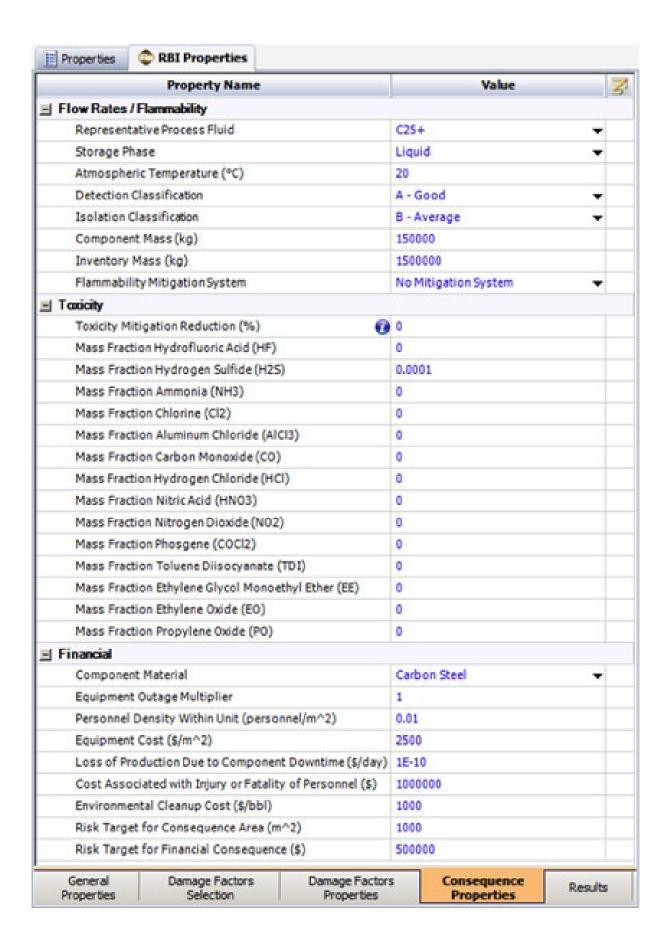
The only two damage mechanisms expected are general thinning and external corrosion.			



For their analysis, the city assumed that the effectiveness of the performed inspections was average. All other property values were estimated based on other similar pipes used elsewhere.



The city based the financial portion of the consequences on the current population density and the property values around the proposed pipe area. For the initial estimate, the city did not take into account inflation or any possible losses associated with property value changes, or possible resident dislike of the pipeline across city land.



#### **Results**

The analyzed results show that in case of a containment failure of the pipe, the expected cost associated with a failure would be almost \$4.9 million. This far exceeds the \$500,000 payment to be received. However, the probability that a failure will occur within 20 years under normal circumstances is estimated to be only 0.7%. Therefore, the expected financial risk is the product of the two, or a little over \$36,000. This is well under the \$500,000 payment to be received.

<ul> <li>Area and Financial Consequence Results</li> </ul>	
★ Area Consequence Results	
Component Damage Cost (\$)	110.457516
Cost to Surrounding Equipment (\$)	84660.731771
Business Interruption Cost (\$)	7.457942E-10
Potential Injury Cost (\$)	4.526616E+06
Environmental Cleanup Costs (\$)	279859.310826
TOTAL Financial Consequence (\$)	4.891246E+06
■ RBI Date Results: 7/31/2013	
☐ Plan Date Results: 1/1/2015	
■ Overall Damage Factor and Probability of Failure	
Total DF (Plan Date)	222.412312
Probability Of Failure	0.007386
Risk Analysis (Area)	
☐ Risk Analysis (Financial)	
Financial Based Risk (\$)	36127.840506
Probability Category	1
Consequence Category	D
Risk Priority	Medium
■ Target Date Results:  ■ Target Date Results:	
Plan Date with Inspection Results: 1/1/2015	
Recommended Inspection(s)	
History	
General Damage Factors Damage Factors Properties Selection Properties	Consequence Results Properties

In terms of a cost analysis of the risk, and not including the potential loss in property value by having the pipe run across city property, the city council recommended that the community accept the proposed pipeline as an additional revenue source with minimal risk.

# **Category 22 on Risk Based Maintenance from The Scoreboard for Maintenance Excellence**

The following pages include category 22 for risk-based maintenance (RBM).

22. Risk-Based Maintenance (RBM) -
Item#
1.
This company has a process and resources to perform the asset condition and risk assessment and defin
2.
3.
Table Continued

Item#	Rating: excellent—10, very good—9, good—8, average—7, below average—6
4.	Physical asset operators and owners within the oil, gas, and petrochemical sector
5.	Preventing all failures is generally not feasible from either a technical or an ecor
6.	Your maintenance strategies have evolved to support the technological requirem
7.	When looking closely at your company, most people will not find a disorientatin
8.	RBM: Your maintenance strategy considers RBM as an evolution of reliability-c
9.	Your company has the capability to quantify problems with probability as well a
10.	API RP 580 standard defines risk as the combination of the probability of an eve
Table Continued	

Item#
11.
12.
13.
14.
15.
The monitoring and maintenance programs for high-risk assets are typically condition-based maintenan
Table Continued

Item#	Rating: excellent—10, very good—9, good—8, average—7, below average—6, poor—5
16.	RBM is a suitable strategy for all maintenance plants as well as your site. As a methodology
17.	A framework for determining risk is in place. Here the RBM framework is applied to each s
18.	Collect data: For each risk that is being identified. Accurate data about the risk needs to be o
19.	Risk Evaluation: At the risk-evaluation stage, your operation considers both the probability
20.	Rank risks: With the risk evaluation complete, the probability and consequence are then con
21.	Create an inspection plan: If the risk is unacceptable, you evaluate a plan to inspect the system.
22.	Propose mitigation measures: At this stage, you have a proposal for mitigating the risk, usin
23.	Reassessment: Finally, your proposal is evaluated against other factors, such as legal and res
24.	RBM decision methods can be categorized into qualitative, quantitative, and semiquantitative
	22. Risk-based maintenance Subtotal score possible: 240

#### **Further Reading**

American Petroleum Institute. API RP 581 Risk-based Inspection Technology. second ed. Washington, D.C: American Petroleum Institute; 2008.

<sup>1</sup> This overview of basic RBI concepts is reprinted with permission from ReliaSoft Corporation based on "Introduction to Risk Based Inspection (RBI)," Reliability HotWire, Issue 151 (September 2013). http://www.weibull.com/hotwire/issue151/hottopics151.htm

-

### Chapter 15

# Developing Improved Repair Methods and Reliable Maintenance Planning Times with the ACE Team Process

\_

#### **Abstract**

This chapter outlines the methodology for applying the ACE Team Benchmarking process. This very easy-to-use procedure will allow a planner/scheduler to be the central organizer of the ACE Team within an organization desiring to use this methodology for developing benchmark jobs, the use of slotting, plus allowances to develop reliable planning times for scheduling. This chapter also includes a step by step process to charter the ACE Team. It is a true team-based process that utilizes skilled crafts people, technicians, supervisors, planners and other knowledgeable people to do two things; a) Improve current repair methods, safety and quality and then b) Establish work content time for selected "benchmark jobs" for planners and others to use in developing reliable planning times

### **Keywords**

ACE System time ranges; ACE Team; Benchmark analysis sheet; Benchmark jobs; Craft performance; OCE; Range of time concept; Reliable planning times;

# Slotting; Spread sheets; Work content comparison; Wrench time

Work measurement within maintenance has never been nor will it be an exact science. However, we must have a reliable method to establish maintenance repair time that is acceptable, accurate within limits, and reasonable from the point of view of the craftspeople. There have been several ways that time standards for maintenance work have been developed. These include

- 1. Construction Trade Estimates (Commercially published): These types of standards are used by contractors when bidding on construction jobs. Therefore, they are not recommended for in-house maintenance work because construction is not recommended for skilled craft technicians. These standards include engineering safety standards in the interest of better safety, and most relate to construction rather than maintenance.
- 2. Educated Guesses: Many planning and scheduling processes start, they normally began with pure estimates or educated guesses. Of course, they are the least costly and least time-consuming. Disadvantages include that they reflect personal judgment, whether by a supervisor or planner. In addition, the time is typically the time in which the person feels they could accomplish the repair. One key point here is that as a planner gets started and the time estimated is needed for the backlog, there must be a starting point and educated guesses can be useful. It is very important to quantify backlog not in jobs but rather in man hours. Remember that the common denominator is man hours. As time and experience continues, other methods may be considered.
- 3. Historical Averages: This method considers work orders of the same type and taking out extreme highs and lows and then taken an average of a specific job. Some computerized maintenance management systems (CMMS) have this functionality, but results are just averages with all of the current nonrelated maintenance activities included. The craft performance (CP) factor of overall craft effectiveness (OCE) is standard labor hours divided by actual labor hours. Using historical averages, CP is normally 100%. Therefore, this makes performance and schedule compliance looked favorable when using historical estimates. Thus, we might ask "how demanding are these expectations." If work order descriptions are not complete, then the averages will not be reliable. In essence, they reflect the current work environment, methods, and tooling rather

than standard procedures and methods.

- 4. Adjusted Averages: Adjusted averages provide the first step toward true expectancy or a standard. These averages require a base, perhaps 6 months, during which time averages are collected for repetitive jobs and activity work sampling is concurrently performed. This work sampling looks to establish the average CP for various crews. If a given job averages 10 labor hours and the crew averages 70% performance during the base, then 7 labor hours becomes the adjusted average. This method is not recommended in any situation.
- 5. Slotting: This is what the ACE Team Process is all about. However, it goes way beyond just an estimate of time. It includes finding ways to improve repair methods and identify how the failure occurred and how future failures can be detected before actual failure. It is a method that uses experienced craftspeople, planners and supervisors to provide benchmark job estimates on jobs they understand and have had a hand in developing "work content time for benchmark jobs."
- 6. Universal Maintenance Standards (UMS): UMS look at method analysis and use "standard data" for every detailed motion of using a maintenance tool. It was first used by the U.S Navy and then by consulting firms such as H. B Maynard. I take back what I said earlier about the Harvard Business Review. They did publish a great White Paper on UMS, covering it very well.

Why the ACE Team Process: The ACE Team exists to provide a well-qualified team of experienced craftspeople, technicians, and supervisors to establish benchmark repair jobs and work content time for these jobs. The ACE Team is chartered to help develop the ACE System for establishing maintenance performance standards at each site.

Process: What are the steps to be followed, and what are the questions to be answered by this team?

- 1. Orientation, charter review, and charter acceptance or modification.
- 2. Ensure that all team members understand team objectives and agree on what needs to be achieved and the criticality of this initiative to the planning and scheduling process.
- 3. Understand the current concepts of the ACE System as defined in your

organization's maintenance planning and scheduling standard operating procedure (SOP).

- 4. Understand the basics of the new XYZ system for CMMS/enterprise asset management (EAM), the characteristics, functionality, and performance.
- 5. Determine critical repair jobs that should be used as representative benchmark jobs; define key steps and elements for each benchmark job; and define any special tools, safety requirements, and other special requirements for the job.
- 6. Determine ways to improve doing the jobs being analyzed as benchmark jobs, considering better tools, equipment, skills, and even better preventive maintenance (PM)/predictive maintenance techniques to avoid this type of failure problem.
- 7. Conduct the ACE Team Process as outlined in the 10-step approach from the SOP.
- 8. Develop a team consensus on work content times for all of the benchmark jobs selected.
- 9. Continuously improve the ACE Team Process within the XYZ organization as an element of our continuous reliability improvement efforts.

# Evidence of Success: (What results are expected, in what periods, for this team to be successful?)

- 1. A sufficient number of benchmark jobs will be developed as to individual tasks and steps along with estimated work content times to complete the site's ACE Team spreadsheets.
- 2. The actual period to complete the initial spreadsheets will depend on the time allocated by the ACE Team at each site.
- 3. ACE Teams from one site are expected to share their results with the other sites. Because of the similar nature of equipment, the sharing of benchmark job write-ups and even work content times that ACE Teams have developed can be shared throughout the operation.
- 4. Overall success will be determined by each planner having adequate

spreadsheets that cover all construct areas as well as types of crafts work (mechanical, electrical, etc.) so that planning times can eventually be established for 80% or more of the available craft hours.

Resources: (Who are the team members, team leader, and team facilitator that will support the team if needed? How much time should be spent in meetings and outside of meetings?). The ACE Team should consist of the following representatives:

- One maintenance planner/team leader
- One maintenance supervisor
- Two to three crafts representatives from area 1
- Two to three crafts representatives from area 2
- Two to three craft representative from area 3

Note: Crafts representatives should rotate periodically and sufficient numbers should be designated so as to have at least two to three representatives from each craft area when benchmark jobs from these areas are being reviewed for job steps and estimated for work content time.

• An initial ACE Team meeting will be for 1 h or more. The team shall meet initially for at least 3 h each week. This team's activities and success will be considered as part of each team member's job.

Constraints: (What authority does the team have, what items are outside of the scope of the team, and what budget does the team have?)

- 1. No changes to organization structure are anticipated.
- 2. Benchmark job plans are to be reviewed and approved by the maintenance manager.
- 3. Each team must obtain buy in and overcome concerns from the other crafts on their estimates for benchmark jobs and repair methods recommended for each benchmark job.

- 4. Team presents implementation status reports as required and any additional recommendations to the XYZ maintenance excellence strategy team.
- 5. The ACE Team has the authority to recommend new and improved repair methods, new tools to help craft productivity and safety, and other improvements to improve asset reliability as developed during the ACE Team Process.

Expectations: (What are the outputs, when are they expected, and to whom should they be given?)

- 1. Spreadsheets for the site that cover all crafts areas and construct types are completed by \_\_\_\_\_.
- 2. Reliable planning times are provided for benchmark jobs so that effective planning, performance measurement, backlog control, and level of PM work can be established with a high level of confidence.
- 3. ACE Team provides a steady source of continuous improvement ideas to make repair jobs safer and easier.
- 4. Minutes are to be completed for all team meetings and sent to the maintenance manager and the XYZ maintenance excellence strategy team.

# The Methodology for Applying the ACE Team Benchmarking Process

This section will outline the methodology for applying the ACE Team Benchmarking process. This very easy-to-use procedure will allow a planner/scheduler to be the central organizer of the ACE Team within an organization desiring to use this methodology for developing benchmark jobs, the use of slotting, and allowances to develop reliable planning times for scheduling. A graphical illustration of this process is included in Figure 15.1.

### **ACE Team Benchmarking Process**

### A New Maintenance Work Measurement Tool from the Maintenance Excellence Institute International

A True Team-Based Approach: Here, we will outline a new and highly recommended methodology for establishing team-based maintenance performance standards that we call reliable planning times. The ACE Team Benchmarking process (ACE System) was developed by The Maintenance Excellence Institute International founder back in the 1980s. It is a true team-based process that uses skilled craftspeople, technicians, supervisors, planners, and other knowledgeable people to do two things:

- 1. Improve current repair methods, safety, and quality
- 2. Establish work content time for selected benchmark jobs for planners and others to use in developing reliable planning times



Figure 15.1 The ACE Team benchmark job analysis. ACE, a consensus of experts.

Benchmark Jobs: This is a proven process that uses "a consensus of experts" (ACE) who have performed these jobs and can also help improve them. In turn, relatively few representative "benchmark jobs" are developed for the major work areas/types within the operation. Benchmark jobs are then arranged into time categories ("time slots") on spreadsheets for the various craft work areas.

Spreadsheets: By using spreadsheets to do what is termed "work content comparison" or "slotting", a planner is then able to establish planning times for many jobs using a relative small sample of "benchmark jobs". This publication also provides the step-by-step process on using the ACE System. Most importantly, it will illustrate how this method supports continuous reliability improvement and quality repair procedures for all types of maintenance repair operations.

Nearly every CMMS allows a user to enter "planned" or "standard" hours on a work order and then report on actual versus planned hours (the CP element of OCE) when the job is complete. This holds true for PM and corrective maintenance work orders as well as project-type work for renovation, major overhauls, and capitalized repairs. Most do not use this for one main reason: They do not have reliable planning times or standard hours available.

Determining the standard hours an average maintenance technician will require to complete a task under standard operating conditions provides everyone involved a sense of what is expected. The standards provide management with valuable input for backlog determination, manpower planning, scheduling, budgeting, and costing. Labor standards also form the baseline for determining craft productivity and labor savings for improved methods.

The ACE System Supports Continuous Reliability Improvement: Maintenance work by its very nature seldom follows an exact pattern for each occurrence of the same job. Therefore, exact methods and exact times for doing most maintenance jobs cannot be established as they can for production-type work. However, the need for having reliable performance measures for maintenance planning becomes increasingly important as the cost of maintenance labor rises and the complexity of production equipment increases. To work smarter, not harder, maintenance work must be planned, have a reasonable time for completion, use effective and safe methods that are performed with the best personal tools and special equipment possible and have the right craft skill using the right parts and materials for the job at hand.

Investment for Planners: With an investment in maintenance planners, there must be a method to establish reliable planning times for as many repair jobs as possible. The ACE System provides that method as well as a team-based process to improve the quality of repair procedures. Various methods for establishing maintenance performance standards have been used, including reasonable estimates, scientific wild average guess (SWAGs), historical data, and engineered standards such as UMS using predetermined standard data. These techniques generally require that an outside party establish the standards, which are then imposed upon the maintenance force. This approach often brings about undue concern and conflict between management and the maintenance workforce over the reliability of the standards.

The ACE System: A Team-Based Approach: Rather than progressing forward together in a spirit of continuous improvement, the maintenance workforce in this type of environment often works against management's program for maintenance improvement. The ACE System overcomes this problem with a team-based approach involving craft people who will actually do the work that will be planned later as the planning and estimating process matures. As shown later, the ACE System is truly a team-based process that looks first at improving maintenance repair methods, the reliability of those repairs to improve asset uptime, and then secondly to establish a benchmark time for the job.

Gaining Acceptance for Performance Standards: To overcome many of the inherent difficulties associated with developing maintenance performance standards, the ACE System is recommended and should be established as the standard process for modern maintenance management. Other methods such as the use of standard data can supplement the ACE System. The ACE System methodology primarily relies on the combined experience and estimating ability of a group of skilled craftspeople, planners, and other

#### with technical knowledge of the repairs being made within the operation.

The objective of the ACE Team Benchmarking process is to determine reliable planning times for several selected benchmark jobs and to gain a consensus and overall agreement on the established work content time. This system places a very high emphasis on improving current repair methods, continuous maintenance improvement, and the changing of planning times to reflect improvements in performance and methods as they occur. The ACE System is a very progressive method to developing maintenance performance standards, a very hard area in itself to develop reliable and well-accepted planning times for maintenance. The complete 10-step approach to implementing the ACE Team Benchmark process within your current planning, estimating, and scheduling can be found at http://www.pride-in-maintenance.com.

## **Application Guide for the ACE Team Benchmarking Process**

Generally, the ACE System parallels the concepts of the UMS approach. For the UMS and the ACE System, the "range of time concept" and "slotting" are used once the work content times for a representative number of "benchmark jobs" have been established. The ACE System focuses primarily on the development of work content times for representative "benchmark jobs" that are typical of the craft work performed by the group. An example of an actual UMS benchmark job that has been analyzed with standard data to establish work content time is included in Figure 15.1.

For the example illustrated in Figure 15.2, we see that through the use of UMS standard data, the eight elements of the job, including oiling of the parts, have been analyzed and assigned time values that total 1.07 h. Because the time value for this benchmark job falls within the time range of 0.9–1.5 h (see Figure 15.3), it is assigned a standard work content time of 1.2 h.

What this implies is that the actual work content for this benchmark job will generally be performed within the time range for the work group G (0.9–1.5 h) with a confidence level of 95%. When we refer to "work content," the following applies: The work content of the benchmark job excludes things such as travel time, securing tools and parts, prints, delays, and personal allowances, etc. The benchmark time that is estimated does not include the typical "make-ready" and "put-away" activities that are associated with the job. Therefore, several allowances must be added to the work content time by a planner to get the actual planning time for the job.

#### Benchmark Analysis Sheet

Decription: Remove and reinstall 3 oil wiper rings				B.M. No:				
split type of air compressor 1950 cfm at 100 psi					Craft: Mech			
				Dwns:	N/A			
			- 3	No. of N	Men: 1	Sh.	of :	
	्			Analyst	: JEB	Date:		
	Men	Operation Description		ference ymbol	Unit Time	Freq.	Total Time	
1	1	Remove and reinstall 1 crankcase cover	PWN	-10-10	.030	2	.060	
2	- (1)	Remove and reinstall 2 bolts	PWI	N-10-1	.011	4	.044	
3	- 1	Slide gland off and on	PW	N-10-7	.012	2	.024	
4		Unfasten 3 garter springs and refasten	PWI	N-10-8	.023	6	.138	
5		Remove and reinstall 9 wiper ring	PWI	N-10-9	.012	18	.216	
		segments		0.				
6		Fit 9 ring segments to piston rod	PW	N-5-2	.040	9	.360	
7		Clean 12 springs and rings	PW	N-8-1	.016	12	.192	
8		Oil 12 parts	PW	N-3-9				
		2 squirts per pint	9					
	1	.0023 + .0012(N2)		- 8	.0023	1	.002	
	13	N2 = number of application	8		.0012	24	.029	
T								
	8		4					
1								
1								
1								
1				-				
1			1					
+			10					
+								
+			1					
-			-					
No	tes	1	99200				0.523	
			Ber	nchmark t	ime		1.07	
_	_		Sta	ndard wor	rk group		Е	

Figure 15.2 An example of a benchmark job analysis using UMS standard data. UMS, Universal Maintenance Standards.

Benchmark Job Description				Benchmark Job No.: MECH- AC-5			
		einstall 3 oil wiper rings, split ressor 1950 cfm @100psi	Craft: 1	Mechani	cal		
			Ref. Dra	wing: A	C-9999		
			No. of C	Crafts: 1			
			Analyst	: JEB/A	CE Tear	n	
Line No.	No. of Crafts	Operation Description	Ref. Code	Unit Time	Freq	Tota	
1	1	Remove 2 bolts to remove crankcase cover				.10	
2		Slide gland off and unfasten 3 garter springs				.10	
3		Remove 9 wiper ring segments				.10	
4		Clean 12 springs and rings and properly oil all 12 parts per Lube Spec #AC-2000	CLN-1			.25	
5		Reinstall 9 wiper ring segments and fit to piston rod				.50	
6		Slide glide on and fasten 3 garter springs				.10	
7		Replace. crankcase cover and fasten with 2 bolts				.10	
establ	ished to	Average benchmark time clean and oil this # of small parts ication noted above.	00000	hmark for rk Cont	100	1.25	
		ÿ		ndard V Group	Vork	E	

## Figure 15.3 Example of an ACE Team benchmark analysis. ACE, a consensus of experts.

### Important Note: The estimated time for a benchmark job is for pure work content time and is made under these conditions:

- 1. The right craft skills and level of competency is available to do the job.
- 2. An average skilled crafts person, two-person team, or crew is doing the job giving 100% effort (i.e., a "fair day's work for a fair day's pay").

Task Area: Task areas would be mechanical, electrical, hydraulic, etc or by major areas such as fork lift, conveyor systems or building systems types of repairs.

204.0016	Group F 2.0 Hours	Group G 3.0 Hours	Group H 4.0 Hours
<1.5	>1.5 <2.5	>2.5<3.5	>3.544.5
scription A	Job Description E	Job Description I	Job Description M
scription B	Job Description F	Job Description J	Job Description N
scription C	Job Description G	Job Description K	Job Description O
scription D	Job Description H	Job Description L	Job Description P
	Hour  <1.5 scription A scription C scription D	Hour  <1.5 >1.5 <2.5 scription A Job Description E scription B Job Description F scription C Job Description G	Hour 2.0 Hours 3.0 Hours  <1.5 >1.5 <2.5 >2.5

#### Figure 15.4 Example spreadsheets for workgroups E, F, G, and H.

- 3. The correct tools are available at the job site or with the craftsperson or crew.
- 4. The correct parts are available at the job site or with the craftsperson or crew.
- 5. The machine/process/asset is available and ready to be repaired.
- 6. The craftsperson or crew is at the job site with all of the above and proceeds to complete the job from start to finish without major interruption.

Once a sufficient number of benchmark job times have been established for craft areas and work types, these jobs are categorized onto spreadsheets. They are established on spreadsheets by craft and task area and according to the standard workgroups (Figure 15.4), which represent various ranges of time. This is exactly the concept behind the UMS approach. Figure 15.5 provides an example of a spreadsheet for workgroups E, F, G, and H with jobs that have benchmark times of 1.2, 2.0, 3.0, and 4.0 h, respectively. A complete set of ACE Team Spreadsheets for Workgroup A (0.1 h) up to Workgroup T (30.0 h) is available in the forms section of Appendix G.

ACE System Work Groupings and Time Ranges: Figure 15.6 includes a listing of the ACE System work groupings and the respective time ranges for each workgroup from A to T. Likewise, spreadsheets for Workgroups A, B, C, and D would be developed with benchmark jobs having a work content time below 1.2 h. Spreadsheets for Workgroups I, J, K, and L for benchmark jobs having work content times from 5.0 to 9.0 h, respectively, would also be developed, as they were needed. Figure 15.7 shows the ACE System standard work groupings and time ranges for Workgroup U (from 32 h) to Workgroup CC (68 h).

Spreadsheets Provide Means for Work Content Comparison: After sufficient spreadsheets have been prepared based on the representative benchmark jobs from various craft/task areas, a planner/analyst now has the means to establish planning times for many different maintenance jobs using a relatively few benchmark jobs as a guide for work content comparison. By using work content comparison (or slotting as it is called)

combined with a good background in craft work and knowledge of the benchmark jobs, a planner now has the tools to establish reliable performance standards consistently, quickly, and with confidence for many different jobs.

#### EYE BALLING SPREAD SHEET

Code: 1313.133

Craft: Eyeballing Small Areas

TASK AREA: ESTIMATING SMALL AREAS							
GROUP A	GROUP B	GROUP C	GROUP D				
(0 sq ft) 10 sq ft (15 sq ft)	(15 sq ft) 20 sq ft (25 sq ft)	(25 sq ft) 40 sq ft (50 sq ft)	(50 sq ft) 70 sq ft (90 sq ft)				
A1	B1 B2						

Figure 15 5 Example spreadsheets for comparing areas for Workgroups A, B, C, and D.

## The ACE System Time Ranges

	ACE SYSTEM TIME RANGI			
WORK GROUP	FROM	STANDARD TIME (Slot time)	то	
Α	0.0	.1	.15	
В	.15	.2	.25	
С	.25	.4	.5	
D	.5	.7	.9	
E	.9	1.2	1.5	
F	1.5	2.0	2.5	
G	2.5	3.0	3.5	
Н	3.5	4.0	4.5	
	4.5	5.0	5.5	
J	5.5	6.0	6.5	
K	6.5	7.3	8.0	
L	8.0	9.0	10.0	
М	10.0	11.0	12.0	
N	12.0	13.0	14.0	
0	14.0	15.0	16.0	
P	16.0	17.0	18.0	
Q	18.0	19.0	20.0	
R	20.0	22.0	24.0	
S	24.0	26.0	28.0	
Т	28.0	30.0	32.0	

Figure 15.6 ACE System standard work groupings and time ranges: A to T.

# ACE TEAM BENCHMARKING SYSTEM: WORK GROUPS & TIME RANGES Up to 69 Hours

WORK GROUPS	RANGES FROM (Hrs)	BENCHMARK TIME (Slot Time)	UP TO (Hrs)
U	32.0	34.0	36.0
٧	36.0	38.0	40.0
W	40.0+	42.0	44.0
Х	44.0	46.0	48.0
γ	48.0	50.0	52.0
Z	52.0	54.0	56.0
AA	56.0	58.0	60.0
BB	60.0	62.0	64.0
СС	64.0+	66.0	68.0

### Figure 15.7 ACE System standard work groupings and time ranges: 32–68 h.

Because the actual times assigned to the benchmark jobs are so critical, it is very important to use a technique that is readily acceptable. The ACE System provides such a technique because it is based on the combined experience of a team of skilled craftspeople and others. It is their consensus agreement on the range of time for the benchmark jobs. A consensus of experts who know the mission-essential maintenance work that is to be done.

#### The 11-Step Procedure for Using the ACE System

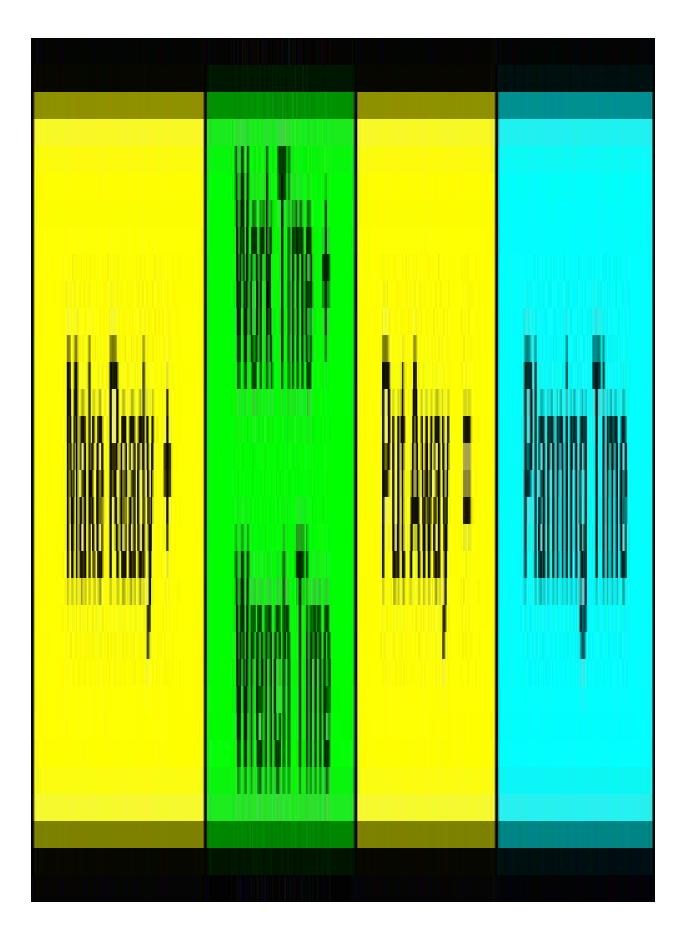
- 1. Select "benchmark jobs": Review past historical data from work orders and select representative jobs that are normally performed by the craft groups. Special attention should be paid to determine the 20% of total jobs (or types of work) that represent 80% of the available craft manpower. Focus on determining repetitive jobs where possible in all craft areas.
- 2. Select, train, and establish a team of experts (ACEs): It is important to select craftspeople, supervisors, and planners who, as a group, have had experience in the wide range of jobs selected as benchmark jobs. All craft areas should be represented in the group. To ensure that this group understands the overall objectives of the maintenance planning effort, special training sessions should be conducted to cover the procedures to be used, reasons for establishing performance measures, etc. A total of 6–10 knowledgeable team members is the recommended size for the team.
- 3. Develop an ACE Team Charter: At this point, it is highly recommended that a formal ACE Team charter is established. Section 1.0 of the Appendix provides a sample charter format that can easily be tailored for each site. The ACE Team has an important task that will take time to accomplish. However, the task of the ACE Team will be important and, in turn, their success as a team can significantly contribute to continuous reliability improvement and increased asset uptime.
- 4. Develop major elemental breakdown for benchmark jobs:
- a. For each benchmark job that is selected, a brief element analysis should be made to determine the major elements or steps for completing the total job. Another example is shown in Figure 15.3. Here, the elements of the same job that we illustrated in Figure 15.2 are used but arranged in a more logical sequence of the actual repair method. In this example, a standard time allowance for cleaning and oiling a small group of parts had already been established; therefore, reference to CLN-1 task was made. This task referenced back to a standardized lube specification (#AC-2000).

- b. This listing of the major steps of the job should provide a clear, concise description of the work content for the job under normal conditions. It is important that the work content for a benchmark job be described and viewed in terms of what is a normal repair and not what may occur as a rare exception. All exceptions along with make-ready and put-away time are accounted for by the planner when the actual planned time is completed.
- c. An excellent resource to consider for doing the basic element analysis for each benchmark job is the craftspeople (ACEs) that are selected for doing the estimating or even other craftspeople within the operation. Brief training on methods/operations analysis can be included in the initial training for the ACEs. Very significant methods improvements and methods to improve reliability can be discovered and implemented as a result of this important step.
- d. The ACE Team Process must include and also lead to getting answers to the following questions
- Are we using the best method, equipment, or tools for the job?
- Are we using the safest method for doing this job?
- Are we using the best-quality repair parts and materials, or is this a part of our problem?
- What type of preventive task and/or predictive task would help identify or eliminate the root cause of the problem?
- Where can we work even smarter, not necessarily harder?
- e. Major exceptions to a routine job should be noted if they are significant; an exception will generally be analyzed as a separate benchmark job along with an estimate of time required for such repair.
- f. This portion of the ACE Team Process ensures that the work content of each benchmark job is clearly defined so that each person/planner doing the estimating has the same understanding about the nature and scope of the job. When the benchmark jobs are finally categorized onto "spreadsheets", the "benchmark job description" information developed in this step is then used as key information about the benchmark job on the ACE Team spreadsheets.

- 5. Conduct first independent evaluation of benchmark jobs:
- a. Each member of the group is now asked to review the work content of the benchmark jobs and to assign each job to one of the UMS time ranges or slots. Each member of the group provides an independent estimate, which represents an unbiased personal estimate of the pure work content time for the benchmark job. It is essential that each team member do an independent evaluation of each benchmark job and not be influenced by others on the team with their first evaluation.
- b. Focus on work content time: It is important here for each member of the team to remember that only the work content of the benchmark job description is to be estimated and not the make-ready and put-away activities associated with the job. This part of the procedure is concerned only with estimating the pure work content excluding things such as travel time, securing tools and parts, prints, delays, and personal allowances, etc.
- c. The estimate should be made for each job under the following conditions:
- An average skilled craftsman is doing the job giving 100% effort, i.e., a "fair day's work for a fair day's pay".
- The correct tools are available at the job site or with the craftsperson.
- The correct parts are available at the job site or with the craftsperson.
- The machine is available and ready to be repaired.
- The craftsperson is at the job site with all of the above and proceeds to complete the job from start to finish without major interruption.
- d. Therefore, the work accomplished under these conditions represents the "pure work content" of the job to be performed. Establishing the "range of time" estimate for this pure work content is the prime objective of the first evaluation.
- e. It is important for each ACE Team member to remember that to develop a planning time requires the pure work content time plus additional time allowances to cover "make-ready" and "put-away" type activities associated with each job as illustrated in Figure 15.8. The "make-ready time" and "put-away time" will be accounted for as the planner adds time and allowances for

these elements as the actual planning time is completed. Make-ready and putaway times are established specifically for each operation and added to the work content time to get the total planned time for the job being estimated.

- 6. Summarize first independent evaluation:
- a. Results of the first evaluation are then summarized to check the agreement among the group as to the time range for each benchmark job. A coefficient of concordance can be computed from the results if required, but normally this level of detail is not needed. A coefficient of concordance value of 0.0 denotes no agreement whereas a value of 1.0 denotes complete agreement or consensus among the ACEs. A consensus can generally be reached by the ACE Team within one, two, and at the most three rounds of evaluations.
- b. Define high and/or low estimates. Team members who are significantly higher or lower than the rest of the group for a particular benchmark job are then asked to explain their reasons for their respective high or low estimates. They explain their reason for their estimate to the group, discussing the method, condition, or situation for their initial time estimate. This information will then be used during the second evaluation to refine the next round of time estimates from the entire group.



#### Figure 15.8 Planning time elements.

- 7. Conduct second independent evaluation of benchmark jobs:
- a. A second evaluation is conducted using the overall results from the first evaluation as a guide for the entire team. Various reasons for high or low estimates from the first evaluation are provided to the group before the second evaluation. This can normally be done in an open team discussion with team members making personal notes to use in their second independent evaluation.
- b. The second round allows for adjustment to the first estimates if the other ACE Team members' reasons for a higher or lower estimated time are considered to be valid. In other words, results from the first evaluation plus reasons for highs and lows will allow each team member to reconsider their first estimate. In many cases, a review of the repair method or scope of work will be more clearly defined, causing a change to the time estimate for the second evaluation.
- 8. Summarize second evaluation:
- a. Results of the second evaluation are then summarized to evaluate changes or improvements in the level of agreement. The goal is a consensus among the ACEs as to the time range (workgroup) for each benchmark job. The second round should bring an agreement as to the time range.
- b. The second independent evaluation should produce improved agreement among the group. If an extreme variance in time range estimates still exists, then further information regarding the work content, scope, and repair method for the job may be needed. Here, those with high/low estimates should review their reasons for their estimates again, with the team describing the scope of work that they see is causing differences from the rest of the team.
- 9. Conduct third independent evaluation if required: This evaluation is required only if there remains a wide variance in the estimates among the group members.
- 10. Conduct a review session to establish final results: This session serves to finalize the results achieved and to discuss any of the high or low estimates that have not been completely resolved. A final team consensus on all time ranges is

the objective of this session.

#### 11. Develop spreadsheets:

- a. The benchmark jobs with good work content descriptions and agreed-upon time ranges can now be categorized onto spreadsheets. From these "spreadsheets," which give work content examples for a wide range of typical maintenance jobs, a multitude of individual maintenance performance standards can be established by the planner through the use of work content comparison.
- b. The basic foundation for the maintenance planning system is now available for generating consistent planning times that will be readily acceptable by the maintenance workforce that developed them. Attachment B to these appendices provides a graphical illustration of the ACE System.

The ACE Team approach combines the DELPHI technique for estimating along with a proven team process plus the inherent and inevitable ability of most people to establish a high level of performance measures for themselves. As used in this application, the objective for the ACE Team Process is to obtain the most reliable, reasonable estimate of maintenance-related work content time from a group of experienced craftspeople, supervisors, and planners. This process provides an excellent means to evaluate repair methods and safety practices and even to do a risk analysis on jobs that leads to improved safety practices. The ACE Team Process can significantly contribute to continuous reliability.

The ACE Team approach allows for independent estimates by each member of the group, which in turn builds into a consensus of expert opinion for a final estimate. Therefore, the final results are more readily acceptable because they were developed by skilled and well-respected craftspeople from within the work unit. Application of the ACE System promotes a commitment to quality repair procedures and provides the foundation for developing reliable planning times for a wide range of maintenance activities. Figure 15.9 illustrates the complete ACE Team Process.

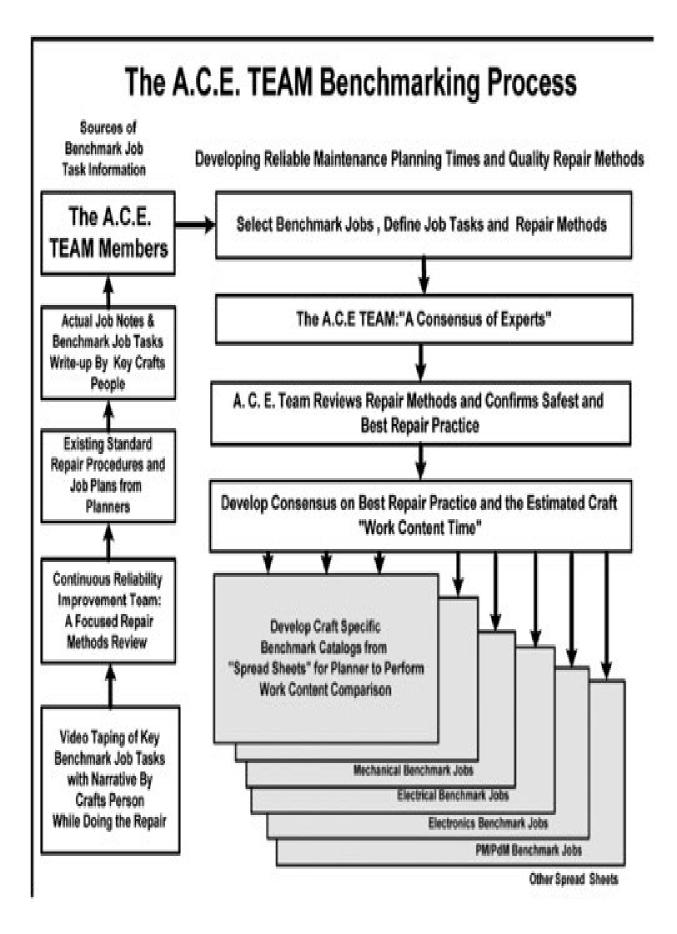


Figure 15.9 The complete ACE Team Process. ACE, a consensus of experts.

# Successful Scheduling by Keeping the Promise and Completing the Schedule

\_

#### **Abstract**

This chapter explains how the planner uses spreadsheets from ACE Team Process for determining reliable planning times for the schedule. It also includes how three types of allowances are added to the benchmark time to get a reliable planning time for the schedule: travel time, miscellaneous allowances, and personal fatigue and delay allowances. This also provides an accurate backlog based on labor hours and current craft performance. We also look at defining a firm schedule in coordination with operations and available craft hours, as well monitoring, controlling, and execution of scheduled work.

#### **Keywords**

Master schedule; Miscellaneous allowances; Personal fatigue and delay allowance; Schedule; Schedule breaks; Schedule compliance; Schedule deviations; Shop load plan; Shop schedule; Travel allowances

In this chapter, we look at scheduling, beginning with how the planner can use the ACE team process for determining reliable planning times for the schedule. First of all, the planner must have an accurate backlog that he or she has calculated based upon current craft performance. Now, we will look at defining a schedule with standard reliable estimates for an expectancy of how long the job will take. Nyman and Levitt described this as "analytical estimating," which is very much like the slotting concept of the ACE team process. Figure 16.1 illustrates how a planner can define the work content for a job being estimated for the schedule. Appendix H provides an excellent baseline for a scheduling standard operating procedure.

At this point, the planner is considering the work content of the job at hand to be estimated. So, in Figure 16.1, the planner looks at jobs in Group D (1.5 h) and sees nothing that compares directly, but the job at hand is certainly greater than 1.5 h. Now, looking at jobs in Work Group E (2.0 h), the planner also sees nothing that matches. Then, when the planner looks at Work Group F (3.9 h), he or she knows for sure that the job at hand is less than 3 h. Because the job is greater than 1.5 h and less than 3 h, the planner slots the job in Work Group E at 2.0 h. This method has proven to be 95% accurate that the job will range from 1.5 h to 2.5 h.

## Using Benchmark Job Spreadsheets for Estimating Wrench Time

Benchmark Jobs Work Group D 1.2 Hours

Benchmark Jobs Work Group E 2.0 Hours

Benchmark Jobs Work Group F 3.0 Hours

Planner Knows for Sure Job Greater Than 1.2 Hours

Job To Estimated Planner Slots Job at 2.0 Hours Planner Knows for Sure Job Less Than 2.5 Hours

This Provides 95% Accuracy that the Work Content Ranges from 1.5 Hours to 2.5 Hours

#### Figure 16.1 Using benchmark spreadsheets for estimating wrench time.

This wrench time must have three types of allowances added for it to become a reliable estimate for the schedules. The three types of allowances are shown in Figures 16.2 and Figures 16.3, Figure 16.4 and Figure 16.5.

# Factors in Determining Total Planned Time for the Schedule

The Planner now must consider adjusting the work content time adding allowances for computing the planned time for scheduling. These include;

- Travel Time Table of Allowances (TT)
- Miscellaneous Allowances (MA)
- Personal Fatigue and Delay Allowances
   (PF&D)

Figure 16.2 Allowances for determining the total planned time for the schedule.

# Example: Travel Time Table of Allowances

	Later Supplier	Allowed Hours Per Person			
From Shop To:	Round Trip Hours	Simple	Average	Complex	
Area A	0.5	0.5	1.0	1.5	
Area B	0.4	0.4	0.8	1.2	
Area C	0.3	0.3	0.6	0.9	
Area D	0.2	0.2	0.4	0.6	
All Other 0.1 Areas		0.1	0.2	0.3	
Round Tri	ps Provided	1	2	3	

Note: This table would be based on site or plant layout and distances and walking pace of 250 feet per minute

Figure 16.3 Example of travel time.

	Example	Miscellaneous Allowances Table				
		Simple Average		Complex		
1	Feedback (paperwork)	WO	Plus PM Checklist	Detailed Feedback		
2	Receive Instructions	Up to 3 minutes	Approx. 5 minutes	Approx. 10 minutes		
3	Gather tools	Tool Belt	From personal tool box	Special shop tools needed		
4	Follow Safety Procedures	Normal	Lockout	Rope area, special clothing		
5	Obtain Parts and Materials	None	Bin Stock	Storeroom requisition		
6	References, Job Plan, Drawings, etc	None	Job Plan	Multiple References		
	Allowed Hours Per Person	0.1	0.3	0.5		

Note: Appropriate estimates must be developed for each plant/operation

Figure 16.4 Example miscellaneous allowance table.

#### Personal, Fatigue and Delay Allowances (PF&D)

### Personal, Fatigue and Unavoidable Delay Allowance Table

Nature of Allowance	%	Light	Average	Heavy
Personal Time, Breaks & Clean Up	5	5	5	5
Fatigue	5-10	5	7	10
Unavoidable Delay	5	5	5	5
Sub-Total	15-20	15	17	20
Crew Balance: Multi-Person	3	3	3	3
Crew Balance: Multi-Craft	2	2	2	2
Total	15-25	15-20	17-22	20-25

#### Notes:

- 1. Use 15% on Travel Time and Job Preparation
- 2. Use Appropriate Fatigue % as applies to Direct Work Only
- 3. Crew Balance% applies to Direct Work only
- 4. Most jobs need only 15% PF&D Allowance



#### How Allowances Apply to Typical Job

#### A Typical Maintenance Job Sequence of Steps and Example Where Allowances Are Applied

	Example Writere Allowances Are Applied
Source	Task
MA	Get ready and receive instructions for doing the job. Miscellaneous Allowances (MA) includes receiving job instructions from supervisor, collecting personal tools, obtaining parts from storeroom and gathering special tools and equipment
TT	Travel to job site (Outbound)
MA	Listen to operations input regarding the problem
MA	Make preliminary diagnosis and trouble shoot prior to shutdown
MA	Shutdown and Lockout. This may be done jointly with line supervisor, control tech and/or line operator
WT	Partial or total disassembly to reach the problem area
MA	Determine full extent of the problem
MA	Identify any additional parts or material , obtain from storeroom or initiate direct purchase
WT	Reassembly of equipment using the replace parts needed
MA	Check proper job completion, test operability of equipment, clean up job site and put away tools
TT	Travel back to shop (inbound)
MA	Report on job and return unused parts, special tools and equipment
PF&D	Personal Fatigue and Unavoidable Allowances for entire job
	Legend:
Most Jobs	MA: Miscellaneous Allowances
15% to	TT: Travel Time
	WT: Wrench Time from Spreadsheets
	PF & D: Personal Fatigue and Unavoidable Delay Allowances

### Coordination Required by Planners for Successful Scheduling

- Downtime will schedule itself at worst possible time
- Planner liaison with operations must be permanent
- Planners must learn and take interest in customer problems
- Planners can help operations to think in advance
- Planner can facilitate planned work to maximize operational plans

### Preparation for the Schedule Coordination Meeting: Daily-Weekly-Monthly??

- □ Upkeep of backlog; current, cleansed and accurate
- ☐ Issuance of backlog report by job status
  - ✓ Send electronically the day before weekly schedule meeting to;
  - √ Maintenance leaders
  - √ Operations staff
  - ✓ Storeroom & Purchasing (denoting jobs awaiting parts)
  - ✓ Engineering (as Required)
  - √ Top Leaders
- □ Planner looks to resolve possible conflicts:
- □ Planner must have good answers to better chair and coordinate any scheduling meetings
- □ Determine resources available for backlog relief
  - Ensure realistic capacities available (in house or contractors)
  - ✓ Ensure schedule commitments can be met

# Preparation for the Weekly Schedule Coordination Meeting

- Planner groups jobs for optimization
  - ✓ Link multiple jobs on same equipment or area
  - ✓ Link multiple jobs requiring same equipment, etc.
- □ Have list of all jobs "Ready to be Scheduled"
  - ✓ Set up by "Required Start Date"
  - ✓ Do not include jobs where material might arrive during the "schedule week"
  - √ Typically plenty of work is in "Ready Backlog"

## Preparation for the Weekly Schedule Coordination Meeting

- Planner develops preliminary (first cut) of next week's schedule considering;
  - √ Resources needed for next week's PM/PdM
  - ✓ Resources needed for any carry-over work
  - ✓ Preliminary schedule that has been reviewed by maintenance
    - Based upon "Required Start Dates" and "Ready Backlog"
    - Current craft capacities and priorities
    - Equipment availability
    - Contractor support

#### The Weekly Schedule Coordination Meeting

- ☐ The best case; Operations approves the schedule!
- □ Operations is the approver of "schedule-breaks" for "urgent" jobs not on the current weekly schedule



### **Key Procedures for Effective Scheduling**

### These three must be performed concurrently for developing an effective schedule;

- ✓ <u>Job Loading</u>: setting up the right jobs, balancing immediate needs of operations with long term maintenance needs for reliability and asset care
- ✓ Job Scheduling: Sequencing the loaded jobs through the schedule based on meaningful estimates of duration and agreed upon access to equipment
- ✓ Manpower/Equipment Commitment: ensure optimal utilization of resources via a labor and equipment deployment plan to achieve schedule

### Weekly Scheduling and Available Resources

10 Crafts x 40 Hrs. =	400.0 Hrs.
Less Carryover	
Less Late & Early	
Less Vacation	
Less PM	
Less Standing WO	
Less Emergency	
Net Hours. Available	

- ✓ Prepare a schedule form for each supervisor; week beginning date, foreman or crew leader etc.
- ✓ Planner must determine from supervisors, vacation time, known absences etc.
- ✓ Define net available hours for next week's schedule
- ✓ Review all jobs in backlog, start with incomplete jobs from current or previous schedules
- ✓ Review Planned job Packages
  - ✓ Ensure all are complete for scheduling and assignment
  - √ Final confirmation of parts, equipment & special tools
  - √ Permits and safety instructions

- ✓ Plan strategy on a weekly basis; rigid enforce rule that schedules complete for each supervisor by <u>Friday</u>...
- √ If coordination meeting on previous <u>Thursday</u>
- ✓ Work schedules must be balanced against available craft hours and equipment
- ✓ Schedule to consume all available craft resources
- ✓ Schedule what can be done, not necessarily what needs to be done

- ✓ Schedule a full day of productive work for each person
- ✓ Schedule majority of crews for important work that needs to start and be completed without interruption
- ✓ But to a "few good people" who are flexible.
  - √ Assign to lower priority jobs
  - √ 10% to 15% of scheduled hours
  - √ Jobs that can be sacrificed for emergencies
  - ✓ So they can break away for urgent schedule-breaks
  - ✓ Come back to scheduled job with minimal loss of efficiency

## Do Not Schedule a Job Until All of These Things are in Place

Right People And Skills

Follow-Up & Continuous Reliability Improvement

Right Parts Materials

Scheduled Jobs Must Have All These in Place Right Tools & Special Equipment

Right Information

Right Timing & Priority for Scheduling Right Equipment Available For Repair

- ✓ List jobs in descending order of important starting with PM/PdM first based upon agreements reached in weekly schedule meeting
- ✓ Determine most logical time to schedule PM/PdM's
  - √ Early morning most likely for breakdown
  - ✓ End of day bad because they might not get done
  - √ Mid morning or mid afternoon is best
- ✓ Add jobs totaling about 10% to 15% of schedule hours as provisional jobs.
  - √If scheduled job is delayed
  - ✓ If scheduled job completed in less than estimated time

- ✓ Establish contingency section of the schedule
  - Jobs where equipment was not expected to be available when the schedule was firmed up
  - But if equipment is available they are more important than some jobs on primary schedule
  - Provisional jobs must <u>also</u> be properly planned
  - Moving these into the schedule is proactive and counts toward schedule compliance

- ✓ Avoid duplicate shutdown by scheduling all work requiring common equipment when appropriate
- ✓ Save minor indoor jobs for severe temperatures and increment weather
- √ Eliminate unnecessary trips
  - √ Jobs in the same location
  - √ Jobs with same equipment, special tools & material
  - ✓ Delivery additional parts & materials needed to site

- ✓ Schedule multi-person jobs as first job in morning, all
  there to start at same time
- ✓ Consider previous assignments when scheduling multiperson jobs later in the day
  - One craft a one hour job
  - Helper to a two hour job
- √ Think about crew balancing on multi-person jobs
  - Think about a 4 person job-Seldom will all be working
  - Often a small job in same area can be worked on concurrently

- ✓ Planner may have to allocate people to specific jobs with supervisor approval
  - Pick based on skill & aptitude
  - Experience over time helps here
  - Balance equipment specialization (Generators, Pumps)
- ✓ Planned job packages delivered to supervisor
  - Ensure nothing falls through crack
  - Responsibility now transitions from planner to supervisor
  - Later supervisor-craft transition for job execution

### Key Guidelines for Completing the Scheduling Process

- √ Operations provided copy of schedule
  - Confirm and document all agreed upon commitments
  - Everyone understands how to handle "schedule-breaks"
- √ Vital that schedules be studied and approved by everyone concerned
- ✓ Weekly schedule now becomes document where all parties have mutual contributions and ownership



# Key Guidelines for Completing the Scheduling Process

- √ When urgent work done at expense of scheduled jobs;
  - √ Schedule overload occurs
  - Carried over to next period
  - ✓ Overtime authorized
  - ✓ Displaced job is one scheduled for area that initiates
- ✓ Schedule breaks should be approved by Maintenance Manager and Operations manager

### Key Guidelines for Completing the Scheduling Process

- ✓ Finalize tactics on a daily basis when schedule is being executed
  - Updated each evening during week it is in force
  - If transitioning from reactive to proactive, the updating process can be a burden
  - Planner will have to do it until schedule compliance improves
  - Supervisor can and should do it later on
- ✓ Operations must advise ASAP when equipment can't be released
- ✓ Maintenance advises operations when schedule runs over. Could be the customer, the tenants etc
- ✓ Planner must ensure coordination takes place

## Job Close Out and Follow Up

- Begins with good feedback from crafts and supervisor
- Job not complete without good feedback on work performed
- For well planned jobs this should be minimal
   Approved out of scope work must be reported

  - ·Planner adds extra planned time in this case
- Most basic feedback is labor hours charged via labor reporting process
- Next is parts and materials crafts had to get from stores
- Equipment costs/rentals should be part of the plan

## Schedule Compliance

- √ Schedule compliance measures customer service
  - · Planners plan for it

  - Supervisors make it happen
     Crafts & crews really make it happen
  - All must keeps plan informed of both good & bad situations
- ✓ Planner calculates schedule compliance each week
- ✓ Not to place blame but to improve future performance
- √ Schedule non-compliance is very serious when maintenance fails to meet the schedule (Keep the promise)
  - Customer concerns
  - Hinders future cooperation
  - Feeds distrust
  - Future reluctance to release equipment
  - · Cost over runs "adds fuel to the fire"

- √As the Planning/Scheduling process begins, it reveals previously hidden problems
- ✓ Many where crafts can not do their job due to practices outside their control
- √ Reasons for non-compliance should be;
  - ✓ Recorded
  - √ Reported
  - √ Studied for trends and ultimate improvement
- √ The following Figures provide typical reasons for schedule non-compliance and recommended codes for tracking each

- √FR: Operations fails to release equipment as promised
- ✓ EE: Excessive emergencies
  - Crafts are pulled off scheduled jobs for work on less important jobs
  - Common where operations is allowed to redirect maintenance
  - Failure to go through work management process
- ✓PA: Poor assignment of crafts; crafts fall short of expectations,
  - Schedule must be feasible from the start
  - Not feasible unless detailed to level of individual or crew assignments

- ✓ IC: Insufficient craft capacity; lack of cross training contributes to shortage of the right skills
- √ SO: Stock outs are frequent
  - √ Inaccurate inventory control
  - ✓ Excessive time finding what is in storeroom
  - ✓ Parts not requisitioned
- ✓ PP: Planned jobs do not reflect reality
  - √ Scope expands
  - √ Plan for parts is incorrect
  - √ Job steps incomplete
  - ✓ Lockout, specifications and regulations not documented

- ✓ DU: Failure to meet estimated job duration
  - Was the estimated time on the schedule wrong?
  - Did the crew perform poorly
  - Other problems; scope creep etc

✓ EA: Excessive absenteeism and simultaneous peak loads

Remember

If You Can't Measure IT, You Can't Improve IT!

### Calculation of Schedule Compliance: Two Methods

A. Schedule Compliance =
Scheduled Craft Hours Completed
Total Craft Hours Scheduled

800 Hrs Completed 1000 Hrs Scheduled = 80% Schedule Compliance

> B. Schedule Compliance = Scheduled Jobs Completed Total Jobs Scheduled

12 Jobs Completed 15 Jobs Scheduled = 80% Schedule Compliance

## Calculation of Schedule Performance

Schedule Performance =
Scheduled Craft Hours Completed
Total Craft Hours Available

800 Hrs Completed
1600 Hrs Available = 50% Schedule Performance

Measures % of craft hours available that were in fact scheduled and completed

## Schedule Compliance and Schedule Performance

- Schedule Compliance can be high because only a small % of craft hours are scheduled
- But start formal scheduling measurement process knowing you have a Win-Win Situation
  - ✓ Begin with lesser number of scheduled craft hours
  - ✓ Work up to more hours as scheduling process matures
  - ✓ Ensure operations understands this from Day One
  - ✓ Operation Wins Maintenance Wins Customer Wins

## Measuring Performance of the Planning and Scheduling Function

- ✓ Overall measurement of maintenance requires a number of metrics (10-15 possibly)
  - We will see this with The Reliable Maintenance Excellence Index
  - Planning/scheduling impacts most of these
  - Planner typically responsible for the overall process
- √ However only a few act as pure measures for planners
- Example; Schedule Compliance and Craft Performance depends on supervisor/crafts
- √ Planner job not to predict results
- ✓ Planner job is to establish expectations

## Specific Measures for the Planning and Scheduling Function

- ✓ Per cent of Work Orders covered with Planned Job Packages
- ✓ Percent of Work Orders with reliable estimate of required craft hours
- ✓ Reliability of Backlog by status (Accuracy, completeness)
- ✓ Mean time from work request to "Ready to be Scheduled"
- ✓ Mean time between "Job Completion" & "Job Close Out"
- ✓ Steady and meaningful expansion of planner technical library
- √ Others as well

## Specific Measures for the Planning and Scheduling Function

- ✓ Customer satisfaction with planner communication, coordination and feedback (periodic survey)
- √Supervisor satisfaction with planner support on planned work orders (periodic survey)
- √Crew satisfaction with thoroughness of planner's work
  (job plan survey)
- √ Timely posting of schedules and associated planned
  job packages
- √ Timely and accurate preparation, distribution or posting
  of control reports/trend charts (where responsible)

## Planning and Scheduling Improves Craft Productivity

PLANNING and SCHEDULING WILL IMPROVE CRAFT LABOR PRODUCTIVITY

#### Maintenance, Repair, and Operations (MRO) Material Management

\_

#### The Missing Link in Reliability

#### **Abstract**

This chapter takes a close look at why our spare parts can have a big impact on reliability. Typically, most operations, maintenance, and reliability professionals associate materials management with having, or not having, spare parts on hand. Despite their focus on optimizing plant performance, too little attention is paid to the maintenance of the spare parts that they hold in stock. The reason for this is that materials management is often thought of as a sideline or support activity rather than as a core function for achieving reliability, and so the influence that materials management actually has on reliability is underestimated. The reality is that many companies could significantly improve their reliability outcomes by improving their materials management.

#### **Keywords**

Asset tracking; Configuration data; Downtime; Maintenance repair operations (MRO) materials management; Reliability program; Spare parts ownership; Spares management; Spares tracking; Work orders

I am very pleased to have contributions from two authors, Phillip Slater and Art Posey, to kickoff this chapter on maintenance, repair, and operations (MRO) material management. As shown in this chapter, there must be close integration between maintenance, storeroom, purchasing, vendors, and even finance. Reliable spares and reliable vendors are part of a reliable MRO supply chain.

### Integration Between Maintenance, Storeroom, Vendors, Planning & Scheduling and Finance Discussion: Do these operations work together in your operation? · Does Maintenance get the customer service Finance? Maintenance from the Storeroom and Purchasing that it needs? What about Purchasing customer service to your Planning & storeroom and to **Purchasing** Scheduling maintenance? Vendors? Storeroom What about your Storeroom and the customer service to maintenance?

#### Introduction

"Oh no, not again!"—Is this the perennial cry of the maintenance and reliability professional? We all know this situation: The maintenance team rectified a failure and that repair has now failed again shortly after. This is both annoying and frustrating—after all, why can't we get these things right the first time? Usually, we are quick to blame the technician, the technique, or the design. But none of these may be the fault; the cause of the breakdown could be a poorly maintained spare part.

Empirically, we can say that equipment failures result from a combination of poor design, incorrect operation, incorrect installation, inappropriate care activities, and poor cleanliness/environmental management. Therefore, it ought to be no surprise that we can also say that a vast majority of failures are self-induced, as we control four of those five factors.

Maintenance and reliability practitioners might also consider that reliable operations are achieved through a combination of equipment selection, maintenance program design, the use of tools to enable condition monitoring, and skills development of the team. However, many self-induced and premature failures are more likely the result of poor materials handling and storage methods for spare parts. For many maintenance and reliability practitioners, materials management is the missing link in achieving reliability.

Typically, most MRO professionals associate materials management with having, or not having, spare parts on hand. Despite their focus on optimizing plant performance, too little attention is paid to the maintenance of the spare parts that they hold in stock. The reason for this is that materials management is often thought of as a sideline or support activity rather than as a core function for achieving reliability, so the influence that materials management actually has on reliability is underestimated. The reality is that many companies could significantly improve their reliability outcomes by improving their materials management.

# Why Your Data Does Not Tell You What You Think It Does

In order to explain this and determine what to do about it, let us initially try to understand why this problem is not obvious—that is, why your data does not tell you have a materials management problem.

Firstly, downtime is typically recorded as equipment failure rather than as a material or spares failure. So, your data is often at too high a level to recognize that the part failure is the root cause. In addition, root cause investigations are not performed on most failures, so assumptions are often made about the cause of the failure; usually, it is blamed on the installation, not a faulty part. This problem is further exacerbated by the time that may elapse between the installation of a spare part and its subsequent failure. If enough time has elapsed, we tend to disassociate the failure from the installation of the part, even though the spare part has exhibited an extremely shortened life span. Without some form of root cause analysis, we are often just too busy getting and keeping the plant going to consider this issue.

Other ways that we can mislead ourselves into not recognizing materials management issues as the cause of our problems include the following:

- Work orders were not closed off. If we are not disciplined in finalizing work orders, then the data is not available anyway. If we accept too long a delay in finalizing work orders, then not only is data timeliness an issue but we also end up relying on memory, which we all know can sometimes be selective!
- Configuration data are out of date. If our records do not reflect our equipment configuration, then how will we confidently track any problem, not just spares problems?
- Equipment hierarchies are not sufficiently granular. As mentioned above, if your equipment records are set at too high a level, then we will not be able to recognize problems.

- The team records their actions, not the equipment needs. That is, records reflect what was done (e.g., replaced fan belt) rather than observing equipment issues and requirements (e.g., broken fan belt seems relatively new, not sure why it was broken).
- Tracking of assets is inaccurate. Who really tracks their spares as assets? Is there an engineering spares register in the COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM (CMMS)?
- Multiple failure causes are rarely listed, even if they are known. If an equipment item fails due to a worn part and the repair is delayed due to a lack of availability of the part, is the delay time documented?
- Improper root cause conclusions can skew the data. If a motor is pulled from stores and prematurely fails, it may be attributed to a poor rewind, when the true root cause may have been poor storage techniques.

# **How Proper Spares Storage Can Significantly Improve Your Reliability**

Let us define maintenance as the actions required to preserve equipment in a suitably operational state such that it operates as expected when required. In that case, perhaps we can extend that definition of equipment to our spare parts—after all, aren't they also part of our equipment and don't we want them to operate as expected when required? Many early-life failures can and do result from poor preservation of the spare parts, which results from improper storage practices.

The key issues for equipment operating in a plant are exposure to the environment and the effects of being in operation. For both mechanical and electrical elements of equipment, the effects of being in operation include the kinetic effects of wear, heat, and vibration. Our primary methods of preserving these parts are lubrication and observation.

For parts that we have in storage, the issues are similar. We still need to deal with the effects of exposure to the environment, but we also need to deal with the effects of not being in operation—that is, the effects of being stationary. Let us consider these issues.

#### **Exposure to the Environment**

The key things to consider are where the spare is kept and how is it stored. For example, is it the same environment as the operating equipment? Sometimes, we are very careful to protect the operating equipment with environmental controls, such as air conditioning or dust proofing, but then keep the spares in a storeroom without either of these.

Even items kept in suitable storage or under cover are exposed to the environment and exhibit failure modes from exposure, such as the following:

- Rust
- Oxidation of rubber components in seals, belts, and other parts
- Buildup of dust (especially important in electrical, rotating, and reciprocating equipment)
- Lubrication failure (through contamination, migration, and evaporation)
- Vibration from the operating facility (slight vibration over a period of time can degrade many spare parts, from bearings to electronic components)

#### **Effects of Being Stationary**

It is easy to assume that because a part is not in operation and is environmentally protected, then it will be acceptable to operate as expected when required. However, the main enemy of reliability for items that are stationary is gravity, and gravity is always with us!

The two main influences of gravity are

- Flat spots that result from a constant weight on one section in seals, shafts, and bearings.
- Lubricants flowing to the lower areas, leaving upper areas without lubrication.

It is really important to recognize that, although you can control exposure, you must manage gravity (i.e., the effects of gravity). Therefore, environmental control is likely to be passive (in that we provide infrastructure that provides the control) but managing the effects of gravity will need to be active (we need to perform tasks regularly to ensure the integrity of the part).

To demonstrate this visually, Figure 17.1 shows the relationship between parts in

operation and parts in storage. Figure 17.2 shows the crossover between active and passive issues for parts in storage.

In Figure 17.1, you can see that whether a part is in storage or in operation, we must still manage the effects of rust, dust, lubrication (lack of), and other environmental impacts. This diagram alone indicates that, for reliable plant operation, we must maintain our parts because they are subject to many of the same issues as the items in operation.

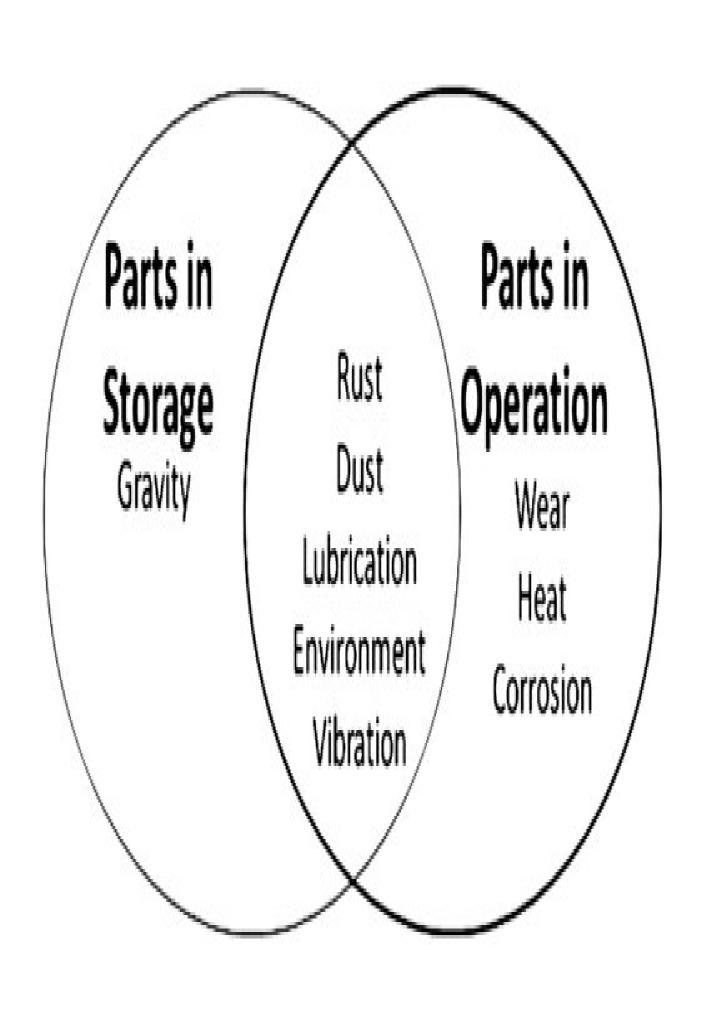
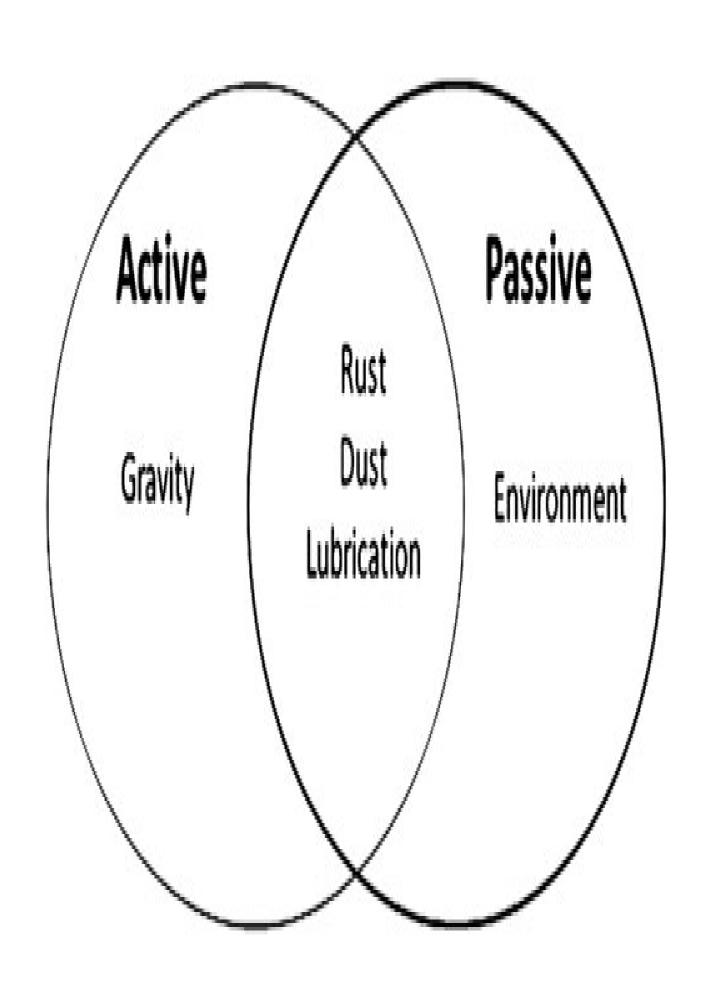


Figure 17.1 The relationship between parts in storage and parts in operation.



## Figure 17.2 The crossover between active and passive issues for parts in storage.

In Figure 17.2, we see that those same core issues of rust, dust, and lubrication require active involvement if we are to ensure that a part will operate as required when needed. This is in addition to actions that must be taken in order to counter the effects of gravity and other environmental protection.

#### The Real Function of Your Storeroom

By viewing spare parts management in this way, we can see that the real function of your storeroom is not just to store and control access to parts but also to maintain them in a condition so that they are fit for use when required. This means ensuring an appropriate care and maintenance routine as well as providing environmental protection. Neatness and organization of spare parts only helps ensure storeroom efficiency; it does not guarantee spare parts integrity.

Some basic storeroom practices that affect reliability include the following:

- Proper storage—safe from the environmental effects of dust, water, vibration, and light
- Preservation of parts—appropriate lubrication and managing the effects of gravity
- Rigorous rotation of parts—using the oldest parts first (it seems that the newest parts are always pulled first by technicians)
- Proper labeling of parts so that the correct part is selected—for example, not selecting a 20  $\mu$ m filter when a 5  $\mu$ m filter is required
- Proper access and equipment for lifting devices—in order to avoid mechanical damage to parts when storing or retrieving them

## Spare Parts Ownership Can Help Drive Reliability Outcomes

Two of the main problems with maintaining spare parts are identifying who is actually responsible for their care and whether they are qualified for the job. With parts in operation, it is usually clear who is responsible for their care and maintenance and for achieving reliability outcomes—the maintenance and reliability function. Spare parts in storage are often given over to the storeroom or warehouse, who is responsible for care and control. However, who sees the whole picture? Who really understands how those parts fit in with the overall reliability plans? Surely this is also the responsibility of the maintenance and reliability function.

Are warehouse clerks really clerks, or should they be warehouse technicians, where the care of the parts is as important as the oversight of receipts, issues, and counts? If so, a warehouse technician cannot perform a job to support plant reliability unless they have access to all manuals that reference storage requirements and have been trained in the following areas:

- Lubrication
- Effects of ozone on rubber components
- Requirements for storage of code materials (if applicable)
- Motor care and storage
- How hydraulic cylinders work and how proper storage can extend the life cycle
- How desiccants work and how they can enhance storage quality
- Bearing types, component storage, and preservation methods
- Valve types and lubrication requirements

• Temperature, humidity, cleanliness, and static electricity effects on electrical components

If you align your spare parts ownership with the need to deliver reliability outcomes, then you can start to see how you can achieve your outcomes with appropriate spare parts maintenance.

#### **Establishing a Spares Maintenance Program**

Establishing a spares maintenance program is really just like establishing the rest of your maintenance/reliability program. As we have discussed, the difference is that maintenance/reliability programs typically address kinetic effects (i.e., reliability issues that arise through the physical operation of the asset), whereas a spares maintenance program will address static effects (i.e., issues that arise through not operating). Both programs, of course, need to address environmental effects.

Therefore, establishing a spares maintenance program only really requires a change in mindset for your failure mode and effects analysis You now need to consider how the item will fail through not operating rather than how it will fail through operating. The rest of the program development is the same as with any other maintenance/reliability program: you need to identify the what, why, when, how, who, and where of your spares maintenance program.

This is an opportunity to expand your maintenance process and procedures to the personnel in the storeroom. A world-class spares maintenance program is not likely to require any more personnel than you currently have. It is an opportunity to transform the perception of your storeroom personnel from a simple receiving, issuing, and counting role to a role integral to the reliability of the facility. A written detailed program could add the structure and professionalism to transform your storeroom and your storeroom personnel.

#### **Conclusion**

Maintenance and reliability professionals spend an overwhelming amount of time and energy ensuring that they preserve the equipment in their care in a suitably operational state such that it operates as expected, when required. However, in doing this, they may overlook one of the single greatest causes of equipment failure and subsequent downtime: poor materials management. For many, this is the missing link in their reliability program. Poor materials management results from systemic issues with the way that reliability data is collected, inappropriate techniques for storage, a misalignment of responsibilities, poor training, and a lack of formal policy and procedures in this area.

Empirically, we know all this to be true; equally, we know from experience that correction of these issues can have a significant impact on the outcomes from any maintenance and reliability program. Materials maintenance is the missing link in most reliability programs and is vital for a reliability program to be a long-term success.

#### **About the Authors**

Art Posey is Senior Manager, Maintenance for Wheelabrator Technologies, Inc., a waste management company. Wheelabrator owns and/or operates energy-fromwaste facilities, several independent power production facilities, and has operations in the United Kingdom and China. Art came to maintenance in 1997 after 16 years in the construction field. Art can be reached at artposey@gmail.com.

Phillip Slater is a materials and spare parts management specialist. He is the founder of the online training and best practice resource center at SparePartsKnowHow.com, and the author of eight books, including Smart Inventory Solutions and The Optimization Trap. For more information on Phillip's services, visit www.PhillipSlater.com.

# How to Measure Total Operations Success with the Reliable Maintenance Excellence Index

\_

#### **Abstract**

This chapter covers the third area for benchmarking, the Reliable Maintenance Excellence Index. As we saw previously, we start with the Scoreboard for Maintenance Excellence, then we can use the CMMS Benchmarking System, the ACE Team system for measuring craft productivity at the shop for level, and then compile the Reliable Maintenance Excellence Index (RMEI) for measuring overall total operations success. The RMEI is a one page, Excel spreadsheet that covers 12–15 key metrics across the total operation.

#### **Keywords**

# Balanced scorecard; Performance metrics; Profit optimization; Reliable Maintenance Excellence Index (RMEI)

During this chapter we will look at the third area for benchmarking which is the reliable maintenance excellence index. As we saw previously we start with the scoreboard for maintenance excellence, then we can use the CMMS benchmarking system, the ace team system for measuring craft productivity at the shop for level and then compile the reliability maintenance excellence index

for measuring overall total operations success. Figure 18.1 again illustrates the four levels of benchmarking.

# THE SCOREBOARD for MAINTENANCE EXCELLENCE: Benchmarking Current Operation Against Global Best Practices THE CMMS BENCHMARKING SYSTEM: Benchmarks Your Current CMMS to Achieve Maximum Utilization of Your IT Investment The RELIABLE MAINTENANCE **EXCELLENCE INDEX:** Defines Internal Benchmarks and KPI's to Measure and Validate Results of Maintenance and Reliability Excellence Actions The ACE TEAM PROCESS: Provides a Means for Improved Repair Methods and Benchmark Jobs for Establishing Reliable Planning Times for Scheduled Work

FOUR LEVELS OF MAINTENANCE BENCHMARKING

Figure 18.1 Illustrates the four levels of benchmarking.

## The Reliable Maintenance Excellence Index

- The RMEI should measure how all key resources that contribute
  - to profit & budget optimization,
  - greater customer service
  - and more effective physical asset management
- The RMEI should include measures for all maintenance resources
  - People resources; internal craft labor & outside contractors
  - Dollar resources; overall budget dollars of maintenance and the customer
  - MRO parts and material resources
  - Planning/scheduling resources, processes & customer service
  - Critical assets; uptime, availability or OEE and reliability
  - Information resources; how data becomes true information via effective CMMS

## The Reliable Maintenance Excellence Index

## The Reliable Maintenance Excellence Index provides:

- A very powerful, one page Excel spreadsheet
- 12-15 key metrics combined for a composite Total RMEI
   Performance Value
- A very "balanced scorecard" for the total facilities and maintenance process.
- An ideal method for measuring Continuous Reliability
   Improvement across a multiple operation & work units
- Support to applying and measuring the impact of standard best practices
- Maintenance planning & scheduling: Must define results!

			The	Relia	ble M	ainten	ance E	xcelle	nce Ir	idex					
A-Performance Measures	1. Actual Maintenance Cost Per Unit of Production	2, % Major Work Completed within 5% of Cost Estimate	3. % Overall Maintenance Budget Compliance	4. % Overall Schedule Compliance	5. % Overall PM Compliance	6. % Planned work	7. % Craft Time for Oustomer Charge Back	8. % Work Orders with Reliable Planned Time	9. % Critical Asset Availability	10. % Whench Time (Craft Utilization)	11, % Craft Performance	12, % Inventory Accuracy	13. Number of Stock Outs of Inventoried Stock Items	F-Performance Level Scores	Current Month Perf
B-Current Month Perf	\$1.30	90	94	90	94	68	75	50	90	34	90	90	15	Perf Level	-
C-Performance Goals	\$1.00	95	98	95	100	80	85	60	95	50	95	98	10	10	
E	1.05	94	96	94	98	78	83	58	94	48	94	97	A	9	
evels If	1.10	93	94	93	96	76	81	56	93	46	93	26	12	8	
30分	1.15	92	92	92	94	74	78	54	92	44	91	95	13	7	Ī
3	1.20	91	90	91	92	72	75	52	91	M	91	94	14	6	
9.Л	1.25	90	88	90	90	70	72	50	90	40	90	93	15	5	
250	\$1.30	89	86	89	88	68	69	48	89	38	89	92	16	4	
F E E	1.35	88	84	88	86	66	66	46	88	36	88	91	17	3 🗸	Baseline
Baseline rformance ailable 🗁	1.40	87	82	87	84	64	63	44	87	34	87	90	18_	-	Perf.
D-Baselin Performar Available	1.45	86	80	86	82	62	60	42	86	32	88_	-	10		Level
DEK	1.50	85	78	85	80	60	57	40-	00	30	85	87	20	0	
E-Performance Level Score	4	5	8	5	7	4	6	5	5	2	5	2	5	E-Perf. Level X	Į,
G-Weighted Value Metric	10	6	6	7	11	7	6	J.	13	8	8	6	5	G- Weighted Value	Total RMEI
H-Performance Level Score (E) × Weight (G)	40	30	48	35	17	28	36	35	45	16		19	25	467	Value
J-Total RMEI Value	Date	Jan 409	Feb 435	Mar 467	Apr	May	June	July	Aug	Sept	Oct	Dec	An		ighted lue of

A. Performance Measures	1. Actual Maintenance Cost Per Unit of Production	2. % Major Work Completed within 5% of Cost Estimate	3. % Overal Maintenance Budget Compliance	4. Overall Schedule Compliance	5. % Overall PM Compliance	6. % Planned Work	7. % Craft Time For Customer Charge Back	8. % Work Orders With Reliable Planned Time	9. % Critical Asset Availability	10. % Whench Time (Craft Utilization)	11.% Craft Performance	12. % Inventory Accuracy	13. Number of Stock Outs of Inventoried Stock Berns	F. Performance Level Scores
B. Current Month	1.30	90	94	90	94	68	75	90	90	34	90	90	15	Perf Level
C. Performance Goal	1.00	95	98	95	100	80	85	60	95	50	95	98	10	10
	1.05	94	96	94	98	78	83	58	94	48	94	97	11	9
	1.10	93	94	93	96	76	81	56	93	46	93	96	12	8
	1.15	92	92	92	94	74	79	54	92	44	92	95	13	- 7
	1.20	91	90	91	92	72	77	52	91	42	91	94	14	6
D. Baseline Performance Levels	1.25	90	88	90	90	70	75	50	90	40	90	93	15	- 5
	1.30	89	86	89	88	68	73	.48	89	38	89	92	16	4
	1.35	88	84	88	86	66	71	46	88	36	88	91	17	3
	1.40	87	82	87	84	-64	69	44	87	34	87	90	18	2
	1.45	86	80	86	82	62	67	42	86	32	86	89	19	-1
	1.50	85	78	85	80	60	65	40	85	30	85	88	20	Ó
E. Performance Level Score	4	5	8	5	1	4	5	5	5	2	5	2	5	I. Total
G. Weighted Value of Metric	10	6	6	1	11	7	6	7	13	8	8	6	5	RMEI Score
H. Performance Level Score (E) x Weight (G)	40	30	48	35	77	28	30	35	65	16	40	12	25	481
J. Total MEI Value Over Time	Date	7.08	8.08	9.08	10.08	11/08	12/08	1/09	2.09	3.09	4.09	5.09	6.09	
	Score	481												

			The	Relia	ble M	ainten	ance E	xcelle	nce li	ndex					
A-Performance Measures	1. Actual Maintenance Cost Per Unit of Production	2. % Major Work Completed within 5% of Cost Estimate	3, % Overall Maintenance Budget Compliance	4. % Overall Schedule Compliance	5, % Overall PM Compliance	6. % Planned Work	7. % Craft Time for Customer Charge Back	8. % Work Orders With Reliable Planned Time	9. % Critical and	G	Perf.	12. % hacy	13. Number of Stock Outs of Inventoried Stock Berns	F-Performance Level Scores	
B-Current Month Perf	\$1,30	99	98	95	100	80	75	60	95	50	95	98	10	Perf Level	
Performance Goals	\$1.30	95	98	95	100	80	85	60	95	50	95	98	10	10	
E	1.05	94	96	94	98	78	83	58	94	48	94	97	11	9	
<u>u</u>	1.10	93	Jane I	93	96	76	81	56	93	46	93	98	12	8	
Levels	1.15	92	92	92		74	78	54	92	44	92	95	13	7	
3	1.20	91	9			72		52	91	42	91	94	14	6	
	1.25		88	So P	erf.	1	72	0.99		40		93	15	5	
9 6 7		8	Le	vel S			69	48	89	38	89	92	16	4	
Baseline rformance ailable ⇔	1.35	84		re All			66	46	88	36	88	91	17	3	
# <u>5</u> E	1.40	87			Mark.	1	63	44	87	4.00	87	90	18	2	
D-Baseline Performan Available	1,45	86	80-	5	-	62	60	42	86	32	86	88	19		
□ 0.4	1.50	85	78	85	80	60	57	40	85	30	85	87	20	0	
-Performance Level Score	10	10	10	10	10	10	10	10	10	10	10	10	10	E-Perf. Level X	l.
G-Weighted Value Metric	10	6	6	7	11	7	6	7	13	8	8	6	5	G- Weighted Value	Tot RM
-Performance evel Score (E) × Weight (G)	100	60	60	70	110	70	60	70	130	80	80	60	50	1000	Valu
J-Total RMEI Value	Date	Jan 409	Feb 435	Mar 467	Apr	May	June	July	Aug	Sept	Oct	Dec	Jan	Maximur Value =	

Step	Description	The 10 Step Process for RMEI Development
Α	Performance Metrics	10 to 15 metrics are selected & agreed upon by the organization.  Select metrics for total maintenance process + operational ones.
В	Current Month Performance	The actual monthly performance level for the metric. This value will also be noted in one of the incremental values blocks below the performance goal. This value will correspond to a value for F, the performance level scores which go from 10 down to 1.
C	Performance Goal	The pre-established performance goal for each of the RMEI metrics. For example, if the Current Month's Performance is at the Performance Goal level, the performance level score for that goal will be a 10, the maximum score.
D	Baseline Performance	The baseline performance level prior to start of RMEI performance measurement. Not always available. Use a 1–3 months performance average as a baseline after start of RMEI.
E	Current Performance Score	Depending on the current month's performance, a performance level score (F) will be obtained. This value then goes to the Current Performance Score row and serves as the multiplier for the (G) the Weighted Value of the Performance Metric.
F	Performance Level	Values from 10 down to one, which denotes the level of current performance, compared to the goal. If current performance achieves the predetermined goal, a performance value of 10 is given. Each metric is broken down into incremental values from the baseline to the goal. Each incremental value in the column corresponds to a performance level value. This value becomes the Current Performance Score.

Step	Description	The 10 Step Process for RMEI Development (cont)
G	Weighted Value of the Performance Metric	The values along this row are the weighted value or relative importance of each of the metrics. These values are obtained via a team process and a consensus on the relative importance of each metric that is selected for the RMEI. All of the weighted values sum to 100.
H	Performance Value Score	The Weighted Values (G) are multiplied by (E) the Current Performance Scores to get the Performance Value Score (H).
- <b>1</b>	Total RMEI Performance Value	The sum of the Performance Value Scores for each of the metrics and the composite value of monthly maintenance performance on all RMEI metrics
J	Total RMEI Performance Values Over Time	Location for tracking Total RMEI Performance Values over a number of months

## Important Notes

- 1. The RMEI is a composite of key metrics, each with relative importance
- 2. Each RMEI metric can be trended and linked to the monthly RMEI
- 3. The RMEI should be balanced across the total maintenance operation
- 4. Other metrics of lesser value can also be tracked.

#	Performance Metric and Purpose	Goal
1.	% Overall Maintenance Budget Compliance: To evaluate management of \$ assets; Obtained from monthly financials	98%
2.	Actual Maintenance Cost per Unit of Production or  (Maintenance Cost Per Square footage Maintained: To evaluate/benchmarkactual costs against stated goals/baselines or against industry standards; Obtained from asset records and monthly CMMS WO file of completed WOs for the month. Obtained from production results and financial report. Provides ideal support to ABC Costing practices	TBD
3.	% Customer or Capital Funded Jobs Completed as Scheduled and within +/- 5% of Cost Estimate: To measure customer service &\$ assets plus planning effectiveness; Obtained from funded WO types from the CMMS WO files, comparing date promised to date completed and estimated cost to actual cost	98%
4.	Other Planned Work Orders Completed as Scheduled: To measure customer service and planning effectiveness; Obtained from a query of all planned WO types in CMMS WO files and comparing date promised to date completed. Could be expressed in % based on craft hours.	95%

#	Performance Metric and Purpose	Goal
5.	Schedule Compliance: To evaluate how effectiveness scheduling was in regards to executing to meet scheduled dates/time; Obtained from query of CMMS completed WO file where all scheduled jobs coded and their actual completion compared to actual planned completion date/time	95%
6.	% Planned Work Orders versus % True Emergency Work Orders: To evaluate positive impact of PM, planning processes and other proactive improvement initiatives (CRI,/RCM/etc); Obtained from a query of all true emergency WO types in CMMS WO files and comparing to total WOs completed. Could be expressed in % based on craft hours.	80% to 85% Planned
7.	% Craft Time to Work Order for Customer Charge Backs: To monitor craft resource Accountability for Internal Revenue Generation (or External); Obtained from a query of all WO types in CMMS WO files that are charged back comparing these craft hours to total craft hours paid	TBD
8.	% Craft Time to Work Orders: To monitor overall craft resource accountability and to support internal revenue generation; Obtained from a query of all WO types in CMMS WO files and summation of actual craft hours	100%

#	Performance Metric and Purpose	Goal
9.	% Craft Utilization (Actual Wrench Time): To maximize craft resources for productive, value-adding work and to evaluate effectiveness of planning process; Obtained from a query of all craft hours reported to non craft work from CMMS time keeping WO files and summation of actual craft hours	60% to 70%
10.	% Craft Performance (Against Reliable Estimates for PM and planned work): To maximize craft resources, to evaluate planning effectiveness and also to determine training ROI; Obtained from completed WO file in CMMS	95%
11.	Craft Quality and Service Level: To evaluate quality and service level of repair work as defined by customer; Obtained from WO file in CMMS where all call backs are tracked and monitored via work control and planning processes  The Overall Craft Effectiveness Factor (%)	98%
	OCE = %CU x CP x CSQ	12

#	Performance Metric and Purpose	Goal
12.	Overall Craft Effectiveness (OCE): To evaluate cumulative positive impact of overall improvements to Craft Utilization (CU), Craft Performance (CP) and Craft Quality and Service Excellence (CQSE) in combination; Obtained from using results of measuring all three OCE Factors: a) Craft Utilization, b) Craft Performance and c) Craft Quality and Service Excellence	65%
13.	% Work Orders with Reliable Planned Times: To measure planner's effectiveness at developing reliable planning times; Obtained from completed WO file in CMMS where panning times are being established for as many jobs as possible by planner/supervisor	70%
14.	<b>% Overall Preventive Maintenance Compliance:</b> (Could be by type asset, production department/location or by supervisory area): To evaluate compliance to actual PM requirements as established for assets under scope of responsibilities; Obtained from completed WO file in CMMS	100%

#	Performance Metric and Purpose	Goal
15.	Gained \$Value from Craft Utilization & Performance: To determine actual gained \$ value of craft productivity gains as compared to original estimate and/or the initial baseline; Obtained only from using results of measuring two of the OCE Factors: a) Craft Utilization, b) Craft Performance.	TBD
16.	% Inventory Accuracy: To evaluate one element of MRO material management and inventory control policies; Obtained from cycle count results and could be based on item count variances or on cost variance	98%
17.	% or \$ Value of Actual MRO Inventory Reduction: To evaluate another element of MRO material management against original estimates and the initial baseline MRO inventory value; Obtained from inventory valuation summation at end of each reporting period	10%

#	Performance Metric and Purpose	Goal
18	Number of Stock Outs of Inventoried Stock Items: To monitor actual stock item availability per demand plus to monitor any negative impact of MRO inventory reduction goals; Obtained from tracking stock item demand and recording stock outs manually or by coding requisition/purchase orders for the items not available per demand	????
19	\$ Value of Direct Purchasing Cost Savings: To track direct cost savings from progressive procurement practices as another element of MRO materials management. Could apply to contracted services, valid benefits received from performance contracting, contracted storerooms, vendor managed inventory;  Obtained via best method per a standard procedure that defines how direct purchasing savings are to be accounted for	TBD
20	Overall Equipment Effectiveness (OEE): World – class metric to evaluate cumulative positive impact of overall reliability improvements to Asset Availability A), Asset Performance (P) and Quality (Q) of output all in combination. (Similar to OCE above but for the most critical production assets); Obtained via downtime reporting process, operations performance on critical assets and the resulting quality of output	85%
21	% Asset Availability/Uptime: To evaluate trends in downtime due to maintenance and the positive impact of actions to increase uptime; Obtained via downtime reporting process	TBD
	Many More Metrics Available	

Some Other Maintenance Metrics	
Category	Benchmark
Yearly Maintenance Cost:	
Total Maintenance Cost/Total Manufacturing Cost	< 10-15%
Maintenance Cost/Replacement Asset Value of the Plant and Equipment	< 3%
Hourly Maintenance Workers as a % of Total	15%
Planned Maintenance:	
Planned Maintenance/Total Maintenance	> 85%
Planned & Scheduled Maintenance as a % of hours worked	~85-95%
Unplanned Down Time	~0%
Reactive Maintenance	< 15%
Run to Fail (Emergency + Non-Emergency)	< 10%
Maintenance Overtime:	
Maintenance Overtime/Total Company Overtime	< 5%
Monthly Maintenance Rework:	
Work Orders Reworked/Total Work Orders	~0%
Inventory Turns:	
Turns Ration of Spare Parts	> 2-3

Some Other Maintenance Metrics				
Category	Benchmark			
Training:	17 - 24.83			
For at least 90% of workers, hours/year	> 80 hours/year			
Spending on Worker Training (% of payroll)  Safety Performance:	~4%			
OSHA Recordable Injuries per 200,000 labor hours Housekeeping	< 2 ~96%			
Monthly Maintenance Strategies:  ✓ Preventive Maintenance: Total Hours PM/Total Maintenance Hours Available	~20%			
✓ <b>Predictive Maintenance:</b> Total Hours <u>PdM</u> /Total Maintenance Hours Available	~50%			
✓ Planned Reactive Maintenance: Total Hours PRM/Total Maintenance Hours Available	~20%			
✓ Reactive Emergency: Total REM/Total Maintenance Hours Available	~2%			
✓ <b>Reactive Non-Emergency:</b> Total RNEM/Total Maintenance Hours Available	~8%			
Plant Availability: Available Time/ Maximum Available Time	> 97%			
Contractors: Contractors Cost/Total Maintenance Cost	35-64%			

# Making Maintenance Performance Based: Profit & Customer-Centered

Step 1: Planning

Understanding Achievement Goals

Step 3: True Maintenance Leadership Step 2: Making
Proactive Performance
a Part of Your
Maintenance Business
Plan

Step 4: Monitoring Your RMEI

### 3 R's of Performance Data Collection

- RELIABLE Data Is Credible,
   Calculations Are Accurate and
   Consistent Over Time
- RELEVANT Pertains to the Source It Is Intended to Measure
- REPRESENTATIVE It is Typical of the Service Being Measured

### Planning & Scheduling of "Human Capital"

- Right People or Person
- Right Skills
- Right Place
- Right Time
- Right Parts
- Right Repair Method
- Right Tools

A Lot of "Rights" to Get Right! 

## How This Book Can Apply to the Very Small Work Unit in Oil and Gas or to Any Type of Maintenance Operation

-

#### **Abstract**

This chapter provides a great case study from a highly experienced planner who had retired from a large, famous company known for maintenance excellence and started his second career in a much smaller plant as more than "just a planner." In contrast, his new company acted as if maintenance was an unwelcomed cost to the business. The lack of support and commitment resulted in underperformance and missing its full potential for value-added cost savings to the organization. However, this planner made the best of the situation, and his story provides a great example of what one planner can do to develop a more proactive maintenance strategy.

#### **Keywords**

## Breakdown maintenance; Contractor management program; Higher throughput; Life cycle; Top management support; Unplanned downtime

This chapter gives a great case study on "Different Schools of Thought on Executing Plant Maintenance." It comes from Gary Royer, a highly experienced

planner retired from a large, famous company known for maintenance excellence, who started his second career in a much smaller plant as more than "just a planner."

My experiences at the "King of Beer" (Anheuser-Busch) and "Queen of Chocolate" shaped up to be like the poles of the earth due to exact opposite support levels that the maintenance group received. The contrasting approach to maintenance appeared to be based on the perceived value that the corporate leadership had of the maintenance group's contributions.

Before I retired from Anheuser-Busch, The "King" recognized the value added back to the organization in the deliverance of a quality product to its consumers. Maintaining the plant equipment through its entire life cycle at peak efficiency and performance translated into higher throughput, less unplanned downtime, and ultimately added profits to the bottom line. Proactive maintenance was an integral part of the culture for the 90 plus machinists and 45 electricians at our 24/7 plant.

In contrast, the "Queen" acted as if maintenance was an unwelcomed cost to the business. The lack of support and commitment resulted in underperformance and missing its full potential for value-added cost savings to the organization. The bedrock of any maintenance organization begins with buy in by top management in any company.

At the "King," maintenance had a seat at the table with a senior vice president who was the "Champion for World Class Maintenance." He made sure the value-added contribution by the maintenance department was well known, respected, and appreciated. Funding and support for staffing, tools, and systems were provided. When it was time for the migration from the previous computerized maintenance management system (CMMS), the change from "Champs" to "SAP" was planned and executed. The mintenance champion made sure that adequate resources and timelines were provided to assure a successful rollout.

The SAP structure tree, equipment hierarchy, preventive maintenance (PM) tasks, and task instructions were preplanned. Workloads were proportionally divided into dedicated business units so that each assigned technical planner was able to do the best job possible in his or her area. Training throughout the SAP rollout was well planned and scheduled. Maintenance audits were later performed on an 18-month rotational schedule at the domestic breweries.

Lessons learned, corporate benchmarks, and best practice PM enhancements were dividends earned from this process.

Adequate maintenance shop support staffing was available to assist in planned modular PMs as each business unit had planned scheduled outages per month. Annual weeklong shutdowns were scheduled for each production line for extended refresh overhauls. Corporate training resources were provided at the "Learning Center" to assist in developing technical skills and for professional development. True "world-class maintenance" requires and achieves maximum results when top management embraces it and demonstrates it by providing a "CHAMPION" for the maintenance team.

Little did I realize that the training and the years of experience with this worldclass operation would later serve me well at my next employer, the "Queen." The supportive culture that I was accustomed was radically different. Everything I was taught and had experienced throughout my career with the "King" was put to the test with the "Queen."

Polar opposite support awaited my arrival. It became apparent that reactive, breakdown maintenance was the norm after I completed an on-boarding assessment of the current state and performance evaluation of the maintenance group. The current CMMS was "MP2" and was not rolled out properly. It had very few PM tasks or instructions documented after 3 years in service. Prior to MP2, several years had transpired after the termination of the previous CMMS "Elke" system. During this time gap, production management tried what ultimately was a failed experiment and was actually directing the maintenance group via direct plant intercom calls to specific crafts people on shift. Proper data migration did not occur. Seamless communication between the accounting systems and MP2 was not established, and as a result, other useful data management tools did not exist. Double data input by maintenance was required for all purchase of parts by the accounting system.

The staff at the "Queen" consisted of fewer than 20 mechanics and electricians to cover three shifts of production that was steadily increasing to meet market demands. A centralized maintenance library for PDF and hard copy manuals and drawings was needed and was one of the earlier project priorities. A weekly maintenance metrics report was started to measure and track key performance indicator (KPI) progress.

One highlight, to my surprise, was that one experienced technician had been selected to get the maintenance storeroom in shape, which he was doing when I arrived. We decided to use barcodes, and he successfully laid out an effective storage arrangement with bins for some items and other appropriate storage and control methods for all items. We even used regular cycle counts to help achieve higher inventory accuracy. Now we were prepared to move forward with the next steps of bar-coded assets and work orders when that time might occur.

A major cultural change was needed. I soon realized that upper management did not support the required investment needed to turn this situation around in a timely fashion. Lip service was extended, but it lacked real meaning without the proper funding and support. To expedite the positive change required with limited external backing, I scheduled communication meetings across the shifts to offer a "vision of the future" that could be done with a total internal commitment by all the skilled craft persons in the department.

As I have explained already, no one in maintenance likes to constantly be called for machine breakdowns and have to break away from a job in progress. Pressure experienced when production is halted, with operators not producing and management standing around watching and asking when will the machine or line be fixed, did not need to occur. The team was open to my proposed antidote to the reactive work with which they were so familiar.

Proactive maintenance was the solution, and they were willing to embrace the efforts required through this journey. This involved their help at times to assist in writing some of the earlier basic PMs that I later entered into the CMMS. It also required their willingness to identify PM repair work on the machinery before breakdowns occurred. The team knew that they had a vested interest in a successful outcome. I shared basic reminders of the importance for proper date-stamped work details documented in each work order and how accurate recorded parts usage would ultimately become a very good time-saving tool used by the team. Properly documented work histories, parts usage, bill of materials (BOM), tasks and task instructions by equipment were recognized as key tools in the turnaround from a reactive to a proactive maintenance culture.

The shift maintenance supervisors (from each of the three shifts) and I focused on the system tools, databases, and procedures that we needed to create, build on, and use to continue the turnaround momentum. Periodic training in the new systems were scheduled. Internal department efforts were steadily paying

dividends, but further external work was needed to build and improve relationships with the service end users in production and process areas.

Maintenance planning meetings were arranged to bridge the differences between maintenance and operation groups that had developed and festered through the years. Regular meetings now occurred to continue working together to communicate and maximize uptime and minimize unplanned downtime. This partnership grew stronger over time as recognition of results of the maintenance team's proactive efforts had directly increased machine efficiencies throughout the plant.

The maintenance team was tasked with maintaining an aged facility and infrastructure along with installation of new technologies, new machinery, and new lines. This required another early initiative and led me to establish a maintenance contractor management program that included an standard operating procedures (SOP) that defines the procedures to follow for work scope identification with detail specifications, reviewing work scope to secure quotes, vendor selection, job scheduling, reviewing job progress, through completion.

It also included a final audit review before payment authorization. The program included a pool of approved contractors to safely perform specific work in a food manufacturing facility.

The attention to this process served us well as the business growth continued. Well-managed and -executed plant shutdowns using both internal and external maintenance resources became the norm.

A comprehensive multiyear preventative PM program was established to address and service all critically identified plant equipment and to provide for timely lubrication, calibrations, and other regulatory required work; utilities systems that provided electric power, boiler steam, condensate return systems, air compressors, dryers, and refrigeration equipment such as chillers, HVAC and exhaust fans, were also included. Proper PM task identification, schedule frequency, parts inventory, and parts kitting management are very important functions for any size manufacturing organization that requires constant review for frequencies and detailed task instruction improvements.

Then there are and use of root cause analyst tools to eliminate downtime occurrences to resolve issues before they become repetitive. A predictive PM

program was begun with continual refinement for improved results. Recruitment, technical training, and development of qualified technicians along with succession planning are other challenges now faced with the baby boomer technicians currently exiting the workforce.

To those who accept the challenges encountered in a smaller or less-developed maintenance organization, be receptive to outside audits that can identify areas to improve and serve as a benchmark to compare how your group performance rates with your peers in industry. Use the maintenance metrics KPI report as a great communication tool with top management. This can demonstrate with facts the progressive positive results being achieved by a highly engaged and well-managed maintenance team.

Finally, with well-documented results showing successes, you should be able to go back and demonstrate the value added by such a well-run maintenance team. Of course our job is never done. Continue to educate others in your organization on the value derived from a well-supported maintenance team. We are not a cost but an investment in their success. In a globally competitive environment, maintenance planners and leaders must continue to evolve, grow, and meet the future challenges. Learn that smart delivery of maintenance service goes hand in hand with a more productive successful world-class organization.

Current and future planners must continually strive to grow in knowledge, experience, awareness of tools and systems available, and their use. You may never know what challenges await you. It is nice to work in a well-structured organization with resources and detailed processes provided for by other team members. However, opportunities do exist in smaller companies lacking all the bells and whistles for the maintenance group, which provides a chance to test your skills and personally grow and achieve greater personal success and satisfaction. The choice is yours, but be prepared. Best wishes to all pursuing and advancing their maintenance career.

By Gary Royer

Maintenance Planner

A Premier Chocolate Company

#### **A Model for Success**

\_

## Developing Your Next Steps for Sustainable and Reliable Maintenance Planning—Estimating and Scheduling

Ricky Smith, and Jerry Wilson

#### **Abstract**

This chapter is an appropriate closing chapter because it can be viewed as a true model of success case study. The maintenance planning and scheduling process must be developed using known best practices and executed to the standards listed in this chapter. Alcoa Mt. Holly has been the standard for proactive planning and scheduling for over 30 years. The chapter author worked at this facility for a number of years, and his experience there helped him understand the advantage of proactive planning and scheduling. The case study numbers listed have been validated by many external organizations over a period of many years. This process requires two things: a different way of thinking and discipline to follow the process.

#### **Keywords**

Job plans; Job scope; Labor needs; Maintenance coordinator; Parts; Permits; Planner skills; Procedures; Scheduling; Special tools and equipment; Specifications; Weekly schedule; World-class wrench time

A maintenance planning and scheduling process must be developed using known best practices and executed to the standards listed in this chapter. Alcoa Mt. Holly has been the standard for proactive planning and scheduling for over 30 years. I worked at this facility for a number of years and my time there helped me understand the advantage of proactive planning and scheduling. The numbers listed below have been validated by many external organizations over a period of many years. This process requires two things: a different way of thinking and discipline to follow the process.

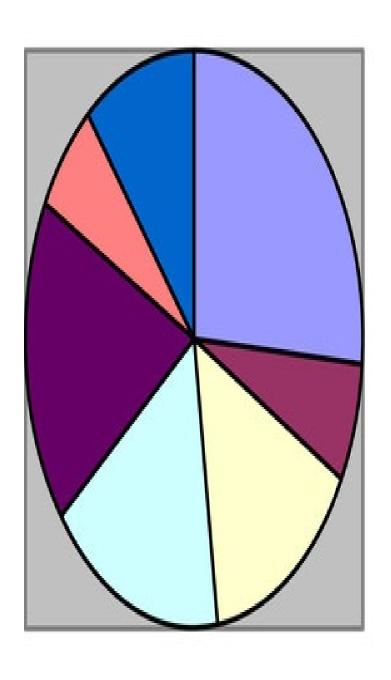
### Alumax Mt Holly (1997) vs. Alcoa Mt Holly (2012)

Category	Alumax-1997	Alcoa-2012
Maintenance Spending / RAV	3.4%	2.0%
Budget Compliance	-0.5%	+3.7%
Overtime / Straight Time	1.0	7.1%
Number of Crafts	4	3
Planners per Tradesperson	1:20	1:19
Absenteeism .	1.6%	1.8%
Backlog in Crew Weeks (Per Tradesperson)	4.4	6.8 Total/6.25 Ready
Schedule Compliance	95%	85.7%
Percent of Urgent (Interruption) Work	10.5%	3%
Percent of PM / PdM to all Work Orders	32%	47.2%
PM Accomplishment	96%	85.7% (10% Rule)
Inventory Accuracy	96%	97.6%
Inventory Turns	3.31	2.86
Maintenance Training S's as % Total Payroll S	4.2%;	1%
Wrench Time	62.3%	58.8%

One of the major objectives of maintenance planning and scheduling is to optimize "wrench time."

Wrench time is defined as the actual amount of time a crafts person spends doing value-added work. A wrench time study, or work sampling study, is aimed at identifying and then eliminating or mitigating the time spent on non-value-added tasks.

- World-class wrench time is 55–65%
- Most companies have a wrench time of 18–30%
- Wrench time can be increased by effective planning.



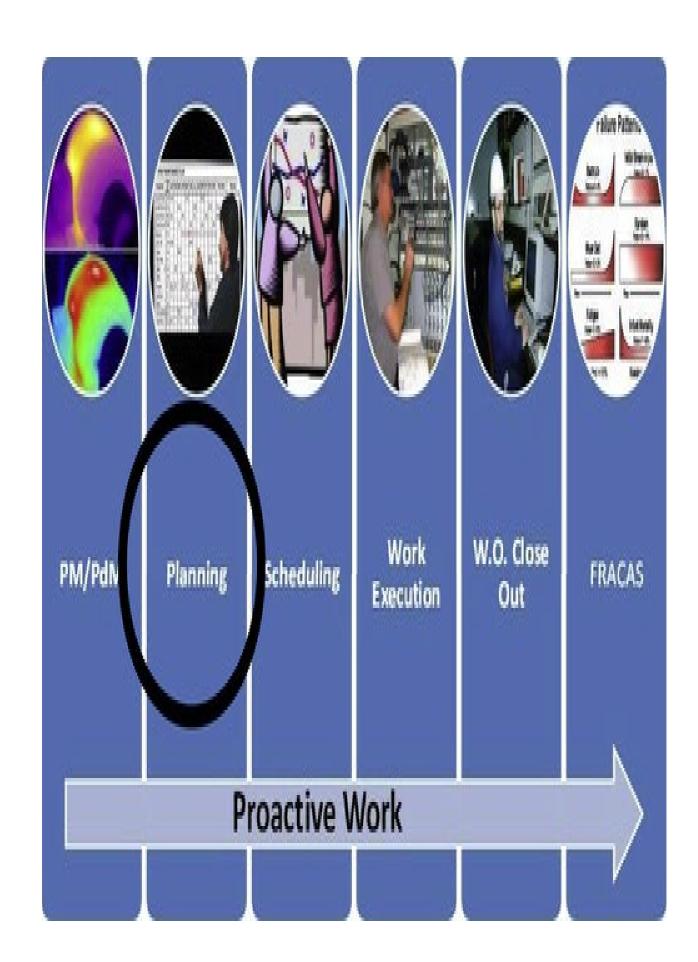
- Wrenchtime
- Waiting
- □ Travel
- ☐ Breaks/Early

  Quits
- Looking for Parts
- Looking for Information
- Permit



#### **Planning**

Planning is the identification of all of the resources required to schedule and execute maintenance work effectively and efficiently. Planning is completed before work is scheduled.



The start of the planning process begins when a planner receives a work request. The planner or a maintenance technician makes a job site inspection in order to identify everything that will be necessary to prevent delays to the job once it is started. The planner should preferably be a fully skilled crafts person who also has the additional skills necessary to execute the responsibilities of planning. Those skills are:

- Broad technical expertise for the craft
- Detail oriented
- Organized
- Communications skills
- Computer skills

If you think you have to get by with something less than a fully qualified maintenance person, then you are selling planning and scheduling (P&S) short. While all of the skills, in addition to technical expertise, are important, most can be easily learned. Technical expertise will allow a planner to quickly asses a work request and job site. In short order, they will have identified everything that is needed for an effective job plan. I say "effective" because I am not one that believes every job plan has to contain a complete list of information, common to all jobs, in order to qualify as fully planned and ready to schedule. All of the activities that are completed during P&S are also completed when no planning and scheduling takes place. The equipment has to be shut down; parts have to be obtained, etc. A planner does these activities much more efficiently. Knowing this, why would any organization choose not to use a fully qualified planner as defined here?

#### The Job Plan

A job plan is required for any job that is critical to the operation. A job plan should only contain the information that the average maintenance technician would need to execute the job at the desired quality level; any more than that, and you start running the risk of the job plan information being ignored. If you want to, you can include reams of data with the job plan, but on the official form, only required information should be present. If your maintenance personnel are ignoring what is documented in the job plans, it could be a result of too much information that they do not need. If this is happening, they are likely missing key information such as changes that have been made in parts, procedures, specifications, etc. that could be crucial to improving reliability. Therefore, I believe that planners should only include what is absolutely necessary.

Too many job plans focus on information that the average maintenance technician already knows. If we approached job plans a little differently by focusing just on what the technician needs to know but might not, we may find that the job plans would become more useful. The job summary should use bullets rather than text to list the major steps of the job. Details that a less experienced technician might need can be put in the job package as an attachment, referred to in the bulleted list. When details are put in attachments, this enables most technicians to quickly access the information they need by reducing the amount of information they must go through. Any changes from what the technicians would think of as status quo should be highlighted to draw their attention. With the exception of attachments, you should only use details in a job plan where you are going to require a signature from the technician to show that the work was done exactly as required, and these details can usually be simplified with bullets. You can make things even easier for your technicians by standardizing groupings of information and by having no more than seven bullets in each grouping. Additionally, each bullet should have no more than seven words where possible.

The following are some basics that must be present for the job to qualify as fully planned, including:

Job scope: What needs to be accomplished by this job, and what are the basic activities that will need to be executed for completion? If prework is needed, like insulation removal, an electrical disconnect, or any other activity that must be completed before the main task can be initiated, the planner will note this and start making arrangements to have the need resolved before the primary work is scheduled to start. Any follow-up work should be noted, such as jobs to repair equipment that was replaced with spares.

Labor needs by craft, skill level, and duration: The planner will make estimates for the labor hours, and number of individuals needed, for each craft, as well as an overall estimate for the chronological time to complete the job from start to finish. The minimum skill level required for each craft should also be documented in the job plan. For example, if a second year apprentice is qualified, that information should be documented in order for the maintenance manager to make the most effective labor utilization.

Parts: All of the necessary parts will be identified, and those not stocked in the storeroom, or otherwise unavailable, will be ordered. The job will not be considered as "ready to schedule" until all necessary parts are available. Usually, all parts required to do the job will be acquired and assembled in a "kit" a day or two before the job is scheduled to commence.

Permits: Necessary permits will be identified and initiated prior to the job start time.

Procedures: If a job requires a procedure that is anything other than common practice due to regulatory compliance, reliability, or safe practice rules, it should be included in the job plan package and listed as an attachment on the job plan form. Usually this information will be stored in, or linked to, the functional location or equipment master in the CMMS, so that the next time the equipment has to be worked on, that information will be immediately available and it will require less time for the planner to prepare the job.

Specifications: These should be listed when applicable and in bullet form when possible. For example, if bolts and nuts are stored in bulk in the shop and a particular job requires a bolt of a different grade than normal, that should be listed.

#### Special tools and equipment: These will be noted and assembled for the job.

Some job plans will be created with much more detail because of the complexity of the job. Job plans should be saved by electronically tying them to the functional location for the equipment in the CMMS system (these are known as "preplanned job packages"). In short order, the planner will have documented plans for the equipment types that fail most often. This will be a big time-saver for the planner in the future.

Many times a planner or maintenance technician may have to visit a site to scope the work. Following is an example of a very simple job site inspection form used by a planner for a mechanical maintenance crew.

Work Order #		JOB SCOPE	NSPECTIO	ON SHE	ET	
Equipnent Type: PumpMotorCouplingValveTank/VesselFilterCPipingOther Installation Type: FlangedWeldedScrewBoltedOther Fastener Size: BoltNutStud Gasket Type: Spiral WoundGylonTeflonFilterCPipingOtherSize	Work Order #	Date				
Equipment Type: PumpMotorCouplingValveTank/VesselFilterE PipingOther Installation Type: FlangedWeldedScrewBoltedOther Fastener Size: BoltNutStud Gasket Type: Spiral WoundSize		F/I				
Pump Motor Coupling Valve Tank/Vessel Filter Diping Other Installation Type: Flanged Welded Screw Bolted Other Fastener Size: Bolt Nut Stud Gasket Type: Spiral Wound Gylon Teflon Fiber Other Size Wrench Sizes:  Wrench Sizes: Special Tools: Job Description:  Job Scope: Safety Hazards: Fleet Floor Flo						
Piping		unling Valv	e Tank/	Vessel	Filter	Dover
Installation Type: Flanged Welded Screw Bolted Other Fastener Size: Bolt Nut Stud Gasket Type: Spiral Wound Gylon Teflon Fiber Other Size:  Wrench Sizes: Special Tools: Job Description:  Job Scope:  Pre-Work Preparation Steps:  Permits: SW OF Entry Electrical Hot Work Excavation Other Other Sequipment Repair Location Tagged? Yes No Power Supply Equipment Repair Location Tagged? Yes No Tools, in addition to hand and power tools, include machines and equipment Repair Location Tagged? Type Hrs Equipment Repair Location Tagged? Person Staffing Requirements:  Materials, Description and Quantity:  Minimal Skill Requirements: MMs # Hrs Equip. Oper. # Hrs Figure Frame Horse Power RPM Amps Volts  Model # Figure Frame Horse Power RPM Amps Volts  Femperature Drawing # NB			100100	*******		
Fastener Size: Bolt			Screw	Bolted	Othe	) I
Gasket Type: Spiral Wound Gylon Teflon Fiber Other Size Wrench Sizes: Special Tools: Job Description:  Job Scope:  Pre-Work Preparation Steps:  Safety Hazards:  Permits: SW OF Entry Electrical Hot Work Excavation Other LO/TO: Yes No Lock Box: Yes No Power Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipment and still Requirements:  Materials, Description and Quantity:  Minimal Skill Requirements: MMs # Hrs Hrs Equip. Oper. # Hrs Follow up Work (Rebuilds, Fabrications, etc.):  Post Completion Steps:  Name Plate Data: Manufacturer Type Serial Size Pressure Model # Figure Frame Horse Power RPM Amps Volts Temperature Drawing # NB						
Fiber Other Sizes:  Wrench Sizes: Special Tools: Job Description:  Job Scope:  Pre-Work Preparation Steps:  Safety Hazards:  Permits: SW OF Entry Electrical Hot Work Excavation Other LO/TO: Yes No Lock Box: Yes No Power Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipment Repair Location and Quantity:  Materials, Description and Quantity:  Minimal Skill Requirements:  Staffing Requirements: MMs # Hrs Equip. Oper. # Hrs Figure Frame Horse Power RPM Amps Volts Temperature Drawing # NB	Gasket Type: Spiral Wour	nd	Gylon	1	eflon	
Wrench Sizes:  Special Tools: Job Description:  Job Scope:  Pre-Work Preparation Steps:  Permits: SW OF Entry Electrical Hot Work Excavation Other LO/TO: Yes No Lock Box: Yes No Power Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipment Repair Location and Quantity:  Materials, Description and Quantity:  Minimal Skill Requirements:  Staffing Requirements: MMs # Hrs Equip. Oper. # Hrs  Follow up Work (Rebuilds, Fabrications, etc.):  Post Completion Steps:  Name Plate Data: Manufacturer Type Serial Size Pressure Model # Figure Frame Horse Power RPM Amps Volts Temperature Drawing # NB	Fiber Other		Size			
Special Tools: Job Description:  Job Scope:  Pre-Work Preparation Steps:  Permits: SW OF Entry Electrical Hot Work Excavation Other LO/TO: Yes No Lock Box: Yes No Power Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and p						
Job Scope:    Job Scope:	Special Tools:			- 70		
Pre-Work Preparation Steps: Safety Hazards: Safety Hazards: Sw OF Entry Electrical Hot Work Excavation Other LO/TO: Yes No Lock Box: Yes No Power Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include machines and equipment addition to hand and power tools, include m	Job Description:					
Pre-Work Preparation Steps:  Safety Hazards:  Permits: SWOFEntryElectrical Hot Work ExcavationOther LO/TO: Yes NoLock Box: Yes NoPower Supply Equipment Repair Location Tagged? Yes No Digital Pics: Yes NoField Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipments in addition to hand and power tools, include machines and equipments.  Materials, Description and Quantity:						
Safety Hazards:	Job Scope:					
Safety Hazards:						
Permits: SWOFEntryElectrical Hot WorkExcavationOther	Pre-Work Preparation S	teps:				
ExcavationOther	Safety Hazards:					
ExcavationOther	Browles CV OF	Centro	Floor	steel then W	famili .	
Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipments, in addition to hand and power tools, include machines and equipments.  Materials, Description and Quantity:  Minimal Skill Requirements:    Staffing Requirements:   MMs #	Permits: SWOF	Enury_	EPECU	rical Hot v	POTK	
Equipment Repair Location Tagged? Yes No Digital Pics: Yes No Field Sketch: Yes No Tools, in addition to hand and power tools, include machines and equipments, in addition to hand and power tools, include machines and equipments.  Materials, Description and Quantity:  Minimal Skill Requirements:    Staffing Requirements:   Hrs   Hrs     CSMs #   Hrs     Equip. Oper. #   Hrs     Follow up Work (Rebuilds, Fabrications, etc.):	ExcavationOthe	1	2.77			
Minimal Skill Requirements:						
Staffing Requirements:   MMs #	Materials, Description a	nd Quantity:				
CSMs #	Minimal Skill Requireme	ents:				
CSMs #						
Equip. Oper. #   Hrs	Staffing Requirements:					
Post Completion Steps:						
Name Plate Data:           Manufacturer         Type	Follow up Work (Rebuild					
Manufacturer         Type           Serial #         Size         Pressure           Model #         Figure         Frame           Horse Power         RPM         Amps         Volts           Temperature         Drawing #         NB	Post Completion Steps:					
Serial #         Size         Pressure           Model #         Figure         Frame           Horse Power         RPM         Amps         Volts           Temperature         Drawing #         NB	Name Plate Data:					
Serial #         Size         Pressure           Model #         Figure         Frame           Horse Power         RPM         Amps         Volts           Temperature         Drawing #         NB	Manufacturer			Type		
Model #         Figure         Frame           Horse Power         RPM         Amps         Volts           Temperature         Drawing #         NB	Serial #		Size	Pre	ssure	
Horse Power						
Temperature Drawing # NB	Horse Power	RPM	Amos		Volts	
Procedures, Specifications, Additional info needed:	Temperature	Drawing #			NB	
	Procedures, Specification	ns, Additional	info needed	l:		
Prepared by:		-				

#### Key traits of an organization that has an effective planner:

- Necessary planner responsibilities do not take a back seat to other needs.
- The majority of a planner's time is spent working on future work.
- Maintenance personnel seldom have to acquire additional parts on "planned" jobs.
- They have documented the type of jobs that should not be planned in order to increase the effectiveness of their planner(s).
- They define emergency work and track its level.
- Emergency work is 15% or less of total labor hours.
- Planning documentation is valued and reviewed by the field personnel. Field personnel realize the importance of sticking to the plan for consistency and maintaining the schedule.
- The planner effectively executes the following responsibilities:

Inspecting the job

Writing a job scope

Ordering parts

Identifying parts

Identifying and assembling necessary procedures

Identifying required permits

Electronically maintaining current status of the work orders and backlogs

Because the planner is such a skilled and resourceful person, one of those who can always make things happen, it is all too easy for him/her to be saddled with responsibilities that rob time from necessary planning responsibilities. Management must always be wary of this and protect against sacrificing planning quality for convenience. I am not saying that your planner cannot have additional responsibilities but only that management must ensure that the planning responsibilities have first priority and that any additional responsibilities do not impinge on them. We discussed earlier how a planner's time is leveraged by three or more times; it is unlikely that any other responsibilities assigned to a planner will have anywhere near that level of value. However, in my experience, it is a common problem that planners have either been assigned, or they have assumed, other responsibilities that limit the amount of time they have to do their foremost job. Thus planning quality and/or quantity suffers. Some common responsibilities that I find planners fulfilling that do not require a planner's expertise and could compete with higher value adding activities necessary for well planned jobs are:

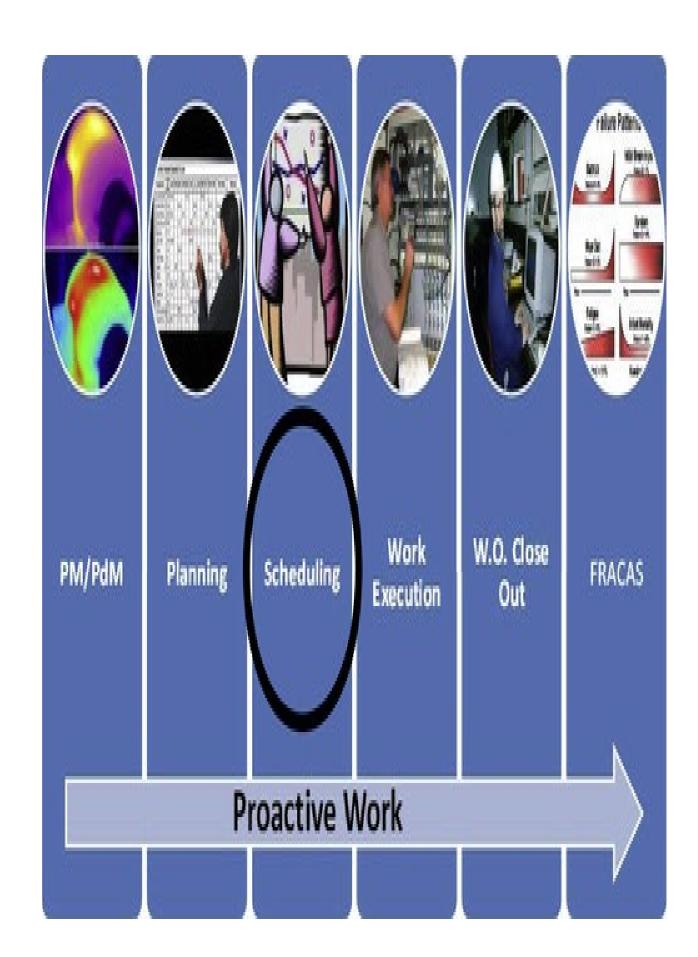
- Kitting the parts
- Stocking new spare parts
- Maintaining the CMMS information
- Ordering parts for emergency jobs or jobs already in progress. Avoid this at all cost!

Note: It is the responsibility of someone else to take of emergency work. Pulling a planner into emergency work reduces wrench time and decreases work efficiency.

## **Scheduling**

Maintenance scheduling is the coordination of the schedule for the maintenance resources (labor, materials, tools, and equipment) and that of the assets (production equipment) in order to:

- Minimize interruptions to the production schedule.
- Maximize maintenance work within the opportunities present in the production schedule.
- Maximize utilization of the maintenance labor resources.
- Proactively initiate and execute preventive, predictive, and corrective maintenance work.
- Maximize wrench time for the maintenance organization.



Each of these bullets has already been discussed in detail. So, let us look at how an effective schedule is built. An effective schedule should have an appropriate amount of fill-in work as discussed earlier. Depending on your organization's level of emergency work, you may need more or less fill-in work to protect the remaining planned and scheduled work from interruption. The majority of the labor hours available will be scheduled as routine work that has been planned. The remaining minority of the hours will be scheduled as fill-in work. By design, fill-in work will be sidelined as emergency work necessitates. Forty-six percent of the survey respondents report that their P&S jobs are frequently interrupted by emergency jobs. Interrupting fill-in work does not count as a schedule breaker nor should it require supervision approval. I have seen highly proactive maintenance organizations effectively operate with as little as 5–10% fill-in work, and I have seen those that required 40–50%. As a rule of thumb, if your P&S system is properly designed and executed, in 6–12 months you should need 20% or less fill-in work to protect your higher value work from interruption by emergency jobs.

One of the most effective tools in scheduling maintenance work, particularly in a situation where a single maintenance organization serves more than one production or manufacturing area, is the use of a maintenance coordinator. A maintenance coordinator, who reports through the production department, serves as a point of contact for all information and a funnel for setting priorities for maintenance. I have often seen where each shift supervisor, and each production manager, believes his or her maintenance work is top priority. A maintenance coordinator can minimize this. They should attend all production meetings and be thoroughly capable of leveling work order priorities across department lines. The maintenance coordinator has knowledge of all production schedule issues such as order ship dates, production start-up and shut-down dates, production delays, and product priorities. A representative from the production department, armed with this information, can much more effectively prioritize, help schedule work orders, minimize priority changes, minimize schedule changes, and find opportunities in the production schedule for maintenance work, than all of the maintenance managers talking with the production supervisors in the plant. I strongly believe that the maintenance coordinator role is just as critical as a planner and scheduler in all but the smallest P&S efforts. In the case of a maintenance coordinator, justification for the position should not come from the maintenance department but from the production department. If your P&S

system is able to deliver positive gains to your maintenance department, a maintenance coordinator position will be paid for by the gains delivered to the production department. The cost associated with an hour for the production department is much more valuable than an hour of maintenance department time. Reducing the time required to perform a maintenance job will in turn save the same amount of time for production. If you have questions about justifying a maintenance coordinator, keep this section in mind.

A maintenance coordinator working with a maintenance scheduler can create a synergy that will cause a paradigm change in the reactiveness of a maintenance organization. This is the result of merging the production and maintenance schedules, along with adjusting priorities, which will enable more proactive work to be scheduled and completed than without a maintenance coordinator.

The last benefit of having a maintenance coordinator that I will mention is that of an advocate in the production management meetings. The maintenance coordinator's allegiance should be to the operating department, but his or her participation in the P&S process with maintenance will instill a high degree of ownership in the maintenance schedule. Having his or her input in the production scheduling meetings will be invaluable to the maintenance organization in getting support for proactive work and eliminating delays to maintenance caused by production. Forty-seven percent of our survey respondents reported that maintenance frequently waits for equipment to be shutdown and/or prepared for work that was scheduled.

\* Key principle: If your maintenance organization has to struggle with competing priorities from the production department and/or a lack of support for the P&S effort, make the case for a maintenance coordinator.

Following are some of the key maintenance coordinator responsibilities:

- Level work priorities across the department.
- Communicate all production schedules to maintenance.

## Weekly & Daily Scheduling Process

Maintenance Coordinators, working with the area maintenance Team Manager or his appointee, identify work to be done the following week and the day(s) it is to be done.

No later than 2:00 p.m. Wednesday, Maintenance Coordinators send a note to all Planners (CSM & MMM) listing all Work Order Numbers to be done the following week and the day(s) they are to be done.

Plant-wide scheduling meeting held

→ Thursday morning at 11:00 a.m. to finalize the next week's schedule.

### Schedules will be published to:

- Maintenance Coordinators
- Maintenance Team Managers
- Crew Managers

No later than 3:00 p.m., the Planners will publish the Daily Schedule by sending an Outlook note with the schedule attached.

Maintenance Coordinators and Crew -Managers will communicate with their respective areas to initiate activities to prepare the equipment for maintenance per the schedule. The Planners will publish the weekly schedule no later than 2:00 p.m. Thursday.

Daily, before 1:30 p.m., the Maintenance Coordinators will review scheduled jobs and any new maintenance needs and communicate to the Planners (CSM & MMM) any necessary schedule changes for the next day.

Work Orders that are not ready to schedule status (RSCH) will be recorded as Schedule Breakers. Per corporate expectations, any job not scheduled for 24 hrs. is a Schedule Breaker.

#### Figure 20.1 The scheduling process.

- Ensure timely equipment preparation for maintenance.
- Delete duplicate and unnecessary work orders.
- Help maintenance find opportunities to complete all proactive work on time.

A process that I have seen work very well is for all maintenance work requests from the operating department to go through the maintenance coordinator before going to the planner. This gives the maintenance coordinator an opportunity to assign a more equitable priority to each work order given his broader perspective across the entire production department. Going through the maintenance coordinator before the planner also helps the planner respond to true priorities.

The scheduling meeting should be attended by the maintenance coordinator, the scheduler(s), the maintenance supervisor, and the planner(s). If the scheduler has properly communicated with the maintenance coordinator and the maintenance supervisor prior to the meeting, the weekly scheduling meeting should be simply a final approval of the schedule. I have sat in scheduling meetings for a large maintenance organization that were very well prepared for and took only 15 min. It was very impressive. The people in those meetings were very good at what they did and they came to the meeting prepared. They had a well-defined process and everyone followed it. I have also sat in scheduling meetings that were either unorganized, ill-prepared for, involved turf wars between maintenance and production, or were simply games being played out because management required the meeting. I have seen these meetings take from one to four hours.

Daily versus weekly scheduling, which is better? I believe that for the most effective scheduling, both should be used. That does not mean that you have daily scheduling meetings. I think you can do both with only a single weekly scheduling meeting.

This allows a weekly schedule, agreed on in advance, that provides the overall target for the following week, then daily updates as needed. Daily changes, if any, are usually small. What this will do for your organization is provide

increased flexibility to meet needs unforeseen when the weekly schedule was built. Inflexibility is one of the key downfalls of a rigid scheduling process. Keep in mind, the scheduling process should be very rigidly adhered to. However, that process can have some degree of flexibility designed into it. For example, let us assume it is Tuesday morning and an operator just reported a blower making an odd noise. A work order is written, and the planner inspects the job. The planner determines that a bearing needs to be replaced. Also, since there are several of these blowers in the plant, there is a documented job plan that was previously created. For this job to be fully planned, all the planner has to do is order the bearings and set the status to "ready to schedule," and all of the remaining information will already exist in the preplanned documentation. Using the process described in Figure 20.1, the job can be placed on Wednesday's schedule as long as everything is ready by 1:30 p.m. This is making the scheduling process work for you rather than punishing the organization that does not have the flexibility to count this as a planned and scheduled job. The planner was not rushed abnormally, and the job plan has the necessary elements of a fully planned and scheduled job.

Figure 20.1 is an actual scheduling process from a plant that has a mechanical maintenance crew and a control system/electrical crew, each with their own maintenance team manager. These two crews maintain three separate production areas that operate around the clock seven days per week. Each production area has its own maintenance coordinator. There is a crew manager for each shift to manage production issues. The entire group (about eight people) gets together for their weekly scheduling meeting. With these clarifications, the process is fairly self-explanatory. In this particular organization, the two planners also served as the schedulers.

Some situations that you want to prevent from being counted as scheduled include, for example, when a rush to meet a deadline results in a poor quality job plan, or when your planner is still creating or amending the job plan while work on the job is underway. In my opinion, this is a cardinal sin. When your planner is planning the job while work is in progress on the job, that is not future work—his time is not being leveraged. You should only use the planner's time where it will be leveraged (more about this in the next chapter). If work is in progress, a regular maintenance person should be executing all necessary activities from turning wrenches, ordering parts, and finding procedures. Once work starts, you have missed the opportunity to leverage a planner's time. This is an essential principle that must be understood and practiced.

Scheduling cutoff times is a critical piece of an effective scheduling process.

In Figure 20.1, you will notice that there are two separate cutoff times. The first is the cutoff to get work on the next week's schedule, which is 2:00 p.m. Wednesday. The second cutoff time is 1:30 p.m. daily for updates to the next day's schedule. Cutoff times are necessary in order to "publish" a schedule. With a firm day and time, the scheduler can electronically issue an official schedule for either the next week or the next day, whichever the case may be. There are no separate schedules; the weekly schedule is updated daily. Once published, the production department can start planning to make the necessary preparations to the equipment before maintenance arrives at the job site. Depending on your type of industry, these activities may include:

- Shutting the equipment down
- Cleaning/decontaminating the equipment
- Preparing permits to work on the equipment (lockout/tag out), etc.

Maintenance can also begin a myriad of activities. For example:

- The parts clerk can start kitting the parts for jobs a day or two before execution time.
- Maintenance can look at the schedule and start planning their personal activities.
- The planner can change the status of the work to "scheduled" and discontinue tracking those jobs; they will now effectively be in progress.

Without a cutoff time, it would be impossible to publish a schedule, causing an almost endless amount of back-and-forth communication between all involved in the process to execute a job. Forty-eight percent of survey respondents report using a formal cutoff time for creating a schedule. Only 41% of respondents report publishing a schedule electronically, available to all. Notice in Figure 20.1 that this organization had a firm rule that in order for work to be counted as scheduled, it had to be on the schedule for at least 24 h. This particular organization had historically "punched the card" by regularly listing work as planned and scheduled when it clearly had not been, thus management created the 24 h requirement in an attempt to improve the quality of planning and

scheduling. Normally, I would not suggest a 24 h requirement such as this.

\* Key principle: Publish a weekly schedule electronically, which is available to any who may need the information, and then update it daily as results and demands change.

Can planning and scheduling be treated separately, or must they be implemented together? Yes to both questions!

- Planning prevents delays by identifying the needs of the job.
- Planning enables scheduling, by quantifying the resource needs in order for a block of time to be set aside to do the job.
- Scheduling enables effectiveness by maximizing resource utilization in both maintenance and production.
- Scheduling alone can improve effectiveness with only an estimate of labor needs by reducing the down time between maintenance jobs, eliminating false starts when production cannot free up the equipment, and by reducing the down time when maintenance has to wait while production shuts down and prepares equipment.
- Together, P&S are much more effective on certain jobs.
- Not all jobs are candidates for P&S (this will be detailed in the next section).

Ultimately, you will want the majority of your work to be both planned and scheduled because this is how you will get the most effectiveness increase.

Some work, however, is not well suited for planning and thus will only be scheduled. One example is fill-in work and inspections; planning would not be done beyond a basic labor estimate, which should always be documented to enable effective scheduling and backlog management. The major consideration would be if the work was very straightforward and only required "free issue" parts (parts stocked in the shop) or no parts at all. Then the job would only need to be scheduled. Running jobs such as this through the planning process would not add value. In this case, more time would be required to plan than would be saved by delays.

The characteristics of a job that present the opportunity for savings are complexity and predictability. Complexity can come in the form of technical difficulties, multiple crew involvement, special permits, special equipment or tools, special procedures, and multiple part/material needs. It is complexity that creates the opportunity, if not the likelihood, of delays. And, it is on the prevention of delays that we want our planner focused. The more labor that is required by a particular job, the more value a half hour savings can be worth. If you save one person a half hour by having a part ready before the job is started, versus saving 10 people a half hour, it can make the difference in whether a job should be planned or not. If the planner would spend more than 30 min inspecting the job, updating status, ordering parts, etc. then he has used more than the 30 min saved, in the example of a one-person job. You must protect your planner from these types of errors. Very simple and/or short jobs do not have much value that can be added via planning, so they would normally not go through the planning process. This practice frees the planner to focus on jobs where planning can leverage his time by three or more times.

Predictability is a term I use to describe if the parts, person-hours, technical skills, and other resources the job will need can be accurately identified. Jobs that have low predictability are not good candidates since a planner would not be able to accurately predict the resource and part needs for the job or may not be able to estimate the amount of time a given job would require to be completed. A good example of this sort is some jobs for an instrumentation crew. Take, for instance, a level transmitter work order. In inspecting the job, a planner will not be able to determine if the fuse is blown, the probe is bad, or if an amplifier or communication card needs to be replaced. In this case, the planner would not be able to specify the parts for the job or how long the repair might take. The best that can be done is to make an "average" time-required estimate and stop the planning there.

## **Reasons why Maintenance and Planning Fail**

1. Not knowing what effective planning and scheduling looks like.

Visit an organization that has proven effective planning and scheduling with key maintenance and production leadership. Talk to and interview key maintenance technicians and planners.

2. Planner/Schedulers are not trained by true maintenance planning and scheduling professionals.

Identify organizations whose primary focus is on training planners and schedulers. Bring the instructor back to your site to train site personnel in effective planning and scheduling. The instructor should help the planner with on-site coaching. If wrench time for maintenance staff of 20 maintenance techs is 20–40%, you just doubled the amount of proactive work conducted at your site.

3. The culture must be changed from reactive to proactive.

Patience and discipline is required to move from reactive to proactive.

If their thinking does not change maintenance planning will always be reactive.

4. Maintenance planning and scheduling metrics are not used to track and lead performance.

Use the Society for Maintenance and Reliability Professional (SMRP) Metrics and Definitions to move your maintenance planning and scheduling to a proactive state. (www.smrp.org)

These metrics were developed by maintenance and reliability professionals worldwide and validated by a large number of professionals. A few SMRP metrics to use for planning and scheduling are:

- Unplanned Work
- Actual Cost to Planning Estimate
- Actual Hours to Planning Estimate
- Reactive Work
- Proactive Work
- Schedule Compliance Hours
- Schedule Compliance Work Orders
- Standing Work Orders
- Ready Backlog
- Total Backlog
- PM & PdM Compliance

Proactive maintenance planning and scheduling takes time to create a proactive culture, however, patience and perseverance will pay off.

## Appendix A

# The Scoreboard for Maintenance Excellence—Version 2015

\_

## 1. Top leaders' support to maintenance and physical asset management

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The organization has a strategic plan that is the starting point for development of
2.	Top leaders realize that the overall maintenance strategy must be holistic and that
3.	Top leaders understand maintenance in regard to its broader sense as systematic
4.	Top leaders consider and optimize the conflicting priorities of asset utilization ar
5.	Top leaders have provided an organizational structure that facilitates the implem
6	Top leaders should arrange for the creation of the asset management strategy. Ke
7.	Top leaders should appoint a member(s) of management at C-level whose respon
8.	Top leaders should ensure that adequate resources are available for establishing
Table Continued	d

Item#		
9.		
10.		

#### -

## 2. Maintenance strategy, policy and total cost of ownership

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
	Your current maintenance strategy provides answers to the following questio
1.	Do we know what (existing) assets we have, where they are, what condition they
2.	Do we know the quality of the existing asset information to include top three dat
3.	Do we know what we want from our assets in the short, medium, and long term
4.	Can our assets deliver our asset management objectives cost effectively within tl
5.	Are we getting the most value from our assets and trying to gain more value from
6.	Do we have enough capability (or overcapacity) in our current asset portfolio?
7.	Have some assets or asset systems become redundant, underused, unprofitable, or
8.	Are we confident that the risks of our assets causing harm to people and the envi
9.	Is our asset-related expenditure (capital investment and costs) insufficient, exces
10.	Can we readily evaluate the benefits (performance, risk reduction, compliance, s
Table Continu	ned

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
	Your current maintenance strategy provides answers to the following questio
11.	Are we allowing future problems to develop and increase maintenance requirem
12.	Have we given due consideration to the other aspects of the organization that aff
13.	Do we review the appropriateness of our asset management strategy in light of c
14.	Are we continually improving our asset management system performance and re
15.	Do we have the necessary asset management policy, strategy, and plan to ensure
16.	Does our approach to sustainable management of the assets take appropriate acc
17.	Are the working conditions, skills and well-being of our employees and contract
18.	Are we optimizing our asset management process(es) and/or procedures in light
19.	Can we answer all of the above questions confidently, with a clear audit trail, and
20.	The steps to forming, implementing, and maintaining the asset management poli
21.	Whole life asset management is being used and includes risk exposures and perf
Table Continu	ued

Item#	Rat
	You
22.	Th
23.	Th
24.	Inf
25.	Th
26.	Re
27.	Со
28.	Th
29.	То
30.	Ma
2. Maintenance strategy, policy and total cost of own	ership score Subtotal Score Possible: 300

## 3. The organizational climate and culture

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The organization's vision, mission, and requirements for success include physica
2.	Senior management is visible and actively involved in continuous maintenance i
Table Continued	

-

Item# Ratin

Item#	Rating: Excellent—10
3.	The organization's bu
4.	Maintenance is kept v
5.	The organization's cul
6.	Open communication
7.	The organization proc
8.	The team-based appro
9.	Crafts understand that
3. The organizational climate and culture score Subtotal Score Possible: 90	
•	1

## 4. Maintenance organization, administration and human resources

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The maintenance organization chart is current and complete with fully defined a
2.	The maintenance organization is sufficiently staffed to respond to cover three ke
3.	Maintenance leaders do not allow extensive craft resources to be consumed with
4.	There are a number of ways to organize maintenance. Does your organization ha
Table Continued	<u>-</u>

5.	The maintenance organization of supervisors and planners is organized such the
6	Having total responsibility for the business of maintenance includes not only the
7.	Clear-cut craft job descriptions have been developed that completely define job
8.	Craft personnel are provided copies of their job descriptions and counseled peri
9.	One single head of maintenance operations is a capable maintenance leader that
10.	The maintenance department head (top leader) has high visibility within the org
11.	The first-line supervisors are responsible for the performance of 12–15 crafts pe
12.	A time-keeping system is in place to charge craft time to each job or task on each
13.	Monthly or weekly reports are available to show distribution of maintenance lab
14.	Monthly or weekly reports are available to monitor backlog status to include tot
15	Backlog trend data is available to highlight the need for craft increases, schedule

Item#
16.
17.
18.
4. Maintenance organization, administration and human resources score Subtotal Score Possible: 180

## 5. Craft skills development and technical skills

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The types and levels of craft skills required for an effective maintenance operation
2.	Job descriptions include well-defined standards for job knowledge and skill leve
3.	An assessment of the current job knowledge and skill level of each crafts person
4.	The overall training needs for the maintenance staff have been developed with a
5.	The organization has committed to providing the necessary resources for mainte
6.	A program for craft skills development has been designed to address priority trai
7.	Results of training are determined by a competency-based approach that ensures
8.	A policy to pay for skills gained is available or is being developed as part of the
9.	The benefits of developing multicraft capabilities within maintenance have been
10.	Individual training plans for each crafts person are being used to document comp
Table Continu	ned

Item#
Rating: Excelle

11.
Actual hands-c

12.
The overall cra

5. Craft skills development and technical skills score Subtotal Score Possible: 120

## 6. Operator-based maintenance and pride in ownership

Item#	Rating: Excellen
1.	Operators are re
2.	Operator trainin
3.	An initial cleani
4.	Operators have
5.	Operators have
6.	The process of t
7.	Operators have
8.	Results from op
9.	The organization
10.	The organization
6. Operator-based maintenance and pride in ownersh	ip score Subtotal Score: 100

## 7. Maintenance leadership, management and supervision

\_

Item#	Ratin
1.	This
2.	The 1
3.	The 1
4.	Nons
5.	Supe
6.	Supe
7.	An e
8.	Mair
9.	Supe
10.	Supe
11.	Supe
12.	Supe

7. Maintenance leadership, management and supervision score Subtotal Score Possible: 1	20

#### -

## 8. Maintenance business operations, budget and cost control

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The maintenance budget is based on a realistic projection of actual needs rather
2.	Maintenance expenditures are charged to back to assets within work centers with
3.	Customers of maintenance are measured based on budget compliance and unit p
	Budget variances are monitored at customer level as well overall maintenance to
4.	Deferred maintenance repairs to operating equipment and facilities-related assets
5.	Maintenance is analyzing the TOC and advising top leaders when replacements
6.	Maintenance has been assigned authority to make purchases at a level that ensur
7.	Maintenance provides key input and support to long-range budget planning for r
8.	Labor and material costs are established for all work orders accumulated to the $\epsilon$
9.	An equipment history file is maintained for major pieces of equipment to track l
10.	The equipment history file is reviewed periodically to analyze repair trends and
11.	Labor and material costs are estimated prior to the start of major planned repair
<u> </u>	

Item	#	Ra
12.		N
13.		С
14.		Т
15.		N
8. N	Maintenance business operations, budget and cost control score Subtotal Score Possible: 150	

### 9. Work management and control: maintenance and repair (M/R)

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	A work management function is established within the maintenance operation ge
2.	Written work management procedures that governs work management and contr
3.	A printed or electronic work order form is used to capture key planning, cost, pe
4.	A written procedure that governs the origination, authorization, and processing of
5.	The responsibility for screening and processing of work orders is assigned and c
6.	Work orders are classified by type, e.g., emergency, planned equipment repairs,
7.	Reasonable "date required" is included on each work order with restrictions again
8.	The originating departments are required to indicate equipment location and nun
9.	A well-defined procedure for determining the priority of repair work is establish
10.	Work orders are given a priority classification based on an established priority sy
Table Continu	ued

Item#	Ratii
11.	Wo
12.	Wol
9. Work management and control: maintenance and repair score Subtotal Score Possible: 120	

# 10. Work management and control: shutdown, turnarounds, and outages (STO)

-

\_

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	Work management and control is established for major overhaul repairs, shutdox
2.	Work management and control of major projects provide means for monitoring [
3.	Work orders are used to provide key planning info, labor/material costs and perf
4.	Equipment history is updated with info from work orders generated from major
5.	The responsibility for screening and processing of work orders for major repairs
6.	Change order procedures and control are clear to all and approved at the appropri
7.	Change orders are reviewed by planners just as they review all jobs: scope of wo
8.	Work orders for major repairs, shutdown, and overhauls are monitored for sched
9.	Cost variances are measured at key milestones with cost variance info so extrem
10.	Has the current level of plant maintenance/asset management achieved the desire
Table Continu	ed

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
11.	The organization has the capability to manage the turnaround program and be co
12.	The organization knows what manpower is available in house, the competence le
13.	Have STOs received significant level of attention of companies, do companies h
14.	The organization's history of planning and preparation for STOs has been: carrie
15.	A process of assessing plant equipment deterioration is in place, the likely impac
16.	The plant beginning an STO has personnel available when required and capable
17.	Top leaders clearly understand that STO is a significant maintenance and engine
18.	The company includes profit lost during period of STO, which is considered par
19.	All involved with STOs realize the potential hazard to plant reliability or can dir
20.	Technical uncertainty due to occurrence of unforeseen problems can be accurate
Table Continu	ued

Item#	
21.	
22.	
23.	
24.	
25.	
26.	
10. Work	management and control: shutdowns, turnarounds, and outages (STO) score Subtotal Score Po

# 11. Shop-level reliable planning, estimating and scheduling (M/R)

\_

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	A formal maintenance planning function has been established and staffed with q
2.	The screening of work orders, reliable estimation of repair times, coordination o
	Planner/schedulers realize their primary scope and role of planning and scheduli
	Planner/schedulers clearly understand the scope of their defined roles and respor
Table Continued	-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
3.	The planner uses the priority system in combination with parts and craft labor as
4.	A daily or weekly maintenance work schedule is available to the supervisor who
5.	The maintenance planner develops reliable and well-accepted estimated times fc
6.	A day's planned work is available for each crafts person, keeping at least a half a
7.	A master plan for all repairs is available indicating planned start date, duration, (
8.	The master plan is reviewed and updated by maintenance, operations, and engine
9.	Total maintenance requirements are a total of Total Backlog + Ready Backlog th
10.	A firm rule of thumb is never to put anything on the schedule without parts in ho
11.	When parts arrive for critical equipment and can be inserted to the current sched
12.	Scheduling/progress meetings are held periodically with operations to ensure un
13.	Operations cooperate with and support maintenance to accomplish repair and PN
14.	Operations staff sign off on the agreed-upon schedule and are responsible to app
15.	Setups and changeovers are coordinated with maintenance to allow scheduling o
16.	Planned repairs are scheduled by a valid priority system, completed on time and
Table Continue	ed

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
17.	Deferred maintenance is clearly defined on the master plan, and increased costs
18.	Maintenance planners and production planners work closely to support planned
19.	The planning process directly supports the supervisor and provides means for el
20.	Planners' training has included formal training in planning/scheduling technique
21.	Benefits of planning/scheduling investments are being validated by various met
22.	Planning and scheduling procedures have been established defining work management
23.	A reasonable number of backup planner/schedulers are selected and properly tra
24	If a maintenance coordinator is assigned within a unit of a large refinery or any
25.	If issues of any nature arise that are not readily resolved by the planner and open
26.	If planned work orders involve participation by several shops or functional crew
27	Planners are in an excellent position to ensure critical spares by asset are account
Table Contin	ued

Item#	
29.	
30.	

# 12. STO and major planning/scheduling with project management

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The planning and scheduling function includes major repairs, overhauls, and ST
2.	The planner team is a resource (or member) for the STO team of senior manager
3.	Are your total backlog jobs coded and planned effectively to await an STO even
4.	Schedulers from Item #3 coordinate parts/materials, develop daily or weekly sch
5.	Current planning/scheduling manpower is available with the competency levels
6.	All planners and schedulers involved with STOs must realize the potential hazar
7.	There may even be poor decisions by managers and engineers, bad workmanshij
8.	The use of work orders, estimation of repair times, coordination and staging of r
Table Continued	

•

tem#		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
12. STO and major n	 / 1 1 1	0.110

#### 13. Contractor management

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	Contracted work is clearly defined because the better the definition at the early s
2.	Loose specifications for both materials and work to be done are avoided.
3.	Communication of your ideas to a contractor is included in the scope of work, as
4.	Ensure that the contractor understands the quality of materials needed from clear
5.	Negotiation and award of the contract has had key due diligence by the key own
6.	For larger jobs, owners may check out finances, credit, insurance, and staff.
7.	Owners may visit other jobs to see contractor quality of work and call references
Table Continued	

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
8.	Maintain at shop level a copy of the contract documents and keep a fair and com
9.	Be aware of and avoid, if possible, lowball bids and negotiate a schedule of extra
10.	Avoid a common ploy where lowballing the bid to get the job floods the compar
11.	Always add in for clauses like "all extras not included in the original price have
12.	Are there deduction clauses in the contract that spell out what you will charge ba
13.	Negotiate cancellation clauses and spell out how and why you can cancel the co
14.	For ongoing service bids, avoid both too short of a contract term and too long of
15.	Is the contract as clear as possible about responsibilities on who supplies what, v
16.	Are there statements about how the site is to be left at the end of each workday?
17.	Ensure who is responsible for locking up, barricades, traffic management, cleani
18.	Does the agreement also include who is responsible for municipal permits, job p
19.	Are contractors' insurance policies reviewed with an agreement about what happ
20.	Damage to a neighbor's property that then might sue you or might spoil a good 1
21.	Are all insurance certificates up to date covering: general liability, casualty (property)
22.	If the contractor did a design build, then malpractice and errors and omissions ar
I	l de la companya de

23.	Define performance as to what a good job would look like.
24.	Add clause like "all work is expected to be done in a professional and workmans
Table Continued	

	Item#	Rating: Excellent—10, Very Good
	25.	Owners should prepare the area to
	26.	Does the owner manage the contra
	27.	Does owner perform frequent inst
	28.	Clear agreements have been made
	29.	To avoid sloppy record keeping, a
	30.	Owner requires copy of paid recei
	31.	Owner should get a "release of all
	13. Contractor management score Subtotal Score Possible: 310	
I		l

### 14. Manufacturing facilities planning and property management

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The equipment asset inventory system provides an accurate and complete record
2.	New facilities planning, equipment additions and renovations are well coordinat
3.	Maintenance staff provides input into the engineering planning process for new
4.	An effective procedure for adding new facilities and new equipment info to the a
5.	Maintenance requirements are clearly designated as to responsibilities for both p
6.	The overall property management function within the organization provides clos
Table Continued	<del>-</del>

Item#	
7.	
8.	
9.	
14. Manufacturing facilities, planning and property management score Subtotal Score Possible: 90	

### 15. Production asset and facility condition evaluation program

-

Item#		Rating: Ex
1.		A process
2.		A facility
3.		The PM a
4.		The PM a
5.		The curre
6.		The curre
15. Prod	uction asset and facility condition evaluation program score Subtotal Score: 60	

16. Storeroom operations and internal MRO customer service

-

=

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The parts inventory system provides an accurate and complete record of informa
Table Continued	•

Item#	Rating: E
2.	The "AB
3.	"A" and
4.	"C" item
5.	Inventor
6.	Inventor
7.	An up-to
8.	Parts usa
9.	A critica
10.	Spare pa
11.	Storeroo
12.	An opera
16. Storeroom operations and internal MRO customer service score Subtotal Score: 120	

### 17. MRO materials management and procurement

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	Procedures and evaluation criteria for adding new maintenance parts and materia
2.	Stores requisitions and issues are tied to the maintenance work order and charge
3.	Maintenance planners and the storeroom personnel coordinate to reserve repair I
Table Continued	- -

Item#	Rating: Excellent—1
4.	Purchasing has an ef
5.	Purchasing has deve
6.	Maintenance storero
7.	Maintenance storero
8.	Maintenance and pu
9.	An effective control
10.	Purchasing and mair
11.	Stock outs are being
12.	Standardization of pa
17. MRO materials management and procurement score Subtotal Score: 120	

#### 18. Preventive maintenance and lubrication

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	The scope and frequency of PM and lubrication services have been established c
2.	Operations staff support and agree with the frequency and scope of the PM and l
3.	Optimum routes for PM inspections and lubrication services are established.
4.	PM checklists with clear, concise instructions have been developed for each piec
5.	Inspection intervals and procedures are periodically reviewed for changes/impro
6.	Planned times are established for all PM and lubrication tasks.
Table Continued	•

Item#	Rating: Excellent-
7.	The total craft labo
8.	The required level
9.	Actual craft time o
10.	Goals for PM com
11.	All noncompliance
12.	Maintenance and o
13.	The success of PM
14.	Preventive mainte
15.	The PM staff are v
16.	A PM master sche
17.	Corrective repair v
18.	PM manpower nee
18. Preventive maintenance and lubrication score Subtotal Score Possible	2: 180

# 19. Predictive maintenance and condition monitoring technology applications

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	Equipment has been evaluated for the application of PdM technology and the sci
2.	A plan for using current PdM technology is being developed or is now being put
Table Continued	- -

Item# 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14.

19. Predictive maintenance and conditioning monitoring technology applications score Subtotal Score F

15.

# 20. Reliability-centered maintenance (RCM)

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	A process such as RCM is used to determine the maintenance requirements of ar
2.	Criticality analysis to define top candidates for review has been conducted regar
Table Continued	

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
3.	The maintenance team strives to ensure any physical asset continues to do whate
4.	Operations context is clearly defined and understood by maintenance and operat
5.	Other factors related to operating context of the asset include: redundancy factor
6.	Strategies and operating principles are defined and characterized, the key steps c
7.	Maintenance can define ways the asset can fail to fulfill its function where a fun
8.	Maintenance understands that it is more accurate to define failure in terms of a s
9.	The organization's work order system captures functional failures, cause of failu
10.	When defining functions, the function statement should consist of a verb, object
11.	Performance standards are defined in two ways: Desired Performance: What the
12.	Function statements may include the appropriate but different types of performa
Table Continu	ued

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
13.	A failure mode that causes functional failures is being documented by the work
14.	Based upon an analysis of work completed, a reactive maintenance strategy of d
15.	Proactive maintenance that deals with events before they occur or deciding, plan
16.	Failure mode categories are designated when (a) capability falls below desired p
17.	Failure mode categories capability falling below desired performance can be ide
18.	When desired performance rises above capability, the following can be identified
19.	The level of detail in defining failure of a mode provides enough detail to select
20.	Failure modes that might reasonably be expected to occur in the current operatin
21.	Failure effects and failure consequences' are not the same. Failure effects answer
22.	Describing the effects of a failure strives to answer this question "What evidence
23.	Completing the failure mode and effects analysis (FMEA) utilizes steps 1–20 ab
Table Continu	ned

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
24.	Failure consequences answer the question, "How does it matter?" There are mar
25.	The focus on consequences starts the RCM process of task selection • Assessme
26.	What can be done to predict or prevent each failure? • Proactive tasks: Tasks und
27.	The organization uses the RCM process to make the best failure management de
28.	Decisions are made on what should be done if a suitable proactive task cannot be
29.	There is a very clear and solid understanding about the P–F interval curve and the
Table Continued	<b>-</b>

It	em#	Rating: Excellent—
	30.	The maintenance o <sub>l</sub>
,	31.	A strategy of just in
;	32.	A method to measu
;	33.	Reduced mean time
;	34.	Reduced MTTR is
	20. Reliability-centered maintenance (RCM) score Subtotal Score Possible: 0	

21. Reliability analysis tools: root cause analysis (RCA), root cause corrective action (RCCA), failure modes effects analysis (FMEA), and failure reporting analysis and corrective action system (FRACAS)

\_

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	A root cause analysis (RCA) process is in place as an effective process supporting
Table Continued	

**Table Continued** 

Rating: Excellent—10, Very Goo
The process includes containing a
A process for notifying affected c
When you have had an event, is i
The team approach is a leadership
The organization also understand
FRACAS is viewed as a way to n

## 22. Risk-based maintenance (RBM)

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average	
1.	Maintenance in this company has been carried out by integrating analysis, measi	
	This company has a process and resources to perform the asset condition and ris	
Table Continued		

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
2.	A risk-based maintenance strategy is in place that prioritizes maintenance resou
3.	This company realizes that the objective of maintenance over the last 20 years h
4.	Physical asset operators and owners within the oil, gas, and petrochemical sector
5.	Preventing all failures is generally not feasible from either a technical or an econ
Table Continued	

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
6.	Your maintenance strategies have evolved to support the technological requirem
7.	When looking closely at your company, most people will not find a disorientatin
8.	Risk-based maintenance: Your maintenance strategy considers risk-based mainte
9.	Your company has the capability to quantify problems with probability as well lo
10.	API RP 580 standard defines risk as the combination of the probability of an eve
11.	API considers the risk-based inspections (RBI) as the next generation of inspecti
12.	F.I. Khan and M.M. Haddara propose an RBM methodology broken down into t
Table Continued	

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average	
13.	Some see RBM as a simpler methodology than RCM; it also requires an initial r	
14.	Your strategy includes maintenance based on equipment performance monitori	
15.	The maintenance frequency and type are prioritized based on the risk of failure.	
	The monitoring and maintenance programs for high risk assets are typically CBI	
16.	Risk-based maintenance is a suitable strategy for all maintenance plants as well	
17	A framework for determining risk is in place. Here the risk-based maintenance f	
18.	Collect data—For each risk that is being identified, accurate data about the risk 1	
19.	Risk evaluation—At the risk evaluation stage, your operation considers both the	
Table Continued		

Item#	Rating: Excellent—10, Very G
20.	Rank risks—With the risk evalı
21.	Create an inspection plan—If tl
22.	Propose mitigation measures—
23.	Reassessment—Finally, your p
24.	Risk-based maintenance decision
22. Risked-based maintenance score Subtotal Score Possible: 240	

## 23. Process control and instrumentation systems technology

-

Item#	Rating: excellent—10, very good—9, good—8, average—7, below average—6
1.	List of all instrumentation systems sorted for criticality.
2.	Instrument systems assigned machine unit (tracking) number along with other vi
3.	Operational instructions and data, installation drawings, catalog info, maintenan-
4.	Instrument system components tagged and identified according to standards.
5.	Calibration procedures and maintenance tasks written and referenced in work or
6.	Calibration records up to date, filed, and indexed. Historical records dated through
7.	Critical system operational and emergency procedures written, up to date, and as
8.	All hand-held and portable instruments used for operational checks and mainten
Table Continued	<b>-</b>

Item# Rati

 $23.\ Process\ control\ and\ instrumentation\ systems\ technology\ score\ Subtotal\ Score\ Possible:\ 90$ 

## 24. Energy management and control

\_

\_

Item#	Rating: Excellent—10, Very Good
1.	Energy costs are reflected in facili
2.	An energy team (or designated state
3.	Steam trap surveys are performed
4.	Air compressions have been prope
5.	Overall systems analysis of the hea
6.	Boilers in the facility are well main
7.	A water management strategy is in
8.	A comprehensive energy audit has
9.	Chronic facility breakdowns and p
10.	New technologies such as infrared
11.	Energy-efficient motors, lights, ba
12.	Facility automatic energy control s
24. Energy management and control score Su	abtotal Score: 120

## 25. Maintenance engineering and reliability engineering support

-

Item#	Rating: 1
1.	Engine
2.	Purchas
3.	Engine
4.	Engine
5.	Engine
6.	Engine
7.	Capital
8.	Up-to-d
9.	Engine
25. Maintenance engineering and reliability engineering support score Subtotal Score	re: 90

## 26. Health, safety, security, and environmental (HSSE) compliance

-

Item#	Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average
1.	Maintenance leaders have created a broad-based awareness and appreciation for
2.	Maintenance employees attend at least one safety meeting per month.
3.	Maintenance has shown a continual improvement in its safety record over the pa
4.	All permits and safety equipment are available and prescribed for each job that r
5.	All cranes, hoists, lift trucks, and lifting equipment are inspected as part of the p
6.	Good housekeeping within maintenance shops and storerooms is a top priority.
7.	Maintenance tools, equipment, and leftover materials are always removed from
8.	Maintenance continually evaluates areas throughout the operation where safety (
9.	The total scope of regulatory compliance issues within the organization has been
Table Continu	ed

Item#	Rating: Exce
10.	Maintenance
11.	Maintenance
12.	Maintenance
13.	A complete
14.	Recommend
15.	Cyber secur
26. Health, safety, security, and environmental compliance score Subtotal Score: 120	

## 27. Maintenance and quality control

-

Item#	Rating: Excellent—10, Very Good-
1.	Quality control has included mainte
2.	Major repairs and setups impacting
3.	Documentation of all equipment co
4.	Quality of maintenance repairs is ex
5.	Maintenance and quality work toge
6.	Optimum machine speeds have been
7.	All machine-related quality defects
8.	Losses due to minor stoppages, idlii
9.	Chronic equipment breakdowns and
27. Maintenance and quality control score Subtotal Score: 90	

## 28. Maintenance performance measurement

-

Item#	Rating: Excellent—10, Ver
1.	Maintenance performance
2.	Maintenance labor and ma
3.	Equipment downtime attril
4.	Realistic labor performanc
5.	Maintenance labor perforn
6.	The measurement of craft 1
7.	Periodic reviews are done
8.	The effectiveness of maint
9.	Baseline performance factor
10.	A method to measure perfc
11.	The craft workforce unders
12.	Maintenance performance

28. Maintenance performance measurement score Subtotal Score: 120

# $29. \ Computerized \ maintenance \ management \ systems \ (CMMS) \ and \ business \ systems$

-

Item#

12.

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11.

| 13.  |
|--|
| 14.  |
| 15.  |
| 16.  |
| 17.  |
| 18.  |
| 29. Computerized maintenance management systems (CMMS) and business systems score Subtotal Sco |

30. Shop facilities, equipment, and tools

-

\_

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average               |
|-----------------|---|
| 1.              | Maintenance shop facilities are located in an ideal location with adequate space, |
| Table Continued |   |

| Item#  | Rating: Excellent—10, Very Good—9, Good—8, Av         |
|--|---|
| 2.   | Standard tools are provided to craft employees and ac |
| 3.   | An adequate number of specialty tools and equipment   |
| 4.   | All personal safety equipment necessary within the or |
| 5.   | Safety equipment for special jobs such as confined sp |
| 6.   | Maintenance achieves a high level of housekeeping in  |
| 7.   | Maintenance maintains a broad awareness of new too    |
| 8.   | Maintenance continually upgrades tools and equipmen   |
| 9.   | An effective process to manage special tools and equi |
| 30. Shop facilities score Subtotal Score: 90 |   |
| '  | '   |

## 31. Continuous reliability improvement

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                 |
|-----------------|---|
| 1.              | Continuous reliability improvement is recognized as an important strategy as evi    |
| 2.              | The current level of commitment to continuous reliability improvement is based      |
| 3.              | Maintenance improvement opportunities have been identified with potential cos       |
| 4.              | Improvement priorities have been established based on projected benefits and va     |
| 5.              | Top leaders have reviewed, modified, and/or approved maintenance improvemen         |
| 6.              | Sufficient resources (time, dollars, and staff) have been established to address pr |
| 7.              | Implementation plans and leaders for each priority area are established.            |
| 8.              | A team-based approach is used to identify and implement practical solutions to r    |
| 9.              | Continuous reliability improvement for the maintenance resource of physical ass     |
| 10.             | Continuous reliability improvement for the maintenance resource of craft labor 1    |
| Table Continued | i   |

| Item#                            | Rating: Excellent—10, Very G     |
|----------------------------------|----------------------------------|
| 11.                              | Continuous reliability improve   |
| 12.                              | Continuous reliability improves  |
| 13.                              | Continuous reliability improves  |
| 14.                              | Maintenance employees partici    |
| 15.                              | Written charters are established |
| 31. Continuous reliability impro | vement score Subtotal Score: 150 |

## 32. Critical asset facilitation and overall equipment effectiveness (OEE)

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average             |
|-----------------|---|
| 1.              | Overall equipment effectiveness (OEE) ratings have been established for major ( |
| 2.              | Priorities have been established with a plan of action for improving OEE.       |
| 3.              | The OEE factor of availability is being measured and methodology rated as:      |
| 4.              | The OEE factor of performance is being measured and methodology is rated as:    |
| 5.              | The OEE factor of quality is being measured and methodology is rated as:        |
| 6.              | Equipment improvement teams have been established to focus on improving equ     |
| 7.              | Improvements in OEE are evaluated against baseline OEE measurements to dete     |
| 8.              | Optimum machine speeds have been established and included in setup procedure    |
| 9.              | All machine-related quality defects are aggressively evaluated and corrected.   |
| 10.             | A process for critical asset facilitation has been implemented.                 |
| 11.             | Critical asset facilitation for condition-based maintenance includes CBM techno |
| Table Continued |   |

| Item#  |
|--|
| 12.  |
| 13.  |
| 14.  |
| 15.  |
| 32. Critical asset facilitation and overall equipment effectiveness (OEE) score Subtotal Score Possible: |

## 33. Overall craft effectiveness (OCE)

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average              |
|-----------------|--|
| 1.              | Improvement of craft productivity and overall craft effectiveness (OCE) is being |
| 2.              | Priorities have been established with a plan of action for improving the OCE fac |
| 3.              | Priorities have been established with a plan of action for improving the OCE fac |
| Table Continued | -  |

 Item#
 Rating: Excellent—10, Very Good

 4.
 Priorities have been established wi

 5.
 Improvements in OCE and craft pr

 6.
 A team effort is being used that inv

33. Overall craft effectiveness (OCE) score Subtotal Score: 50

## 34. Sustainability

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                  |
|-----------------|--|
| 1.              | The organization understands that the organizing principle for sustainability is su  |
| 2.              | Ways of reducing negative human impact are environmentally friendly chemical         |
| 3.              | Sustainability is derived from the Latin sustinere (tenere, to hold; sub, up). Susta |
| 4.              | Top leaders fully understand that sustainability within physical asset managemen     |
| 5.              | The organization's philosophical and analytic framework of sustainability draws      |
| 6.              | There is evidence that the organization is developing fewer carbon-hungry techn      |
| Table Continued | <u>-</u>   |

| Item#   | Rating: Excellent—10, Very Good—9, Goo         |
|---|--|
| 7.  | Water efficiency is being improved on an or    |
| 8.  | Sustainable use of some materials has target   |
| 9.  | Top leaders understand that the effects of so  |
| 10.   | Top leaders realize and strive for a green eco |
| 11.   | Top leaders have benchmarked with research     |
| 34. Sustainability score Subtotal Score Possible: 110 |  |

## 35. Traceability

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average              |
|-----------------|--|
| 1.              | Traceability. Your organization understands traceability to mean the property of |
| 2.              | Measuring and testing equipment. These devices are calibrated against certified  |
| Table Continued |  |

| Item#         | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                  |
|---------------|--|
| 3.            | Your organization uses International Laboratory Accreditation Cooperation (ILA       |
| 4.            | In order to have reciprocity, you have an essential agreement of what the standar    |
| 5.            | Elements of Traceability—Traceability is characterized by a number of essential      |
| 6.            | Does your organization realize that the inevitability of traceability in the oil and |
| 7.            | Has your site viewed traceability as a key feature of the rising tide of transparen  |
| 8.            | The growth of traceability within the industry looks set to focus on so-called "ur   |
| 9.            | The evidence is already there that the trend of traceability is playing out in the p |
| 10.           | To date, the oil and gas industry has taken a rather predictable line of defense: cr |
| 11.           | The position has been enabled by the lack of disclosure from the oil and gas con     |
| Table Continu | ued  |

| Item#   | Rating: Excellent—10, Very Good—9, Good          |
|---|--|
| 12.   | But this looks set to change as nongovernmen     |
| 13.   | Forest Ethics is helping companies trace the fi  |
| 14.   | In parallel, emerging technology is enabling tl  |
| 15.   | Regulatory action is another potential challens  |
| 16.   | Low-carbon fuel standards are emerging in ma     |
| 17.   | The overriding risk for oil companies is that, a |
| 18.   | In the worst case, unconventional assets will t  |
| 19.   | The key message is to jump before you are pu     |
| 35. Traceability score Subtotal Score Possible: 190 |  |

| 6. Process safety management (PSM) and management of change (MOC) |  |  |
|---|--|--|
|   |  |  |
|   |  |  |
| Item#   |  |  |
| 1.  |  |  |
| 2.  |  |  |
| 3.  |  |  |
| 4.  |  |  |
| 5.  |  |  |
| 6.  |  |  |
|   |  |  |
| 7.  |  |  |
|   |  |  |
| 8.  |  |  |
| 9.  |  |  |
| 10.   |  |  |
|   |  |  |

| 11.  |
|--|
| 12.  |
| 13.  |
| Note: All evaluation items starting at #14 may be included in your management of change (MOC) produced in the starting at #14 may be included in your management of change (MOC) produced in the starting at #14 may be included in your management of change (MOC) produced in your managemen |
| 14.  |
| 15.  |
| 16.  |
| 17.  |
| 18.  |
| Table Continued  |

•

| Item#                      |  |
|----------------------------|--|
| 19                         |  |
| 20.                        |  |
| 21.                        |  |
| 22.                        |  |
| 23.                        |  |
| 24.                        |  |
| 25.                        |  |
| 26.                        |  |
| 36. Process safety managem | ent (PSM) and management of change (MOC) score Subtotal Score Possib |

## 37. Risk-based inspections (RBI) and risk mitigation

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average              |
|-----------------|--|
| 1.              | The organization's chief reason for implementing an RBI program is to help man   |
| 2.              | Has your organization had a major event that was dangerous to HSSE requireme     |
| 3.              | A good RBI program can also help an owner/operator understand if the plant is 1  |
| 4.              | By using RBI as a tool, your organization is helping owner/operators increase tu |
| 5.              | Your organization understands why predicting any failure prior to occurrence, w  |
| Table Continued |  |

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                |
|-----------------|--|
| 6.              | Primary cost savings are moving from a time-based to a risk-based approach ofto    |
| 7.              | You have seen the cost benefit of RBI require 50–90% fewer inspection points tl    |
| 8.              | You have seen other benefits of RBI that extend plant shutdown intervals and re-   |
| 9.              | From a HSSE standpoint, a good RBI approach will force an owner/operator to l      |
| 10.             | You have seen and have achieved greater HSSE awareness and compliance by the       |
| 11.             | Your approach to good RBI has helped top leaders down to the operators unders      |
| 12.             | An extension of a good RBI program supports your physical asset integrity oper     |
| 13.             | One of the primary objectives of PSM is to minimize the risk of release of highly  |
| 14.             | All categories of equipment that contain or control a hazardous process, including |
| 15.             | Your organization is going through a process implementing a good RBI program       |
| 16.             | Your organization is going through implementing a good RBI program that will       |
| Table Continued |  |

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                                      |
|-----------------|--|
| 17.             | You have a good documentation trail of inspections, decisions, and nonconformation trail of inspections. |
| 18.             | You have created an inventory and informed analysis for all PSM-related equipn                           |
| 19.             | Your organization is in compliance with the new OSHA and EPA documents tha                               |
| 20.             | The codes and standards are relied upon to establish good engineering practice v                         |
| 21.             | Various engineering societies issue technical reports that impact process design.                        |
| 22.             | The recently enacted Environmental Protection Agency regulation EPA 40 CFR                               |
| 23.             | Worst-case release is defined and used as being "the release of the largest quanti                       |
| 24.             | The shortcoming of a worst-case scenario approach is understood because of its                           |
| 25.             | The API codes covering the inspection of fixed equipment and piping are clearly                          |
| Table Continued | <br>I  |

--

| ] | Item#   | Rating: Exceller |
|---|---|------------------|
|   | 26.   | Class 1 is the h |
|   | 27.   | As an example,   |
|   | 28.   | API 580 require  |
|   | 29.   | Documented m     |
|   | 37. Risk-based inspections and risk mitigation score Subtotal Score Possible: 290 |                  |

\_

# 38. Pride in maintenance

-

-

| Item#           | Rating: Excellent—10, Very Good—9, Good—8, Average—7, Below Average                |
|-----------------|--|
| 1.              | Overall, has your crafts workforce displayed evidence that they were indeed pro    |
|                 | If your craft employees were independently surveyed, would they reveal that the    |
| 2.              | Your organization has held events to recognize employees on their job achievem     |
| 3.              | Your organization has held or sponsored activities such as a softball team, a bow  |
| 4.              | Turnover related to technicians moving to another company has been normal con      |
| 5.              | Subject matter experts, well before official retirement, are able to influence and |
| Table Continued |  |

-

| Item#  | Rating: Excellent—10, Very Good—9       |
|--|---|
| 6.   | Technicians at other plants desire to w |
| 7.   | Craft employees are all given opportu   |
| 8.   | Pride in maintenance is a basic philoso |
| 38. Pride in maintenance score Subtotal Score Possible: 80 |   |

Appendix B

# Acronyms and Glossary of Maintenance, Maintenance Repair Operations Stores/Inventory, and Oil and Gas Terms

**List of Acronyms API** American Petroleum Institute **APL** Applications parts list **BBL** Barrel **BCF** 

Billion cubic feet of natural gas

# **BITE** Built-in test equipment **BOE** Barrel of oil equivalent **BOED** Barrels of oil equivalent per day BOMBill of materials BTUBritish thermal unit **CAGR** Compound annual growth rate **CBM**

Coal bed methane

| CBM   |
|---|
| Conditioned-based maintenance  CCF              |
| Centum cubic feet  CM                           |
| Corrective maintenance  CMMS                    |
| Computerized maintenance management system  CMO |
| Chief maintenance officer  CNG                  |
| Compressed natural gas CO2e                     |

Carbon dioxide equivalents

| СРМ                                     |
|---|
| Critical path method CRI                |
| Continuous reliability improvement  CSS |
| Carbon capture and storage <b>DT</b>    |
| Downtime <b>E&amp;P</b>                 |
| Exploration and production  ECN         |
| Engineering change notice               |
| EOQ                                     |

Economic order quantity

# **EOR**

Enhanced oil recovery

#### **EUR**

Estimated ultimate recovery

#### **EWO**

Engineering work order

#### **FEED**

Front-end engineering and design

#### **FIFO**

First in-first out

# **FISH**

First in still here

#### **FMEA**

Failure modes and effects analysis

# **FMECA**

| Failure modes, effects, and crit | icality analysis |
|----------------------------------|------------------|
| FPSO                             |                  |

Floating production, storage, and offloading

FTA

Fault tree analysis

**GCR** 

Gas cost recovery

**GSE** 

General support equipment

**GWP** 

Global warming potential

**HSSE** 

Health, safety, security, and environment

# **IOR**

Improved oil recovery JIT Just-in-time **JOA** Joint operating agreement **KPI** Key performance indicator **LCA** Life cycle analysis LCC Life cycle cost LDC

Local distribution company

# **LIFO** Last in–first out LNG Liquefied natural gas LOR Level of repair LSA Logical support analysis **MBBL** One thousand barrels of crude oil, bitumen, condensate, or natural gas liquids **MBD** One thousand barrels per day **MBOE** One thousand barrels of oil equivalent

#### **MCF**

One thousand cubic feet

#### **MIL-STD**

United States military standard

#### **MMBBL**

One million barrels

#### **MMBOE**

One million barrels of oil equivalent

#### **MMBTU**

One million British thermal units

#### **MMCF**

One million standard cubic feet of natural gas

#### **MOC**

Management of change

# MRO

| Maintenance repair operations  MTBF |
|-------------------------------------|
| Mean time between failures  MTPA    |
| Millions of tons per annum  MTTR    |
| Mean time to repair  NDT            |
| Nondestructive testing              |

Natural gas liquids

NGV

NGLs

Natural gas vehicle

# **NYMEX**

| New York Mercantile Exchange  OBM            |
|--|
| Operator-based maintenance  OCE              |
| Overall craft effectiveness  OEE             |
| Overall equipment effectiveness  PCCM        |
| Profit and customer-centered maintenance PCM |
| Profit-centered maintenance  PdM             |

Predictive maintenance

### **PERT**

| Projection evaluation and review technique | e |
|--|---|
| PM   |   |

Preventive maintenance

#### **PMRPW**

Preventive maintenance-related planned work

#### **PRA**

Probabilistic risk assessment

#### **PSA**

Probabilistic safety assessment

Psi

Pounds per square inch

# **PSM**

Process safety management

| PSC  |
|--|
| Production sharing contract  RBI                 |
| Risk-based inspection  RBM                       |
| Risk-based maintenance  RCM                      |
| Reliability-centered maintenance  RIME           |
| Ranking index for maintenance expenditures  ROCE |
| Return on capital employee                       |

Return on investment

ROI

# ROMI

| Return on maintenance investmen | 11 |
|---------------------------------|----|
| ROP                             |    |

Reorder point

**RPI** 

Reliability performance indicator

S-LCA

Social life cycle analysis

**SAGD** 

Steam-assisted gravity drainage

**SKU** 

Stock keeping unit

**TCF** 

One trillion cubic feet of natural gas

# TCO

| Total cost of ownership <b>ToSS</b> |
|-------------------------------------|
| Total system support  TPM           |
| Total productive maintenance TRR    |
| Total recordable rate <b>UM</b>     |
| Unscheduled maintenance <b>WO</b>   |
| Work order <b>YTD</b>               |

Year-to-date

# **Glossary**

ABC inventory policy A collection of prioritizing practices to give varied levels of attention to different classes of inventories. For example, Class A items typically make up 15 to 25% of stock items but 75 to 85% of inventory value. Class C items, in turn, might be 60% of the stock items but only 10% of the inventory value. Class B items would be somewhere in between these two.

ACE system Today's best methodology for establishing quality repair methods and team-based planning times (see ACE Team Benchmarking Process).

ACE Team Benchmarking Process (also known as the ACE Team Process) A propriety system for maintenance work measurement developed by The Maintenance Excellence Institute International in the 1980s. It is a team-based process for using experienced craftspeople, supervisors, and planners to develop a consensus on maintenance repair method improvement, job task times, and total work content/wrench time. It involves a consensus of experts (ACE) for first evaluating a job for improved methods, tools, special equipment, and root cause elimination. Secondly, this process develops a consensus on work content and then spreadsheets for work content comparison (slotting). The process provides a methodology for a planner to include various job-specific allowances to wrench time and then develop reliable planning times for scheduling purposes. The ACE Team process allows for a wide range and number of jobs to be estimated using a relatively small number of benchmark jobs arranged on spreadsheets by craft areas.

Acreage Land leased for oil and gas exploration and/or land for which a company owns the mineral rights.

Actuarial analysis Statistical analysis of failure data to determine the agereliability characteristics of an item.

Adjustments Minor tune-up actions requiring only hand tools, no parts, and usually lasting less than a half hour.

American Petroleum Institute (API) The American Petroleum Institute is the oil and gas industry's trade organization. API's research and engineering work provides a basis for establishing operating and safety standard issues and specifications for the manufacturing of oil field equipment and furnishes statistical and other information to related agencies. Visit API at www.api.org.

Anticline A convex-upward formation of rock layers, which may form a trap for hydrocarbons.

Applications parts list A list of all parts required to perform a specific maintenance activity, typically set up as a standard list attached to a standard job for routine tasks. Not to be confused with a bill of materials.

Apprentice A craftsperson in training, typically following a specifically defined technical training program while gaining hands on experience in a craft area to gain a specified number of hours experience.

Aquifer An underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be extracted using a water well.

Area maintenance A method for organizing maintenance operations in which the first-line maintenance leader is responsible for all maintenance crafts within a certain department, area, or location within the facility.

Asset care An alternative term for the maintenance process. A kinder, gentler term but still pure maintenance and physical asset management.

Asset list A register of physical assets (equipment, facilities, building systems, etc.) usually with information on manufacturer, vendor, specifications, classification, costs, warranty, and tax status.

Asset management The systematic planning and control of a physical asset resource throughout its economic life; the systematic planning and control of a physical resource throughout its life. This may include the specification, design, and construction of the asset; its operation, maintenance and modification while in use; and its disposal when no longer required.

Asset number A unique alphanumerical identification of an asset list, which is used for its management.

Asset register A list of all the assets in a particular workplace, together with information about those assets, such as manufacturer, vendor, make,

model, specifications, etc.

Asset utilization The percentage of total time the equipment/asset is running.

Assets The physical resources of a business, such as plant equipment, facilities, building systems, fleets, or their parts and components; unlike in the accounting definition, in maintenance this is commonly taken to be any item of physical plant or equipment.

Availability The probability that an asset will, when used under specified conditions, operate satisfactorily and effectively. Also, the percentage of time or number of occurrences for which an asset will operate properly when called upon; the proportion of total time that an item of equipment is capable of performing its specified functions, normally expressed as a percentage. It can be calculated by dividing the equipment available hours by the total number of hours in any given period.

Available hours The total number of hours that an item of equipment is capable of performing its specified functions. It is equal to the total hours in any given period, less the downtime hours.

Average life How long, on average, a component will last before it suffers a failure. Commonly measured by mean time between failures (MTBF).

Backlog Work orders planned and prioritized, awaiting scheduling and execution; work that has not been completed by the "required by" date. The period for which each work order is overdue is defined as the difference between

the current date and the "required by" date. All work for which no "required by" date has been specified is generally included on the backlog. Backlog is generally measured in crew-weeks: the total number of labor hours represented by the work on the backlog, divided by the number of labor hours available to be worked in an average week by the work crew responsible for completing this work. As such, it is one of the common key performance indicators (KPI) used in maintenance.

Bar code An identification method using symbols for encoding data using lines of varying thickness, with designated alphanumeric characters. It can be used on work orders, physical assets, and parts to form a state-of-the-art information gathering methodology.

Barrel (BBL) One stock tank barrel of 42 US gallons liquid volume used in reference to crude oil, bitumen, condensate, or natural gas liquids.

Barrel of oil equivalent (BOE) A measure used to aggregate oil and gas resources or production, with one BOE being approximately equal to 6000 cubic feet of natural gas.

Basin A large, natural depression on the earth's surface in which sediments, generally brought by water, accumulate.

Benchmarking The process of comparing performance with other organizations, identifying comparatively high-performance organizations, and learning what it is they do that allows them to achieve that high level of performance.

Bill of materials (BOM) List of components and parts for an asset, usually structured in hierarchical layers from gross assemblies or major end items to minor items down to component parts; a list of all the parts.

Bitumen A highly viscous form of crude oil (greater than 10,000 cP) resembling cold molasses (at room temperature). Bitumen must be heated or combined with lighter hydrocarbons for it to be produced. It contains sulfur, metals, and other nonhydrocarbons in its natural form.

Borehole A hole in the earth made by a drilling rig.

Breakdown Failure to perform to a functional standard; a specific type of failure where an item of plant or equipment is completely unable to function.

Breakdown maintenance A maintenance strategy or policy where no maintenance is done until an item fails and no longer meets its functional standard; see No scheduled maintenance.

British thermal unit (BTU) A unit of measure for heat energy. The quantity of heat necessary to raise the temperature of one pound of water 1 °F under a stated pressure.

Built-in test equipment (BITE) Diagnostic and checkout devices integrated into equipment to assist operation, trouble shooting and service.

Business vacation A well-planned event that combines real business and/or

training with a fun time either before or after the event. "Killing two birds with one stone" for fun and professional development at a place such as The Maintenance Excellence Institute International's oceanfront site, The Breakwaters on Oak Island in North Carolina.

Calibrate To verify the accuracy of equipment and assure performance within tolerance, usually by comparison to a reference standard that can be traced to a primary standard.

Call-out To summon a tradesperson to the workplace during his normal nonworking time so that he can perform a maintenance activity (normally an emergency maintenance task).

CAPEX Capital expenditures.

Capital Durable items with long lives or high values that necessitate asset control and depreciation under tax guidelines, rather than being expensed.

Carbon capture and storage (CCS) Process by which carbon dioxide emissions are captured and removed from the atmosphere and then stored, normally via injection into a secure underground geological formation.

Carbon dioxide equivalents (CO2e) The quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO2 that would have the same global warming potential (GWP) when measured over a specified timescale (generally 100 years).

Carbon intensity The quantity of greenhouse gas emissions associated with producing an intermediate or final product. For the oil and gas industry, carbon intensity is commonly expressed in units of tons CO2e per product volume (e.g., tons CO2e/BBL or tons CO2e/MCF).

Carbon sequestration The fixation of atmospheric carbon dioxide in a carbon sink through biological or physical processes.

Carbon sink A reservoir that absorbs or takes up released carbon from another part of the carbon cycle. The four sinks, which are regions of the earth within which carbon behaves in a systematic manner, are the atmosphere, terrestrial biosphere (usually including freshwater systems), oceans, and sediments (including fossil fuels).

Carrying costs Expense of handling, space, information, insurance, special conditions, obsolescence, personnel, and the cost of capital or alternative use of funds to keep parts in inventory. Also, called holding costs and generally in the 30–40% range when all factors are considered.

Casing Thick-walled steel pipe placed in wells to isolate formation fluids (such as freshwater) and to prevent borehole collapse.

Central maintenance A method for organizing maintenance operations in which the maintenance leader is responsible for all maintenance and all craft areas operating on call from a central location to support the entire operation.

Centum cubic feet (CFF) One hundred cubic feet; residential billing units

are common in CCF. One cubic foot of natural gas contains about 1000 BTUs; 1 CCF contains about 100,000 BTUs. CCF is a volumetric measurement. Because the exact composition of the natural gas can be different, so can the BTUs it contains. One Therm is exactly 100,000 BTUs of any fuel. Some gas companies therefore use the Therm as their unit of sale. Often, the Therm and CCF are used interchangeably, although technically they are not exactly the same thing unless the natural gas is pure methane.

Change out The removal of a component or part and the replacement of it with a new or rebuilt one.

Chief maintenance officer (CMO) The technical leader (or actual leader) of a profit-centered maintenance operation within a large or small corporation or nonmanufacturing organization. First coined, defined and promoted by staff from The Maintenance Excellence Institute International in the late 1990s. The CMO represents the prototype of the New Millennium leader for maintenance and physical asset management and managing the maintenance process as a true profit center.

Checkout The determination of the working condition of a system.

City gate stations City gate stations mark the point where natural gas leaves the transmission system and enters the distribution System. City gate stations have equipment that reduces the pressure of the gas, meter/measure it, add odorant, and may include heaters to heat the gas if the pressure drop is large enough to cause it to drop below 32 °F.

Clean To remove all sources of dirt, debris, and contamination for the purpose of inspection and to avoid chronic losses.

CMMS benchmarking system A methodology developed by staff from The Maintenance Excellence Institute International to evaluate the effectiveness of a computerized maintenance management system (CMMS)/ enterprise asset management (EAM) installation. A process for evaluating CMMS/EAM implementation progress and full utilization of system functionality to enhance best practices.

Coal bed methane (CBM) Natural gas extracted from coal beds.

Code Symbolic designation used for identification, such as failure code, repair code, and commodity code.

Commodity code Classifications of parts by group and class according to their material content or type of consolidation of procurement, storage, and use.

Completion The process of making a well ready to produce natural gas or oil. Completion involves installing permanent equipment, such as a wellhead, and often includes hydraulic fracturing.

Component A constituent part of an asset, usually modular and replaceable, that may be serialized and interchangeable; a subassembly of an asset, usually removable in one piece and interchangeable with other, standard components (e.g., truck engine).

Component number Designation, usually structured by system, group, or

serial number.

Compound annual growth rate (CAGR) The average year-over-year growth rate of a metric over a specific period of time.

Compressed natural gas (CNG) Natural gas that is compressed into storage cylinders for use in transportation fuel in buses, trucks, cars, and forklifts. CNG is not the same as liquid propane gas that is typically contained in cylinders.

Computerized maintenance management system (CMMS) Integrated computer system modules such as work orders, equipment, inventory, purchasing, planning, and preventive maintenance that support asset management and overall maintenance management.

Condensate Mixture of hydrocarbons that are in a gaseous state under reservoir conditions and, when produced, become a liquid as the temperature and pressure is reduced.

Condition-based maintenance (CBM) Maintenance based on the measured condition of an asset. Testing and/or inspection of characteristics that will warn of pending failure and performance of maintenance after the warning threshold but before total failure. Predictive maintenance technologies such as vibration analysis, thermography/infrared, oil analysis, and ultrasonic provide tools and technology for condition-based maintenance. An equipment maintenance strategy based on measuring the condition of equipment in order to assess whether it will fail during some future period, and then taking appropriate action to avoid the consequences of that failure. The terms condition based maintenance, on-condition maintenance and predictive maintenance can be used interchangeably.

Condition monitoring The use of specialist equipment to measure the condition of equipment. Vibration analysis, oil analysis and thermography are all examples of condition monitoring techniques.

Conditional probability of failure The probability that an item will fail during a particular age interval, given that it survives to enter that age.

Confidence Degree of certainty that something will happen. For example, a low confidence of replenishment means repair parts probably will not be readily available and is one reason that maintenance personnel retain excess parts in uncontrolled areas.

Configuration The arrangement and contour of the physical and functional characteristics of systems, equipment, and related items of hardware or software; the shape of a thing at a given time. The specific parts used to construct a machine.

Consumables Supplies such as fuel, lubricants, paper, printer ribbons, cleaning materials, and forms that are exhausted during use in operation and maintenance.

Contingency Alternate actions that can be taken if the main actions do not work.

Continuous reliability improvement (CRI) A process developed and used by staff from The Maintenance Excellence Institute International that goes beyond current reliability-centered maintenance (RCM) approaches to

# outline a continuous, integrated process for improving total reliability of the following resources:

- Equipment/facility resources (asset care/management and maximum uptime via RCM techniques)
- Craft and operator resources (recognizing the most important resource: craftspeople and equipment/process operators)
- Maintenance repair operations (MRO) resources (establishing effective materials management processes)
- Maintenance information resources (effective information technology applications for maintenance)
- Maintenance technical knowledge/craft skills base (closing the technical knowledge resource gap)
- Synergistic team processes (tapping the value-added resource of effective leadership-driven team, self-managed teams to support total operations success)

# CONTINUOUS RELIABILITY IMPROVEMENT GOES BEYOND RCM AND TPM **Physical Asset**

Synergistic Team **Based Resources**  and Equipment Resources

> Craft Labor Resources

Craft Knowledge and Technical Skill Resources

Continuous Reliability **Improvement** 

> Spare Parts and Material Resources

Information Resources and **CMMS** 

Contract acceptance sheet A document that is completed by the appropriate contract supervisor and contractor to indicate job completion and acceptance. It also forms part of the appraisal of the contractor's performance.

Conventional resources Discrete accumulations of hydrocarbons contained in rocks with relatively high matrix permeability, which normally have relatively high recovery factors.

Coordination Daily adjustment of maintenance activities to achieve the best short-term use of resources or to accommodate changes in needs for service.

Corrective maintenance (CM) Unscheduled maintenance or repair actions, performed as a result of failures or deficiencies, to restore items to a specific condition. Maintenance done to bring an asset back to its standard functional performance. Any maintenance activity that is required to correct a failure that has occurred or is in the process of occurring. This activity may consist of repair, restoration, or replacement of components.

Craft availability Percentage of time that craft labor is free to perform productive work during a scheduled working period.

Craft leaders Subject matter experts (SMEs), crew leaders, and technician specialists.

Craft utilization Percentage of time that craft labor is engaged in

productive work, hands-on during a scheduled working period. The actual wrench time as compared to total time paid.

# **How Your Valuable Craft Time Can Slip Away**

Total Available Craft Days: 52 Weeks/Yr x 5 Days per Week
= 260 Available Craft Days Maximum
Without Overtime

260 Total Craft Days - 10 Holidays Per Year = 250 Craft Days Now Available

250 Days/Yr - 15 Vacation/Sick Days Average Per Year = 235 Craft Days Now Available

235 Days -15 Days Break Time\* Per Year = 220 Craft Days/Year Now Available

#### BOTTOM LINE 220 Days + 260 Days = .846 = 85% +/- Maximum Craft Time Available for Work 85% = Maximum Craft Utilization 70% = World Class Levels of Craft Labor Utilization Wrench Time 60% = Very Good (Pure Wrench Time) Wrench time 50%= Good Wrench Time 30% to 40% Typical for Reactive Unplanned 10% to 20% On Call Like the Maytag Repair

Note: Example with 15 min x 2 breaks/ day = 1/2 hour/day x 235 days = 117.5 hours + 8 hours/day = 15 Total Days Per Year for Break Time

What is Your Craft Labor Utilization?

Man

Craftsperson A skilled maintenance worker who has typically been formally trained through an apprenticeship program. See also MVP and Tradesperson.

Critical Describes items that are especially important to product performance and more vital to operation than noncritical items.

Critical equipment Items especially important to performance, capacity, and throughput and more vital to the operation than noncritical items.

Criticality The priority rank of a failure mode based on some assessment criteria.

Critical path method (CPM) A logical method of planning and control that analyzes events, the time required, and the interactions of the considered activities.

Critical spare Parts and materials that are not used often enough to meet detailed stock accounting criteria but are stocked as "insurance items" because of their essentially or the lead time involved in procuring replacements; similar to safety stocks, except on low-use parts. Normally critical spares require special approval.

Crossdocking Term for the function capability of an inventory management module to track high-priority inbound orders into receiving, to initiate immediate delivery and to receive/process issue transactions with minimal manual effort. Crossdocking provides quick turnaround at receiving without putting items into

storage locations and then having to pick for issue later.

Cycle count An inventory accountability strategy where counting and verification of stock item quantities is done continuously based on a predetermined schedule and frequency based on the ABC classification of the item. As opposed to an annual physical inventory, cycle counting allows for continuous counting, immediate reconciliation of inventory discrepancies and inventory accuracy of 98% plus.

Dead stocks Items for which no demand has occurred over a specific period of time.

Defect A condition that causes deviation from design or expected performance. A term typically used in the maintenance of mobile equipment. A defect is typically a potential failure or other condition that will require maintenance attention at some time in the future, but which is not currently preventing the equipment from fulfilling its functions.

Deferred maintenance Maintenance that can be or has been postponed from a schedule.

Deterioration rate The rate at which an item approaches a departure from its functional standard.

Demand Requests and orders for an item. Demands become issues only when a requested part is given from stock.

Developed acreage The number of acres that are allocated or assignable to productive wells or wells capable of production.

Developed reserves Reserves that can be expected to be recovered through existing wells with existing equipment and operating methods or in which the cost of the required equipment is relatively minor compared to the cost of a new well and, if extraction is by means other than a well, through installed equipment and infrastructure operational at the time of the reserves estimate.

Development well A well drilled within the proved area of an oil or gas reservoir to the depth of a stratigraphic horizon known to be productive.

Direct costs Any expenses that can be associated with a specific product, operation, or service that is value added.

Directional Drilling The application of special tools and techniques to drill a wellbore at a predetermined angle. Horizontal drilling is a form of directional drilling where the wellbore is ultimately drilled at  $\pm 90^{\circ}$  to the vertical direction.

Discard task The removal and disposal of items or parts. One type of maintenance strategy for selected components.

Disposal The act of getting rid of excess or surplus property under proper authorization. Such processes as transfer, donation, sale, abandonment, destruction, or recycling may accomplish disposal.

Distribution line System of low-pressure pipes used to move gas to customers within a service area.

Distribution system The distribution system moves the natural gas from city gate stations to the users. Distribution systems typically operate in the 2-60 psi range for residential areas, often higher in industrial areas. The operating pressure depends on how old the system is, what it is made of (i.e., cast iron, steel, plastic), what load it needs to serve and how far it is from the city gate station.

Down Out of service, usually due to breakdown, unsatisfactory condition, or production scheduling.

Downtime (DT) The time that an item of equipment is out of service, as a result of equipment failure. The time that an item of equipment is available, but not utilized is generally not included in the calculation of downtime.

Drilling rig The machine used to drill a wellbore.

Dry gas is almost pure methane and occurs in the absence of liquid hydrocarbons or by processing natural gas to remove liquid hydrocarbons and impurities.

Dry hole A well incapable of economically producing salable hydrocarbons in sufficient quantities to justify commercial exploitation.

Economic life The total length of time that an asset is expected to remain actively in service before it is expected that it would be cheaper to replace the equipment rather than continuing to maintain it. In practice, equipment is more often replaced for other reasons, including because it no longer meets operational requirements for efficiency, product quality, comfort etc., or because newer equipment can provide the same quality and quantity of output more efficiently.

Economic order quantity (EOQ) Amount of an item that should be ordered at one time to get the lowest possible combination of inventory carrying costs and ordering costs.

Economic repair A repair that will restore the item to a sound condition at a cost less than the value of its estimated remaining useful life.

Economically producible A resource that generates revenue that exceeds, or is reasonably expected to exceed, the costs of the operation.

Emergency maintenance A condition requiring immediate corrective action for safety, environmental, or economic risk, caused by equipment breakdown.

Emergency maintenance task A maintenance task carried out in order to avert an immediate safety or environmental hazard, or to correct a failure with significant economic impact.

Engineering change Any design change that will require revision to specifications, drawings, documents, or configurations.

Engineering change notice (ECN) A control document from engineering authorizing changes or modifications to a previous design or configuration.

Engineering work order The prime document used to initiate an engineering investigation, engineering design activity, or engineering modifications to an item of equipment.

Enhanced oil recovery (EOR) One or more of a variety of processes that seek to improve recovery of hydrocarbon from a reservoir after the primary production phase.

Environmental assessment A study that can be required to assess the potential direct, indirect, and cumulative environmental impacts of a project.

Environmental consequences A failure has environmental consequences if it could cause a breach of any known environmental standard or regulation.

Equipment configuration List of assets usually arranged to simulate the process, or functional or sequential flow.

Equipment maintenance strategies The choice of routine maintenance tasks and the timing of those tasks, designed to ensure that an item of

equipment continues to fulfill its intended functions.

Equipment repair history A chronological list of defaults, repairs, and costs on key assets so that chronic problems can be identified and corrected and economic decisions made.

Equipment use Accumulated hours, cycles, distance, throughput, etc., or performance.

Estimated plant replacement value The estimated cost of capital required to replace all the existing assets with new assets capable of producing the same quantity and quality of output.

Estimated ultimate recovery (EUR) The sum of reserves remaining as of a given date and cumulative production as of that date.

Estimating index The ratio of estimated labor hours required completing the work specified on work orders to the actual labor hours required to complete the work specified on those work orders, commonly expressed as a percentage. This is also a measure of craft performance, one element of craft labor productivity, particularly when there are well-defined estimating standards.

Examination A comprehensive inspection with measurement and physical testing to determine the condition of an item.

Expediting Special efforts to accelerate a process. An expediter coordinates and assures adequate supplies of parts, materials and equipment. Typically found in a reactive maintenance operation.

Expense Those items that are directly charged as a cost of doing business. They generally have a short, nondurable life. Most nonrepairable repair parts are expensed when installed on equipment.

Expensed inventory Parts written off as a "cost of sales." Material transferred from ledger inventory to expensed inventory is to be used within 12 months.

Expert system Decision support software with some ability to make or evaluate decisions based on rules or experience parameters incorporated in the database; a software-based system that makes or evaluates decisions based on rules established within the software. Typically used for fault diagnosis.

Exploratory well A well drilled to find a new field or to find a new reservoir in a field previously found to be productive of oil or gas in another reservoir.

Failsafe An item is failsafe if, when the item itself incurs a failure, that failure becomes apparent to the operating workforce in the normal course of events.

Failure Termination of the ability of an item to perform its required function to a standard; an item of equipment has suffered a failure when it is no longer capable of fulfilling one or more of its intended functions. Note that an item does

not need to be completely unable to function to have suffered a failure. For example, a pump that is still operating, but is not capable of pumping the required flow rate, has failed. In reliability-centered maintenance terminology, a failure is often called a functional failure.

Failure analysis The logical, systematic examination of an item or its design, to identify and analyze the probability, causes, and consequences of real or potential malfunction. A study of failures to analyze the root causes, to develop improvements, to eliminate or reduce the occurrence of failures. (See also Failure modes, effects, and critical analysis.)

Failure cause See Failure mode.

Failure coding Identifying and indexing the causes of equipment failure on which corrective action can be based, such as lack of lubrication, operator abuse, material fatigue, etc.; a code typically entered against a work order in a CMMS that indicates the cause of failure (e.g., lack of lubrication, metal fatigue).

Failure consequences A term used in reliability-centered maintenance. The consequences of all failures can be classified as being eitherhidden, safety, environmental, operational, or nonoperational. Very important to a risk-based maintenance approach that considers probability of failure and failure consequences.

Failure effect A description of the events that occur after a failure has occurred as a result of a specific failure mode. Used in reliability-centered maintenance and FMEA/FMECA analyses.

Failure finding interval The frequency with which a failure finding task is performed. It is determined by the frequency of failure of the protective device, and the desired availability required of that protective device.

Failure finding task Used in reliability-centered maintenance terminology. A routine maintenance task, normally an inspection or a testing task, designed to determine, for hidden failures, whether an item or component has failed. A failure finding task should not be confused with an oncondition task, which is intended to determine whether an item is about to fail. Failure finding tasks are sometimes referred to as functional tests.

Failure mode Any event that causes a failure.

Failure modes and effects analysis (FMEA) A structured method of determining equipment functions, functional failures, assessing the causes of failures and their failure effects. The first part of a reliability-centered maintenance analysis is a FMEA.

Failure modes, effects, and critical analysis (FMECA) A logical, progressive method used to understand and assess the root causes of failures and their subsequent effect on production, safety, cost, quality, etc.

Failure pattern The relationship between the conditional probability of failure of an item and its age. Failure patterns are generally applied to failure modes. Research in the airline industry established that there are six distinct failure patterns. The type of failure pattern that applies to any given failure mode is of vital importance in determining the most appropriate equipment maintenance strategy. This fact is one of the key principles underlying reliability-centered maintenance.

Failure rate The number of failures per unit measure of life (cycles, time, miles, events, and the like) as applicable for the item.

Farm-in The acquisition of part or all of an oil, natural gas, or mineral interest from a third party.

Farm-out The assignment of part or all of an oil, natural gas, or mineral interest to a third party.

Fault tree analysis (FTA) A review of failures, faults, defects, and shortcomings based on a hierarchy or relationship to find the root cause.

Field An area consisting of a single hydrocarbon reservoir or multiple geologically related reservoirs all grouped on or related to the same individual geological structure or stratigraphic condition.

Fill rate Service level of a specific stock point. An 85% fill rate means that if 100 parts are requested, then 85 of them are available and issued. This also means that 15% of parts requests are not filled due to stock outs. Goal for service levels should be 98% plus.

First in–first out (FIFO) Use the oldest item in inventory next. FIFO accounting values each item used at the cost of the oldest item in inventory. Contrasts with LIFO (last in–first out).

First in still here (FISH) A fun term for obsolete parts not identified and still taking up space.

Flaring The burning of natural gas for safety reasons or when there is no way to transport the gas to market or use the gas for other beneficial purposes (e.g., enhanced oil recovery, reservoir pressure maintenance). The practice of flaring is being steadily reduced as pipelines are completed and in response to environmental concerns. One major refining company calls flaring "the flames of incompetency."

Floating production, storage, and offloading (FPSO) Provides alternative to pipeline to store oil production and load vessels for movement to markets.



## Peng Bo FPSO in Bohai Bay, China

Forecast To calculate or predict some future event or condition, usually as a result of rational study and analysis of pertinent data. The projection of the most probable, as in forecasting failures and maintenance activities.

Formation A rock layer that has distinct characteristics (e.g., rock type, geologic age).

Forward workload All known backlog work and work which is due or predicted to become backlog work within a pre-specified future time period.

Fossil fuel A fuel source (e.g., oil, condensate, natural gas, natural gas liquids or coal) formed in the earth from plant or animal remains.

Frequency Count of occurrences during each time period or event. A typical frequency chart for inventory plots demand versus days.

Front-end engineering and design (FEED) Part of a project's life cycle.

Fugitive emissions Emissions of gases or vapors from pressurized equipment, including pipelines, due to leakage, unintended, or irregular releases of gases.

Function A separate and distinct action required to achieve a given objective, to be accomplished by the use of hardware, computer programs, personnel, facilities, procedural data, or a combination thereof; or an operation a system must perform to fulfill its mission or reach its objective; the definition of what we want an item of equipment to do, and the level of performance that the users of the equipment require when it does it. An item of equipment can have many functions, commonly split into primary and secondary functions.

Functional failure Used in reliability-centered maintenance terminology. The inability of an item of equipment to fulfill one or more of its functions. Interchangeably used with "failure."

Functional levels Rankings of the physical hierarchy of a product. Typical levels of significance from the smallest to the largest are part, subassembly, assembly, subsystem, and system.

Functional maintenance structure A method for organizing the maintenance operation where the first-line maintenance leader is responsible for conduction a specific kind of maintenance, for example, electrical maintenance, pump maintenance, HVAC maintenance, etc.

Gantt chart A bar chart format of scheduled activities showing the duration and sequencing of activities.

Gas cost recovery (GCR) Most gas utility companies bill their customers based on the actual cost of gas as a separate charge from the distribution charge and other charges on the bill. The GCR factor is the cost for the gas itself, before delivery and other charges are added on.

Gathering system Pipelines, compressors, and additional equipment used to move gas from the wellhead to a processing facility.

General support equipment (GSE) Equipment that has maintenance application to more than a single model or type of equipment.

Global warming potential (GWP) The relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. GWP is calculated over a specific time interval, commonly 100 years. GWP is expressed as a multiple of that for carbon dioxide (whose GWP is standardized to 1).

Go-line Used in relation to mobile equipment. Equipment that is available but not being utilized is typically parked on the go-line. This term is used interchangeably with ready line.

Greenhouse gas Atmospheric gases that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect of these gases is a trapping of absorbed radiation and a tendency to warm the planet's surface. The greenhouse gases most relevant to the oil and gas industry are carbon dioxide, methane, and nitrous oxide.

Hardware A physical object or physical objects, as distinguished from capability or function. A generic term dealing with physical items of equipment-tools instruments, components, parts-as opposed to funds, personnel, services, programs, and plans, which are termed "software."

Heavy oil Crude oil with an API gravity that is less than 20°. Heavy oil generally does not flow easily due to its elevated viscosity.

Hidden failure A failure that, on its own, does not become evident to the operating crew under normal circumstances. Typically, protective devices that are not fail-safe (examples could include standby plant and equipment, emergency systems, etc.)

Hold for disposition stock Defective material held at a stock location pending removal for repair or for scrap.

Horizontal drilling A drilling technique whereby a well is progressively turned from vertical to horizontal so as to allow for greater exposure to an oil or natural gas reservoir. Horizontal laterals can be more than a mile long. In general, longer exposure lengths allow for more oil and natural gas to be recovered from a well and often can reduce the number of wells required to develop a field, thereby minimizing surface disturbance. Horizontal drilling technology has been extensively used since the 1980s and is appropriate for many, but not all, developments.

Hot work Typically used in welding, a work area that is too hot to handle safely without special personal protective equipment (PPE).



Hydraulic fracturing Hydraulic fracturing (also referred to as frac'ing or fracking) is an essential completion technique in use since the 1940s that facilitates production of oil and natural gas trapped in low-permeability reservoir rocks. The process involves pumping fluid at high pressure into the target formation, thereby creating small fractures in the rock that enable hydrocarbons to flow to the wellbore.

Hydraulic fracturing fluids Mixture of water and proppant along with minor amounts of chemical additives used to hydraulically fracture low permeability formations. Water and sand typically comprise up to 99.5% of the mixture.

Hydrocarbons An organic compound containing only carbon and hydrogen and often occurring in nature as petroleum, natural gas, coal, and bitumens or in refined products such as gasoline and jet fuel.

Identification Means by which items are named or numbered to indicate that they have a given set of characteristics. Identification may be in terms of name, part number, drawing number, code, stock number, or catalog number. Items may also be identified as part of an assembly, a piece of equipment, or a system.

Improved oil recovery (IOR) Term used to describe methods employed to improve the flow of hydrocarbons from the reservoir to the wellbore or to recover more oil or natural gas. Enhanced oil recovery (EOR) is one form of IOR.

Indirect costs Expenses not directly associated with specific products, operations, or services; usually considered overhead.

Infant mortality The relatively high conditional probability of failure during the period immediately after an item returns to service.

Infill wells Wells drilled into the same reservoir as known producing wells so that oil or natural gas does not have to travel as far through the formation, thereby helping to improve or accelerate recovery.

Inherent reliability A measure of the reliability of an item, in its present operating context, assuming adherence to ideal equipment maintenance strategies.

In-situ recovery Techniques used to extract hydrocarbons from deposits of extra-heavy crude oil, bitumen, or oil shale without removing the soil and other overburden materials.

Inspection A review to determine maintenance needs and priority on equipment. Any task undertaken to determine the condition of equipment, and/or to determine the tools, labor, materials, and equipment required to repair the item.

Insurance items Parts and materials that are considered as critical spares but not used often enough to meet detailed stock accounting criteria. Insurance items are stocked because of their essentially or the lead time involved in procuring replacements. May be of high dollar value to classify them as capital spares.

Interchangeable Parts with different configurations and numbers that may be substituted for another part, usually without any modification or different performance, because they have the same form, fit, and function.

Interface A common boundary between two or more items, characteristics, systems, functions, activities, departments, or objectives. That portion impinges upon or directly affects something else.

Interval-based Periodic preventive maintenance based on calendar time or hours operated.

Inventory turnover Ratio of the value of materials and parts issues annually to the value of materials and parts on-hand, expressed as percentage. For maintenance, two to three turns per year is expected, with much more being a sign of excess inventory.

Inventory Physical count of all items on hand by number, weight, length, or other measurement, as well as any items held in anticipation of future use. Annual physical inventory remains accurate for a short time unless cycle counting is used.

Inventory control A phase or function of logistics that includes management, cataloging, requirements, determination, procurement, inspection, storage, distribution, overhaul, and disposal of material. Managing the acquisition, receipt, storing and issuance of materials and spare parts; managing the investment efficiently of the store's inventory.

Issues Stock consumed through stores.

Item Generic term used to identify a specific entity. Items may be parts, components, assemblies, subassemblies, accessories, groups, parents, components, equipment, or attachments.

Item of supply An article or material that is recurrently purchased, stocked, distributed, used and is identified by one distinctive set of numbers or letters throughout the organization concerned. It consists of any number of pieces or objects that can be treated as a unit.

Jack-up rig An offshore rig with retractable steel legs that are placed on the ocean floor to raise the rig above the waterline.

Joint operating agreement (JOA) An agreement governing the rights and obligations of co-owners in a field or undeveloped acreage, which defines, amongst other things, how costs and revenues are to be shared among the parties and who is the operator.

Just-in-time (JIT) A buzzword term for proactive planning of many processes, such as JIT inventory service, JIT maintenance services, JIT training conducted as needed for project activities rather train-train-train and then doing projects and activities, etc. Often seen with total productive maintenance (TPM) training that drags out long before an actual start date.

Keep full Term used for maintaining set levels of shop stock inventory of Class C items (see also Shop stock). May involve vendor-supplied C items and periodic refill of "bins" and invoice of amount used to refill.

Key performance indicators (KPIs) A select number of key measures that enable performance against targets to be monitored.

Knuckle buster A poor-quality, imitation, adjustable wrench.

Last in–first out (LIFO) Use newest inventory next. LIFO accounting values each item used at the cost of the last item added to inventory. Contrasts with First-in-first out (FIFO).

Lead time Allowance made for that amount of time estimated or actually required to accomplish a specific task such as acquiring a part. Remote locations may have much longer lead times than operations near a large city or industrialized area.

Lease A legal document executed between a mineral owner and a company or individual that conveys the right to explore for and develop hydrocarbons and/or other products for a specified period of time over a given area.

Ledger inventory Items carried on the corporate financial balance sheet as material valued at cost.

Level of repair (LOR) Locations and facilities at which items are to be repaired. Typical levels are operator, field technician, bench, and factory.

Level of services (stores) Usually measured as the ratio of stock outs to all stores issues.

Life That strange experience you have in a maintenance context when an emergency breakdown occurs; you may want to look at equipment life.

Life cycle analysis (LCA) LCA is an analytical methodology used to comprehensively quantify and interpret the environmental flows to and from the environment (including air emissions, water effluents, solid waste, and the consumption/depletion of energy and other resources) over the life cycle of a product or process. LCAs should be performed in adherence to the International Organization for Standardization (ISO) 14040 series of standards.

Life cycle The series of phases or events that constitute the total existence of anything. The entire "womb to tomb" scenario of a product from the time concept planning is started until the product is finally discarded.

Life cycle cost (LCC) All costs associated with the items of life cycle including design, manufacture, operation maintenance, and disposal; a process of estimating and assessing the total costs of ownership, operation, and maintenance of an item of equipment during its projected equipment life. Typically used in comparing alternative equipment design or purchase options in order to select the most appropriate option.

Liquefied natural gas (LNG) Natural gas that has been converted to a liquid by refrigerating it to -260 °F. Liquefying natural gas reduces the fuel's volume by 600 times, enabling it to be shipped economically from distant producing areas to markets.

Local distribution company (LDC) A company that delivers natural gas to

end users in a geographic area. Could also apply to a local distributor for maintenance parts and materials.

Logistics engineering The professional art of applying science to the optimum planning, handling and implementation of personnel, materials and facilities. This includes life-cycle designs, procurements, production, maintenance, and supply.

Logistics support analysis (LSA) A methodology for determining the type and quantity of logistics support required for a system over its entire life cycle. Used to determine the cost-effectiveness of asset-based solutions.

Main Gas pipe generally laid along street right-of-ways from which extends smaller lateral service lines to individual customer gas meters.

Maintainability The inherent characteristic of a design or installation that determines the ease, economy, safety, and accuracy with which maintenance actions can be performed. Also, the ability to restore a product to service or to perform preventive maintenance within required limits. The rapidity and ease with which maintenance operations can be performed to help prevent malfunctions or correct them if they occur, usually measures as mean time to repair; the ease and speed with which any maintenance activity can be carried out on an item of equipment. May be measured by mean time to repair; a function of equipment design, and maintenance task design (including use of appropriate tools, jigs, work platforms, etc.)

Maintainability engineering The application of applied scientific knowledge, methods, and management skills to the development of equipment, systems, projects, or operations that have the inherent ability of being effectively and efficiently maintained; the set of technical processes

that apply maintainability theory to establish system maintainability requirements, allocate these requirements down to system elements, and predict and verify system maintainability performance.

Maintenance The function of keeping items or equipment in, or restoring them to, serviceable condition. It includes servicing, test, inspection, adjustment/alignment, removal, replacement, reinstallation, troubleshooting, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation. Maintenance includes both corrective and preventive activities. Any activity carried out to retain an item in, or restore it to, an acceptable condition for use or to meet its functional standard.

Maintenance engineering Developing concepts, criteria, and technical requirements for maintenance during the conceptual and acquisition phases of a project. Providing policy guidance for maintenance activities, and exercising technical and management direction and review of maintenance programs. A staff function intended to ensure that maintenance techniques are effective, equipment is designed for optimum maintainability persistent and chronic problems are analyzed and corrective actions or modifications are made.

The Reliable Maintenance Excellence Index (RMEI) An essential component to The Maintenance Excellence Institute International's implementation of profit and customer-centered maintenance. It is a progressive approach to managing the business of maintenance with performance measurement of maintenance operations achieved by integrating multiple metrics into a composite total RMEI value. It includes the comparison of current performance to both the performance goal and baseline value for each metric selected. It is ideally suited to measure progress across multiple sites within a large organization.

Maintenance leaders Maintenance managers, supervisors, foremen,

maintenance engineers, and reliability engineers.

Maintenance policy A statement of principle used to guide maintenance management decision-making.

Maintenance repair operations (MRO) Term for maintenance repair operations and generally used as MRO items referring to parts, materials, tools, and equipment used in the maintenance process.

Maintenance requirements There are two foundational needs for an effective facility management or plant maintenance operation:

Maintenance business process improvement: Business process improvement is what this book strives to help and promote with a profit and customer-centered strategy and related attitudes. If this is truly present, then the plant maintenance leader or facilities management leader in governmental operations at least has a chance to survive. However, regardless of the type of maintenance operation, they must be able to show top leaders they really are maximizing all available maintenance resources and there is a true need for resources to address the next item, the basic maintenance requirements.

## **Total maintenance requirements**

a) Knowing your total maintenance requirements: Achieving the total maintenance requirement is the primary mission. It is executing the required maintenance while providing, maintaining, and improving the asset or facilities and related services for production operation and the tenants/customers. This is what maintenance leaders must achieve in addition to many other activities that compete for engineering, craft, and administrative resources. Defining true

maintenance requirement to top leaders is extremely important when all resources are maxed out and basic preventive maintenance is being neglected. If you do not know and cannot convince top leaders what your total true maintenance requirements are, then you will experience really mean times between failures with your boss and your boss's boss!

- b) Inspection is a maintenance requirement when the basic objective is to assure that a requisite condition or quality exists. In order to inspect for the desired condition, it may be necessary to remove the item, to gain access by removing other items, or to disassemble partially the item for inspection purposes. In such cases, these associated actions necessary to accomplish the required inspection would be specific tasks.
- c) Troubleshooting is a maintenance operation that involves the logical process (series of tasks) that leads to positive identification, location, and isolation of the cause of a malfunction.
- d) Remove is a maintenance requirement when the basic objective is to separate the item from the next higher assembly. This requirement is usually applied for a configuration change.
- e) Remove and replace is a maintenance requirement that constitutes the removal of one item and replacement of it with another like item. Such action can result from a failure or from a scheduled action.
- f) Remove and reinstall is a maintenance requirement when an item is removed for any reason, and the same items reinstalled.
- g) Adjustment/alignment is a maintenance requirement when the primary cause of the maintenance action is to adjust or align, or to verify adjustment/alignment of specific equipment. Adjustment/alignment accomplished subsequent to repair of a given item is not considered to be a separate requirement and is included as a task in the repair requirement.
- h) Functional test constitutes a system or subsystem operational checkout either as a condition verification after the accomplishment of corrective maintenance action or as a scheduled requirement on a periodic basis.
- i) Conditioning is a maintenance requirement whenever an item is completely disassembled, refurbished, tested, and returned to a serviceable condition,

meeting all requirements set forth is applicable specifications. It may result from either a scheduled or unscheduled requirement and is generally accomplished at the depot/factory level of maintenance.

Maintenance schedule A comprehensive list of planned maintenance and its sequence of occurrence based on priority in a designated period of time; a list of planned maintenance tasks to be performed during a given time period, together with the expected start times and durations of each of these tasks. Schedules can apply to different time periods (e.g., daily schedule, weekly schedule).

Maintenance shutdown A period of time during which a plant, department, process, or asset is removed from service specifically for maintenance.

Maintenance strategy Principles and strategies for guiding decisions for maintenance management; a long-term plan, covering all aspects of maintenance management that sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function.

Maintenance task routing file A computer file containing skills, hours, and descriptions to perform standard maintenance tasks.

Maintenance, winning Maintenance that wins most than it loses; maintenance that plays well as part of the total operations team; maintenance that never, never, never gives up on trying to get better; maintenance that performs like Richard Petty's pit crew.

Management of change (MOC) May refer to the management of organizational changes. From a technical standpoint in a complex continuous operation, this may be defined in a formally written management of change (MOC) process procedures and cover complete documentation of all physical and procedural changes depending on the scope of the change.

Mean time between failures A measure of equipment reliability. Equal to the number of failures in a given time period, divided by the total equipment uptime in that period.

Mean time to repair A measure of maintainability. Equal to the total equipment downtime in a given time period, divided by the number of failures in that period.

Mercaptan A distinctive odorant added to natural gas. The rotten-egg smell ensures that gas escaping into the atmosphere will be detected.

Model work order A work order stored in the CMMS which contains all the necessary information required to perform a maintenance task (see also Standard job).

Modification Change in configuration; any activity carried out on an asset which increases the capability of that asset to perform its required functions.

Modularization Separation of components of a product or equipment into physically and functionally distinct entities to facilitate identification, removal and replacement unitization.

Most valuable people (MVP) Your craftspeople and your storeroom staff.

MRO materials management The overall management of the process for requisitioning, storage/warehousing, purchasing, inventory management and issue of MRO type items used in the maintenance process.

Natural gas A fossil fuel composed mostly of methane (CH4). Naturally occurring hydrocarbon gases found in porous rock formations. Its principal component is usually methane. Nonhydrocarbon gases, such as carbon dioxide and hydrogen sulfide, can sometimes be present in natural gas.

Natural gas liquids (NGLs) A general term for highly volatile liquid products separated from natural gas in a gas processing plant. NGLs include ethane, propane, butane and condensate.

Natural gas vehicle (NVG) A vehicle designed or converted to run on compressed natural gas (CNG).

Net acres The percentage that a company owns in an acreage position with multiple owners. For example, a company that has a 50% interest in a lease covering 10,000 acres owns 5000 net acres.

Nondestructive testing (NDT) Testing of equipment to detect abnormalities in physical, chemical, or electrical characteristics, using such technologies as ultrasonic (thickness), liquid dye penetrates (cracks), X-ray (weld discontinuities), and voltage generators (resistance).

Nonoperational consequences A failure has nonoperational consequences if the only impact of the failure is the direct cost of the repair (plus any secondary damage caused to other equipment as a result of the failure).

Nonrepairable Parts or items that are discarded upon failure for technical or economic reasons.

Nonroutine maintenance Maintenance performed at irregular intervals, with each job unique, and based on inspection, failure, or condition. Any maintenance task that is not performed at a regular, predetermined frequency.

No scheduled maintenance An equipment maintenance strategy where no routine maintenance tasks are performed on the equipment. The only maintenance performed on the equipment is corrective maintenance, and then only after the equipment has suffered a failure. Also described as a "run-to-failure" strategy.

Obsolescence Decrease in value or use of items that have been superseded by superior items.

Obsolete Designation of an item for which there is no replacement. The part has probably become unnecessary as a result of design change.

Odorant Any material added to natural gas to impart a distinctive odor to aid in leak detection, commonly mercaptan.

Oil analysis See Teratology.

Oil sands Geologic formation comprised predominantly of sand grains and bitumen, a highly viscous form of crude oil.

On-condition maintenance See Condition-based maintenance.

One million barrels (MMBBL) One million barrels of crude oil, bitumen, condensate or natural gas liquids.

One million cubic feet (MMCF) In the United States, standard conditions are defined as gas at 14.7 psia and 60 °F.

One thousand cubic feet (MCF) A common volumetric unit of measurement for natural gas. One MCF has about 1 million BTUs in it, when natural gas has about 1000 BTUs per cubic foot.

Operating context The operational situation within which an asset operates. For example, is it a stand-alone piece of plant, or is it one of a duty-standby pair? Is it part of a batch manufacturing process or a continuous production process? What is the impact of failure of this item of equipment on the remainder of the production process? The operating context has enormous influence over the choice of appropriate equipment maintenance strategies for any asset.

Operating hours The length of time that an item of equipment is actually operating.

Operational consequences A failure has operational consequences if it has a direct adverse impact on operational capability (lost production, increased production costs, loss of product quality, or reduced customer service).

Operational efficiency Used in the calculation of overall equipment effectiveness. The actual output produced from an asset in a given time period divided by the output that would have been produced from that asset in that period, had it produced at its rated capacity. Normally expressed as a percentage.

Operator The entity responsible for managing operations in a field or undeveloped acreage position.

Operator-based maintenance (OBM) A maintenance excellence strategy where equipment or process operators are trained and accountable for selected maintenance tasks. Also known as autonomous maintenance.

Order point Quantity of parts at which an order will be placed when usage reduces stock to that level; also called reorder point (ROP).

Order quantity Number of items demanded. The economic order quantity (EOQ), also called minimum cost quantity, is a specific number; but the actual order quantity may vary as a result of cost, transportation, discounts, or extraordinary demand.

Outage A term used in some industries, for example, electrical power distribution, to denote when an item or system is not in use.

Overall craft effectiveness (OCE) The OCE Factor is a method developed by TMEI founder Ralph "Pete" Peters to measure craft labor productivity that combines three key elements: craft utilization, craft performance and craft methods and quality. Typically, the OCE factor is determined by only the two elements: % Craft Utilization × Craft Performance. Compares to overall equipment effectiveness in basic concepts but applies directly to productivity of craft labor assets.

## The OCE Factor (%) Overall Craft Effectiveness

Craft Utilization
%(CU) =
[True Wrench
Time (WT) =
WT Hrs/Total
Paid Time as %]

X

Craft Performance
% (CP) =
[Planned Time/
Actual
Repair Time as %]
For Planned Jobs

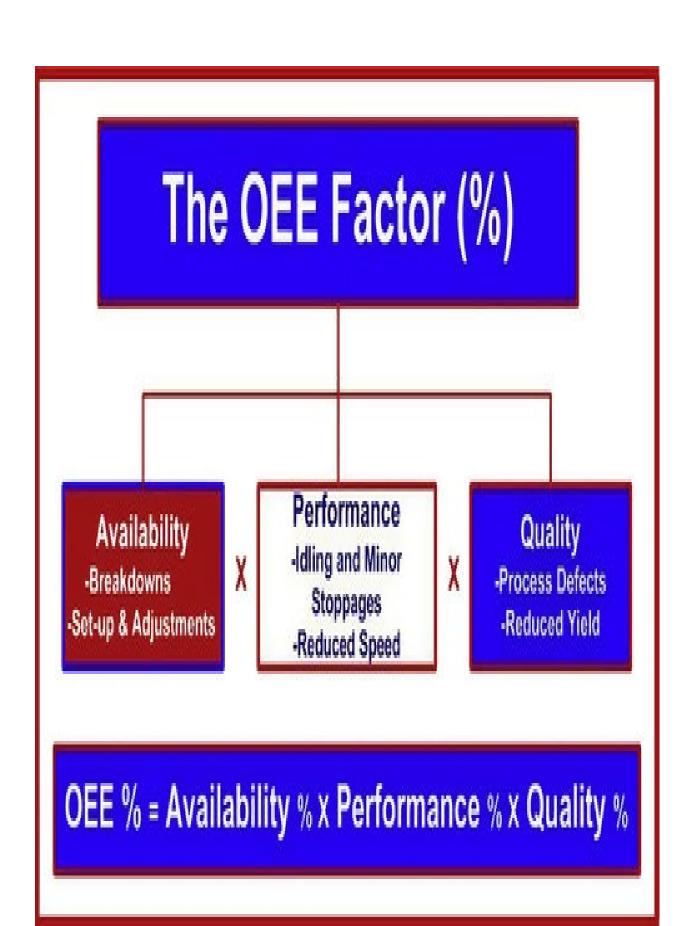
Craft Service
Quality
% (CSQ) =
[1<sup>st</sup> Quality
Repairs/Total
Repairs as %]

X

OCE % = CU % X CP % X CSQ %

The Maintenance Excellence Institute

Overall equipment effectiveness (OEE) The OEE factor is a method to measure overall equipment effectiveness that originated with Japan's total productive maintenance (TPM) strategy for maintenance improvement. The OEE factor combines three key elements; equipment availability, performance, and quality measurement into a common metric that reflects key elements of the manufacturing environment. The OEE factor equals % Availability  $\times$  % Performance  $\times$  % Quality. Compares to OCE in basic concept but applies directly to the productivity of physical assets.



Overhaul A comprehensive examination and restoration of an item to an acceptable condition.

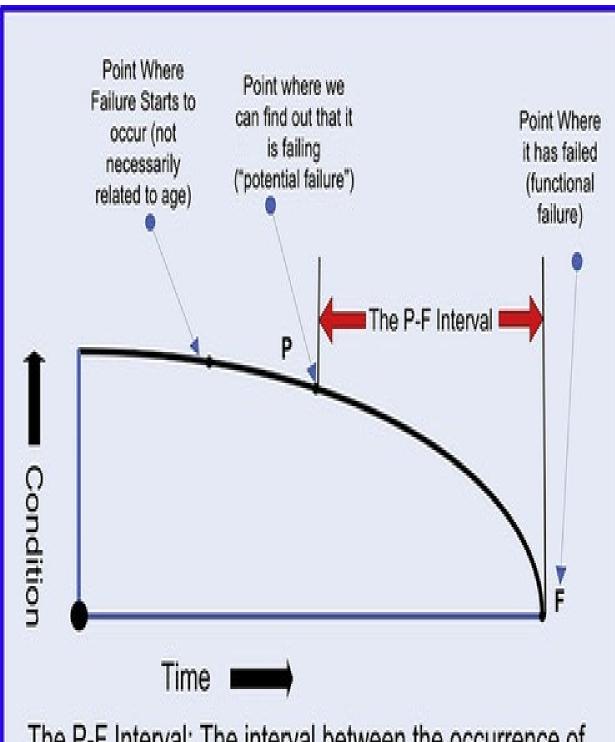
Pareto's principle Named for Vilfredo Pareto, a very smart Italian economist whose principle applies to about anything! A critical percentage (often about 20%) of parts or people or users should receive attention before the insignificant many, which are usually about 80%.

Part numbers Unique identifying numbers and letters that denote each specific part configuration; also called stock numbers or item numbers.

Periodic maintenance Cyclic maintenance actions carried out at regular intervals, based on repair history data, use, or elapsed time.

Percent planned work The percentage of total work (in labor hours) performed in a given time period which has been planned in advance.

P–F interval A term used in reliability-centered maintenance. The time from when a potential failure can first be detected on an asset or component using a selected predictive maintenance task, until the asset or component has failed. Reliability-centered maintenance principles state that the frequency with which a predictive maintenance task should be performed is determined solely by the P–F interval.



The P-F Interval: The interval between the occurrence of a potential failure and its decay into a functional failure

Permeability The permeability of a rock is the measure of the resistance to the flow of fluid through the rock. High permeability means fluid passes through the rock easily.

Pick list A selection of required stores items for a work order or task.

Planned maintenance Maintenance carried out according to a documented plan of tasks, skills, and resources; any maintenance activity for which a predetermined job procedure has been documented, for which all labor, materials, tools, and equipment required to carry out the task have been estimated, and their availability assured before commencement of the task.

Plant engineering A staff function whose prime responsibility is to ensure that maintenance techniques are effective, that equipment is designed and modified to improve maintainability, that ongoing maintenance technical problems are investigated, and appropriate corrective and improvement actions are taken. Used interchangeably with maintenance engineering and reliability engineering.

Play An area in which hydrocarbon accumulations or prospects with similar characteristics occur, such as the Lower Tertiary play in the deepwater Gulf of Mexico or the Marcellus play in the eastern United States.

Pounds per square inch (Psi) The common method of measuring natural gas pressure. One psi is equal to 28" of water column. A common delivery pressure for residential applications is 1/4 psi or 7" water column. A common delivery pressure for industrial customers may be 10 psi. Power plants may get gas pressure delivered in several 100 psi or have a

compressor on-site to boost the pressure to run combustion turbines.

Porosity The measure of a rock's ability to hold a fluid. Porosity is normally expressed as a percentage of the total rock that is taken up by pore space.

Possible reserves Additional reserves that are less certain to be recovered than probable reserves.

Potential failure A term used in reliability-centered maintenance. An identifiable condition which indicates that a functional failure is either about to occur, or in the process of occurring.

Predictive maintenance (PdM) Use of measured physical parameters against known engineering limits for detecting, analyzing, and correcting equipment problems before a failure occurs; examples include vibration analysis, sonic testing, dye testing, infrared testing, thermal testing, coolant analysis, teratology, and equipment history analysis. Subset of preventive maintenance that uses nondestructive testing such as spectral oil analysis, vibration evaluation, and ultrasonic with statistics and probabilities to predict when and what maintenance should be done to prevent failures; an equipment maintenance strategy based on measuring the condition of equipment in order to assess whether it will fail during some future period, and then taking appropriate action to avoid the consequences of that failure. The terms condition based maintenance, on condition maintenance, and predictive maintenance can be used interchangeably.

Preventive maintenance (PM) Maintenance carried out at predetermined intervals, or to other prescribed criteria, and intended to reduce the likelihood of a functional failure. Actions performed in an attempt to keep an item in a specific operating condition by means of systematic inspection,

detection, and prevention of incipient failure; an equipment maintenance strategy based on replacing, overhauling or remanufacturing an item at a fixed interval, regardless of its condition at the time. Scheduled Restoration tasks and scheduled discard tasks are both examples of preventive maintenance tasks. See also Scheduled maintenance.

PRIDE-in-Maintenance Coined originally in 1981 as the theme for a presentation to the craft work force at a manufacturing plant in Greenville, Mississippi. It is about changing the hearts, minds and attitudes about the profession and practice of maintenance. It is about PRIDE and People Really Interested in Developing Excellence in maintenance operations of all types. Its foundation starts with the most important maintenance resource, the crafts work force. The goal is to achieve PRIDE-in-Maintenance from within the crafts work force and among their maintenance leaders and to have top leaders realize the true value of their total maintenance operation and take positive action.

Priority The relative importance of a single job in relationship to other jobs, operational needs, safety, etc., and the time within which the job should be done; used for scheduling work orders.

Proactive maintenance A maintenance strategy that is anticipatory and includes a level of planning; any tasks used to predict or prevent equipment failures.

Probable reserves Additional reserves that are less certain to be recovered than proved reserves but which, together with proved reserves, are as likely as not to be recovered.

Probabilistic risk assessment A "top-down" approach used to apportion risk to individual areas of plant and equipment, and possibly to individual

assets so as to achieve an overall target level of risk for a plant, site, or organization. These levels of risk are then used in risk-based techniques, such as reliability-centered maintenance, to assist in the development of appropriate equipment maintenance strategies and to identify required equipment modifications.

Probabilistic safety assessment Similar to probabilistic risk assessment, except focused solely on safety-related risks.

Process safety management (PSM) Several PSM regulations and industry guidelines drive PSM practices. Most companies have in-house staff or contracted services to help their companies comply with these PSM regulatory requirements as well as other established industry sector standards, such as those from API.

Processing Processing is the process of removing impurities and byproducts such as water, carbon dioxide, sulfur, helium, and heavy hydrocarbons from the natural gas that is processed.

Processing natural gas The extraction of impurities such as water vapor, H2S (hydrogen sulfide), and CO2 from newly produced gas or gas in storage.

Procurement Process of obtaining persons, services, supplies, facilities, materials, or equipment. It may include the function of design, standards determination, specification development, and selection of suppliers, financing, contract administration, and other related functions.

Produced water Water produced in connection with oil and natural gas exploration and development activities.

Production The process of extracting natural gas from the rocks buried beneath the earth's surface. The wells in the gas field produce by allowing pressured gas in the rock formations to flow or be lifted to the surface in a controlled manner.

Wellhead is a series of valves, flanges, gages and vertical piping that delivers fluids/gas from the well to the surface of the earth.

Gathering Lines deliver gas from wells and transport it to the processing plant or directly to the transmission system.

Production sharing contract (PSC) An agreement between a host government and the owners (or co-owners) of a well or field regarding the percentage of production each party will receive after the parties have recovered a specified amount of capital and operational expenses.

Productive well A well that is capable of producing hydrocarbons in sufficient quantities to justify commercial exploitation.

Profit-centered maintenance (PCM) A value-adding business approach to the leadership and management of maintenance and physical asset management. Simply stated, it asks the question, "If I owned this maintenance operation as a business to make a profit, what would I do differently?" On a broader scope, it is the application of world-class maintenance practices, attitudes, and leadership principles. When applied, it makes an in-house maintenance operation equivalent to a profit center

| with both a financial system and performance measurement process in place to validate results. |
|--|
|  |
|  |
|  |
|  |
|  |
|  |
|  |
|  |
|  |
|  |



PROFIT-CENTERED? CUSTOMER-CENTERED?

"If I owned my maintenance operation as a business to make a profit or increase customer service, what would I do differently?

What is Your Answer to This Question?

Profit and customer-centered maintenance (PCCM) On a broader scope, it combines the philosophies of profit-centered with customer-centered into management and leadership of all types of maintenance processes. It is the application of maintenance best practices, attitudes, and leadership principles to both profit and maintenance customer service. When applied, it makes an in-house maintenance operation equivalent to a profit center when both a financial system and performance measurement process in place to validate results.

PROFIT-CENTERED

CUSTOMER-CENTERED

Profit and
CustomerCentered
Maintenance
(PCCM)

DEVELOP YOUR
PROFIT & CUSTOMER-CENTERED
MAINTENANCE PHILOSOPHY &
BUSINESS ATTITUDE

Project evaluation and review technique (PERT) chart Scheduling tool that shows the interdependencies between project activities in flowchart format.

Proppant Sand or manmade, sand-sized particles pumped into a formation during a hydraulic fracturing treatment to keep fractures open so that oil and natural gas can flow through the fractures to the wellbore.

Protective device Devices and assets intended to eliminate or reduce the consequences of equipment failure. Some examples include standby plant and equipment, emergency systems, safety valves, alarms, trip devices, and guards.

Proved developed reserves Proved reserves that can be expected to be recovered through existing wells with existing equipment and operating methods or in which the cost of the required equipment is relatively minor compared to the cost of a new well.

Proved reserves Proved oil and gas reserves are those quantities of oil and gas that, by analysis of geosciences and engineering data, can be estimated with reasonable certainty to be economically producible.

Provisioning Process of determining and selecting the varieties and quantities of repair parts, spares, special tools, and test and support equipment that should be procured and stocked to sustain and maintain equipment for specified periods of time. It includes identification of items of supply; establishing data for catalogs, technical manuals, and allowance lists; and providing instructions and schedules for delivery of provisioned items.

Purchase order The prime document created by an organization, and issued to an external supplier, ordering specific materials, parts, supplies, equipment or services.

Purchase requisition The prime document raised by user departments authorizing the purchase of specific materials, parts, supplies, equipment or services from external suppliers.

Quality rate Used in the calculation of overall equipment effectiveness (OEE) and overall craft effectiveness (OCE). For OEE, the proportion of the output from a machine or process that meets required product quality standards. For OCE, the proportion of repairs completed right the first time. Normally specified as a percentage.

Risk-based maintenance (RBM) A risk-based maintenance strategy is in place to prioritize maintenance resources toward assets that carry the most risk if they were to fail. It is a methodology for determining the most economical use of maintenance resources. This is done so that the maintenance effort across a facility is optimized to minimize the total risk of failure. A risk-based maintenance strategy is based on the main phases of risk assessment for probability of failure, consequences of failure, and maintenance planning based on the risk.

Reaction time/response time The time required between the receipt of an order or impulse triggering some action and the initiation of the action.

Ready line Used in relation to mobile equipment. Equipment that is available but not being utilized is typically parked on the ready line. This

term is used interchangeably with go-line.

Reasonable certainty A high degree of certainty. Much more likely to be achieved than not.

Rebuild Restore an item to an acceptable condition in accordance with the original design specifications.

Rebuild/recondition Total teardown and reassembly of a product, usually to the latest configuration.

Recompletion The process of entering an existing wellbore and performing work designed to establish production from a new zone.

Recordable cases As related to health, safety and environment (HSE), recordable cases include occupational death, nonfatal occupational illness and those nonfatal occupational injuries which involve one or more of the following: loss of consciousness, restriction of work or motion, transfer to another job or medical treatment (other than first aid).

Redesign A term that, in reliability-centered maintenance, means any one-off intervention to enhance the capability of a piece of equipment, a job procedure, a management system, or people's skills.

Redundancy Two or more parts, components, or systems joined functionally so that if one fails, some or all of the remaining components are capable of

continuing with function accomplishment; fail-safe; backup.

Refurbish Clean and replace worn parts on a selective basis to make the product usable to a customer. Less involved than rebuild.

Reliability The probability that an item will perform its intended function without failure for a specified time period under specified conditions. The ability of an item to perform a required function under stated conditions for a stated period of time; is usually expressed as the mean time between failures. Normally measured by mean time between failures.

Reliability analysis The process of identifying maintenance of significant items and classifying them with respect to malfunction on safety environmental, operational, and economic consequences. Possible failure mode of an item is identified and an appropriate maintenance policy is assigned to counter it. Subsets are failure mode, effect, and criticality analysis (FMECA), fault tree analysis (FTA), risk analysis, and HAZOP (hazardous operations) analysis.

Reliability-centered maintenance (RCM) Optimizing maintenance intervention and tactics to meet predetermined reliability goals. A structured process, originally developed in the airline industry, but now commonly used in all industries to determine the equipment maintenance strategies required for any physical asset to ensure that it continues to fulfill its intended functions in its present operating context. A number of books have been written on the subject. The seven key elements of RCM are shown in the following figure.

# The 7 Key Elements of RCM

## 7. Default Actions

What should be done
if a suitable
proactive task
cannot be found?

6. Proactive Tasks & Task Intervals

What should be done to predict or prevent each failure?

5. Failure Consequences

In what way does each failure matter?

### 1. Functions

What are the functions and associated desired standards of performance of the asset in its present operating context? Failures In what ways ca

2. Functional

In what ways can it fail to fulfil its functions?

RELIABILITY
CENTERED
MAINTENANCE

3. Failure Modes

What causes each functional failure?

> 4. Failure Effects

What happens when each failure occurs?

Reliability engineering A staff function whose prime responsibility is to ensure that maintenance techniques are effective, that equipment is designed and modified to improve maintainability, that ongoing maintenance technical problems are investigated, and appropriate corrective and improvement actions are taken. Used interchangeably with plant engineering and maintenance engineering.

Reorder point (ROP) The minimum quantity, established by economic calculation and management direction, that triggers the ordering of more items.

Repair To restore an item to an acceptable condition by the renewal, replacement, or mending of worn or damaged parts. Restoration or replacement of parts or components as necessitated by wear, tear, damage, or failure; to return the facility, equipment, or part to efficient operating condition; any activity which returns the capability of an asset that has failed to a level of performance equal to, or greater than, that specified by its functions, but not greater than its original maximum capability. An activity that increases the maximum capability of an asset is a modification.

Repair parts Individual parts or assemblies required for the maintenance or repair of equipment, systems, or spares. Such repair parts may also be repairable or nonrepairable assemblies, or one-piece items. Consumable supplies used in maintenance or repair, such as wiping rags, solvents, and lubricants, are not considered repair parts. Repair parts are also service parts.

Repairable Parts or items that are technically and economically repairable. A repairable part, upon becoming defective, is subject to return to the repair point

for repair action.

Replaceable Item Hardware that is functionally interchangeable with another item but differs physically from the original part to the extent that installation of the replacement requires such operations as drilling, reaming, cutting, filling, or shimming in addition to normal attachment or installation operations.

Reserves Estimated remaining quantities of oil and gas and related substances anticipated to be economically producible, as of a given date, by application of development projects to known accumulations. In addition, there must exist, or there must be a reasonable expectation that there will exist, the legal right to produce or a revenue interest in production, installed means of delivering oil and gas or related substances to market and all permits and financing required to implement the project.

Reservoir A porous and permeable underground formation containing a natural accumulation of producible oil and/or gas that is confined by impermeable rock or water barriers and is individual and separate from other reservoirs.

Resources Quantities of oil and gas estimated to exist in naturally occurring accumulations. A portion of the resources may be estimated to be recoverable, and another portion may be considered to be unrecoverable. Resources include both discovered and undiscovered accumulations.

Restoration Any activity which returns the capability of an asset that has not failed to a level of performance equal to, or greater than, that specified by its functions, but not greater than its original maximum capability. Not to be confused with a modification or a repair.

Return-on-assets An accounting term that, with regard to maintenance, is the profit attributable to a particular plant or factory, divided by the amount of money invested in plant and equipment at that plant or factory. It is normally expressed as a percentage. As such, it is roughly equivalent to the interest rate that you get on money invested in the bank, except that in this case the money is invested in plant and equipment.

Return on capital employed (ROCE) ROCE is a measure of the profitability of a company's capital employed in its business compared with that of its peers. ROCE is calculated as a ratio, with the numerator of net income plus after-tax interest expense and the denominator of average total equity plus total debt. The net income is adjusted for nonoperational or special items impacts.

Ranking index for maintenance expenditures (RIME) A maintenance priority methodology that provides a method to include a ranking of equipment/asset criticality combined with the repair work classification ranking to produce a priority index value.

Reliability performance indicators (RPI) Also known as key metrics that relate to the measurement of asset reliability. Examples include the following:

- Maximum corrective time (MCT) and maximum preventive time (MPT). The most time expected for maintenance, usually specified at 95% confidence level.
- Mean active maintenance time (MAMT). Weighted average of mean corrective time and mean preventive time but excluding administrative and logistics support time.
- Mean downtime (MDT). Average time a system cannot perform its mission; including response time, active maintenance, supply time and administrative and

logistics support time.

- Mean time between failures (MTBF). The average time/distance/events a product or equipment process delivers between breakdowns.
- Mean time between maintenance (MTBM). The average time between corrective and preventive actions.
- Mean time to repair (MTTR). The average time it takes to fix a failed item.

Risk The potential for the realization of the unwanted, negative consequences of an event. The product of conditional probability of an event, and the event outcomes.

Risk-based inspection An organization's chief reason for implementing an RBI program is to help manage the risk of a complex and potentially dangerous system. A good RBI program can also help an owner/operator understand of the plant is not being run as designed or if a new feedstock is causing more harm than expected to remaining life of equipment. Also, RBI is tool for helping owner/operators increase turn around schedules and avoiding shutdown inspection activities while maintaining production.

Rotable A term often used in the maintenance of heavy mobile equipment. A rotable component is one which, when it has failed or is about to fail, is removed from the asset and a replacement component is installed in its place. The component that has been removed is then repaired or restored, and placed back in the maintenance store or warehouse, ready for re-issue.

Routine maintenance task Any maintenance task that is performed at a regular, predefined interval.

Running maintenance Maintenance that can be done while the asset is in service.

Run-to-failure An equipment maintenance strategy where no routine maintenance tasks are performed on the equipment. The only maintenance performed on the equipment is corrective maintenance, and then only after the equipment has suffered a failure. Also known as "no scheduled maintenance."

Safety consequences A failure has safety consequences if it causes a loss of function or other damage that could hurt or kill someone.

Safety stock Quantity of an item, in addition to the normal level of supply, required to be on hand to permit continuing operation with a specific level of confidence if the supply is late or demand suddenly increases.

Salvage The saving of reuse of condemned, discarded, or abandoned property, and of materials contained therein for reuse or scrapping. As a noun, it refers to property that has some value in excess of its basic material content, but is in such condition that it has no reasonable prospect of original use, and its repair or rehabilitation is clearly not practical.

Schedule compliance The number of scheduled jobs actually accomplished during the period covered by an approved schedule; also the number of scheduled labor hours actually worked against a planned number of scheduled labor hours, expressed as percentage; one of the key performance indicators often used to monitor and control maintenance. It is defined as the number of scheduled work orders completed in a given time period (normally one week), divided by the total number of scheduled work orders that should have been completed during that period, according to the approved maintenance schedule for that period. It is normally expressed as

a percentage, and will always be less than or equal to 100%. The closer to 100%, the better the performance for that time period.

Scheduled discard task Replacement of an item at a fixed, predetermined interval, regardless of its current condition; a maintenance task to replace a component with a new component at a specified, predetermined frequency, regardless of the condition of the component at the time of its replacement. An example would be the routine replacement of the oil filter on a motor vehicle every 6000 miles. The frequency with which a scheduled discard task should be performed is determined by the useful life of the component.

Scheduled maintenance (SM) Preplanned actions performed to keep an item in specified operating condition by means of systematic inspection, detection, and prevention of incipient failure. Sometimes called preventive maintenance, but actually a subset of PM.

Scheduled operating time The time during which an asset is scheduled to be operating, according to a long-term production schedule.

Scheduled restoration task A maintenance task to restore a component at a specified, pre-determined frequency, regardless of the condition of the component at the time of its replacement. An example would be the routine overhaul of a slurry pump every 1000 operating hours. The frequency with which a scheduled restoration task should be performed is determined by the useful life of the component.

Scheduled work order A work order that has been planned and included on an approved maintenance schedule.

Scoping A planning activity which outlines the extent/scope and detail of work to be done and defines the resources needed.

Scoreboard for Excellence Baseline for today's most comprehensive benchmarking guides for maintenance operations. Developed initially in 1981 and enhanced into its present format of five different Scoreboard for Excellence versions. See Scoreboard for Facilities Management Excellence and Scoreboard for Maintenance Excellence.

### 1993 Version of The Scoreboard for Maintenance Excellence Maintenance and Organization Culture Maintenance Facilities, Maintenance Facilities, Equipment and Tools Computerized Maintenande Companion and Management Systems Work Authorization Supervision / Leadership Maintenance Performance Budget and Cost Control Measurement South Maintenance Safety, Housekeeping and MAINTENANCE EXCELLENCE Planning and Scheduling Regulatory Compliance Craft Skills Development IMPROVEMENT Maintenance Storeroom Predictive Maintenance Operator-Based Maintenance Ernamoering Support Lubrication Program Effectiveness (OEE) Overall Equipment Polal Productive Maintenance **Included Related TPM Practices**

Scoreboard for Facilities Management Excellence Today's most comprehensive benchmarking guide for pure facilities maintenance operations. Developed along the same format as the Scoreboard for Maintenance Excellence, the New Millennium version includes 27 evaluation (best practice) categories and 300 evaluation categories. An excellence benchmarking guide for operations within large physical plant and facilities complexes such as universities, state and municipal building complexes, healthcare facilities, secondary school complexes and retail organizations with nationwide system of sites. Provides an essential benchmarking guide where results become an important external benchmark against recognized best practices and also the user's baseline for Continuous Reliability Improvement.

## The Scoreboard for Facilities Management Excellence

| CATEGORY | The Scoreboard for Facilities Management Excellence<br>Category Descriptions (Part 1) | Evaluation<br>Items | Total<br>Points in<br>Category |
|----------|---|---------------------|--------------------------------|
| A.       | The Organizational Culture and PRIDE in Maintenance                                   |                     | 50                             |
| В.       | Facilities Organization, Administration and Human Resources                           | 10                  | 100                            |
| C.       | Craft Skills Development  | 10                  | 100                            |
| D.       | Facilities Management Supervision/Leadership  | 10                  | 100                            |
| E.       | Business Operations, Budget and Cost Control  | 15                  | 150                            |
| F.       | Work Management and Control: Maintenance and Repair (M/R)                             |                     | 100                            |
| G.       | Work Management and Control: Construction and Renovation (C/R)                        |                     | 50                             |
| H.       | Facilities Maintenance and Repair Planning and Scheduling                             |                     | 150                            |
| I.       | Facilities Construction and Renovation Planning /Scheduling and Project Management    |                     | 100                            |
| ј.       | Facilities Planning and Property Management   |                     | 100                            |
| К.       | Facilities Condition Evaluation Program   |                     | 50                             |
| L.       | Facilities Storeroom Operations and Internal MRO Customer<br>Service                  |                     | 150                            |
| M.       | MRO Materials Management and Procurement  | 10                  | 100                            |

## The Scoreboard for Facilities Management Excellence

| CATEGORY | The Scoreboard for Facilities Management Excellence<br>Category Descriptions (Part 2 Continued) | Evaluation<br>Items | Total<br>Points in<br>Category |
|----------|---|---------------------|--------------------------------|
| N.       | Preventive Maintenance and Lubrication  | 20                  | 200                            |
| 0.       | Predictive Maint. and Conditioning Monitoring Technologies                                      | 10                  | 100                            |
| P.       | Building Automation and Control Technology  | 5                   | 50                             |
| Q.       | Utilities Systems Management  | 10                  | 100                            |
| R.       | Energy Management and Control   | 10                  | 100                            |
| S.       | Facilities Engineering Support  | 10                  | 100                            |
| T.       | Safety and Regulatory Compliance  | 15                  | 150                            |
| U.       | Security Systems and Access Control   | 10                  | 90                             |
| V.       | Facilities Management Performance Measurement   | 15                  | 150                            |
| W.       | Facilities Maintenance Management System (FMMS) and Business System                             | 15                  | 150                            |
| X.       | Shop Facilities, Equipment, and Tools   | 10                  | 100                            |
| γ.       | Continuous Reliability Improvement  | 10                  | 100                            |
| Z.       | Grounds and Landscape Maintenance   | 15                  | 150                            |
| ZZ.      | Housekeeping Service Operations   | 15                  | 150                            |
|          | Total Evaluation Items and Points   | 300                 | 3000                           |

@ 2001-2006 The Maintenance Excellence Institute. All Rights Reserved

Scoreboard for Maintenance Excellence TMEII has today's most comprehensive benchmarking guide for plant maintenance operations and now an updated 2015 version for complex continuous processing operations. Developed initially in 1982 and enhanced into its present format of 38 evaluation (best practice) categories and 600 evaluation items. Previous versions have been used for over 200 assessment/audits and has been used by approximately 5000 organizations for benchmarking all types of maintenance operations. Provides an essential benchmarking guide where results become an important external benchmark against recognized best practices and also the user's baseline for Continuous Reliability Improvement.

## THE SCOREBOARD FOR MAINTENANCE EXCELLENCE™ 2015 Part 1

#### MAINTENANCE BENCHMARK EVALUATION SUMMARY

| Category<br>Number | Benchmark Category Descriptions & Rating Values for Each Evaluation Criteria<br>5-Poor, 6-Below Average, 7-Average, 8-Good, 9-Very Good & 10- Excellent | Number<br>of<br>Criteria | Total<br>Assessment<br>Points per<br>Category |
|--------------------|---|--------------------------|---|
|                    | New Benchmark or Expanded Category  | VIIII                    |   |
| 1                  | Top Management Support to Maintenance and Physical Asset Management   | 10                       | 100   |
| 2                  | Maintenance Strategy, Policy and Total Cost of Ownership  | 30                       | 300   |
| 3.                 | The Organizational Climate and Culture  | 9                        | 90  |
| 4.                 | Maintenance Organization, Administration and Human Resources  | 18                       | 180   |
| 3.                 | Craft Skills Development and Technical Skills   | 12                       | 120   |
| 6.                 | Operator Based Maintenance and PRIDE in Ownership   | 10                       | 80  |
| 7.                 | Maintenance Leadership, Management and Supervision  | 12                       | 120   |
| 8.                 | Maintenance Business Operations, Budget and Cost Control  | 15                       | 150   |
| 9.                 | Work Management and Control: Shop Level Maintenance Repair (M/R)  | 12                       | 120   |
| 10.                | Work Management and Control: Shutdowns, Turnarounds and Outages (STO)   | 26                       | 260   |
| 11                 | Shop Level Reliable Planning, Estimating and Scheduling M.R.  | 30                       | 300   |
| 12.                | STO and Major Planning Scheduling and Project Management  | 16                       | 160   |
| 13.                | Contractor Management   | 31                       | 310   |
| 14.                | Manufacturing Facilities Planning and Site Property Management  |                          | 90  |
| 15.                | Production Asset and Facilities Condition Evaluation Program  |                          | 60  |
| 16.                | Storeroom Operations and Internal MRO Customer Service  | 12                       | 120   |
| 17.                | MRO Materials Management and Procurement  | 12                       | 120   |
| 18.                | Preventive Maintenance and Lubrication  | 18                       | 180   |
| 19.                | Predictive Maintenance and Condition Monitoring Technology Applications   | 15                       | 150   |
| 20.                | Reliability Centered Maintenance (RCM)  | 34                       | 340   |

#### THE SCOREBOARD FOR MAINTENANCE EXCELLENCE™ 2015 Part 2 Number Total Benchmark Category Descriptions & Rating Values for Each Evaluation Criteria of Category Assessment 5=Poor, 6=Below Average, 7=Average, 8=Good, 9-Very Good & 10= Excellent Points Per Criteria Category New Benchmark Category or Expanded Category Reliability Analysis Tools: Root Cause Analysis (RCA), Root Cause Corrective Action (RCCA) 17 170 Failure Modes Effects Analysis (FMEA), Root Cause Failure Analysis (RCFA) and Failure Reporting Analysis and Corrective Action System (FRACAS) 22 Risk Based Maintenance (RBM) 24 240 Process Control and Instrumentation Systems Technology ģ 90 Energy Management and Control 12 24 120 Maintenance Engineering and Reliability Engineering Support ğ 90 26 Health, Safety, Security and Environmental (HSSE) Compliance 15 150 27 Maintenance and Quality Control 90 ġ. Maintenance Performance Measurement 12 推 120 Computerized Maintenance Management System (CMMS) as a Business System 18 29 180 Shop Facilities, Equipment, and Tools 30. ģ 90 Continuous Reliability Improvement 15 150 31. Critical Asset Facilitation and Overall Equipment Effectiveness (OEE) 15 32 150 Overall Craft Effectiveness (OCE) 33 ő 60 Sustainability 34 11 110 Traceability 19 35 190 Process Safety Management (PSM) and Management of Change (MOC) 26 36 260 Risk Based Inspections (RBI) and Risk Mitigation 29 17 290 38 PRIDE in Maintenance 8 80 Total Evaluation Items: 600 Scoreboard Total Possible Points: 6000 Actual Total Benchmark Value Score of All Ratings: Assessment Performed By: Date:

Secondary damage Any additional damage to equipment, above and beyond the initial failure mode, that occurs as a direct consequence of the initial failure mode.

Secondary failures Malfunctions that are caused by the failure of another item.

Secondary function A term used in reliability-centered maintenance. The secondary functionality required of an asset generally not associated with the reason for acquiring the asset, but now that the asset has been acquired, the asset is now required to provide this functionality. For example, a secondary function of a pump may be to ensure that all of the liquid that is pumped is contained within the pump (i.e., the pump does no't leak). An asset may have tens or hundreds of secondary functions associated with it.

Serial number Number or letters that uniquely identify an item.

Service contract Contract calling directly for a contractor's time and effort rather than for a specific end product.

Service level Frequency usually expressed as a percentage, with which a repair part demand can be filled through a particular service stock echelon. A 95% level of service means that 95 out of 100 demands are properly issued. If viewed from the end customer service technician perspective, the service level is the percent of parts received out of those requested, from all levels of the support system.

Service line The pipe the carries the gas from the distribution mains in the street, across private property to the customer's meter.

Serviceability Characteristics of an item, equipment, or system that make it easy to maintain after it is put into operation; similar to maintainability.

Servicing The replenishment of consumables needed to keep an item in operating condition.

Shale A very fine-grained sedimentary rock that is formed by the consolidation of clay, mud, or silt and that usually has a finely stratified or laminated structure. Certain shale formations, such as the Eagle Ford and the Barnett, contain large amounts of oil and natural gas.

Shelf life The period of time during which an item can remain unused in proper storage without significant deterioration.

Shop stock Self-service items, such as nuts, bolts, fitting, etc., that are stored directly in the shop work area. May be on consignment directly from the vendor or vendor may inventory and "keep full" as needed without significant paperwork requirement.

Shutdown The period of time when equipment is out of service.

Shutdown, turnaround, and outages (STO) Typically, a well-planned, scheduled, and executed amount of work (all types) with complete or partial

shutdown of production activities. Much more complex for oil and gas operations as compared to discrete manufacturing.

Shutdown maintenance Maintenance done while the asset is out of service, as in the annual plant shutdown.

Social life cycle analysis (S-LCA) A methodology for assessing internalities and externalities of the production of goods and services based on social and socioeconomic indicators.

Sour gas is natural gas or any other gas containing significant amounts of hydrogen sulfide (H2S).

Spacing The distance between wells producing from the same reservoir. Spacing is often expressed in terms of acres (e.g., 80-acer spacing) and is often established by regulatory agencies.

Specifications Physical, chemical, or performance characteristics of equipment, parts, or work required to meet minimum acceptable standards.

Standard item Part, component, material, subassembly, assembly, or equipment that is identified or described accurately by a standard document or drawing.

Standardization Process of establishing the greatest practical uniformity of items and of practices to assure the minimum feasible variety of such items and

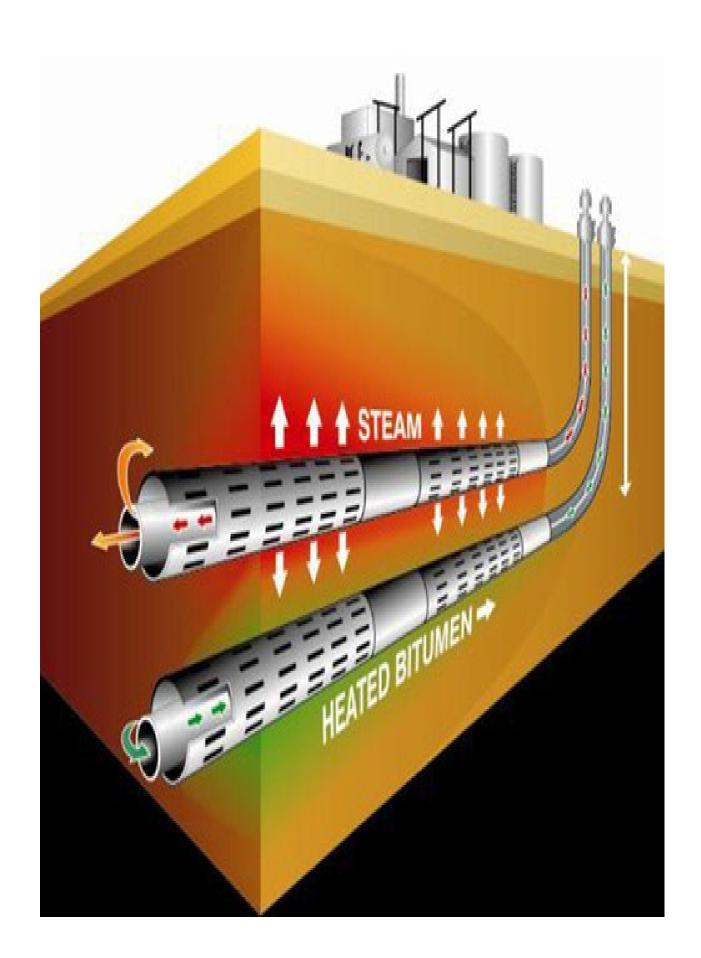
practices, and affect optimum interchangeability.

Standard job A work order stored in the CMMS that contains all the necessary information required to perform a maintenance task (see also Model Work Order).

Standby Assets installed or available but not in use.

Standing work order A work order that is left open either indefinitely or for a predetermined period of time for the purpose of collecting labor hours, costs, and/or history for tasks for which it has been decided that individual work orders should not be raised. Examples would include standing work orders raised to collect time spent at safety meetings, or in general housekeeping activities; a work order that remains open, usually for the annual budget cycle, to accommodate information small jobs or for specific tasks.

Steam-assisted gravity drainage (SAGD) A process used to recover bitumen that is too deep to mine. A pair of horizontal wells is drilled from a central well pad. In a plant nearby, steam generators heat water and transform it into steam. The steam then travels through above-ground pipelines to the wells. It enters the ground via the steam injection well and heats the bitumen to a temperature at which it can flow by gravity into the producing well. The resulting bitumen and condensed steam emulsion is then piped from the producing well to the plant, where it is separated and treated. The water is recycled for generating new steam.



Stock keeping unit (SKU) A warehouse inventory management term for individual stock items carried in inventory.

Stock number Number assigned by the stocking organization to each group of articles or material, which are then treated as if identical within the using supply system; also called part number, item number, or part identifier.

Stock out Indicates that all quantities of a part normally on hand have been used, so that the items are not presently available. Demand for a nonstock part is usually treated as a separate situation and procured via defined procedures and vendors.

Storage Natural gas can be stored in underground storage fields. Storage fields are typically old gas fields that have been depleted of natural gas, salt-domes that have been hollowed out by solution mining, or other porous rock that is surrounded by impermeable rock.

- Injection is the process of pumping natural gas into storage fields, using during off-peak summer months
- Withdrawal is the process of pumping natural gas out of storage fields, usually during periods of winter peak demand

Storage underground The use of subsurface porous rock formations for storing gas. Depleted natural gas production fields are often used for storage. Typically, natural gas is pumped into a field during the summer when demand and commodity prices usually are lower and pumped out of storage during winter when demand is high.

Stores issue The issue and/or delivery of parts and materials from the store or warehouse.

Stores requisition The prime document raised by user departments authorizing the issue of specific materials, parts, supplies, or equipment from the store or warehouse.

Sweet Gas Natural gas that contains little or no hydrogen sulfide.

Supply Procurement, storage, and distribution of items.

Support equipment Items required to maintain systems in effective operating condition under various environments. Support equipment includes general and special-purpose vehicles, power units, stands, test equipment, tools, or test benches needed to facilitate or sustain maintenance action, to detect or diagnose malfunctions, or to monitor the operational status of equipment and systems.

Sustainability Sustainable development is present in regards to maintenance and physical asset management to meet the needs of the current operation without compromising the ability of future site operations to meet their own need to maintain physical assets. The organization understands that the organizing principle for sustainability is sustainable development, which includes the four interconnected domains ofecology, economics, politics, and culture.

Teamwork works! The proven practice of the synergistic results by uncommon people working toward a common mutual goal. Often, this is ordinary people achieving extraordinary results (see also Maintenance, winning)

Technical data and information Includes, but is not limited to, production and engineering data, prints and drawings, documents such as standards, specifications, technical manuals, changes in modifications, inspection and testing procedures, and performance and failure data.

Terotechnology An integration of management, financial, engineering, operating maintenance, and other practices applied to physical assets in pursuit of an economical life cycle; the application of managerial, financial, engineering and other skills to extend the operational life of, and increase the efficiency of, equipment and machinery.

Test and support equipment All special tools and checkout equipment, metrology and calibrations equipment, maintenance stands, and handling equipment required for maintenance. Includes external and built-in test equipment (BITE) considered part of the supported system or equipment.

Thermography The process of monitoring the condition of equipment through the measurement and analysis of heat. Typically conducted through the use of infra-red cameras and associated software. Commonly used for monitoring the condition of high voltage insulators and electrical connections, as well as for monitoring the condition of refractory in furnaces and boilers, amongst other applications.

Throwaway maintenance Maintenance performed by discarding used parts rather than attempting to repair them.

Top leaders C-positions, especially the CFO, VP operations, managing directors, and engineering/maintenance managers.

Total asset management An integrated approach to asset management that incorporates elements such as reliability centered maintenance, total productive maintenance, design for maintainability, design for reliability, value engineering, life cycle costing, probabalistic risk assessment, and others, to arrive at the optimum cost-benefit-risk asset solution to meet any given production requirements.

Total productive maintenance (TPM) A Japanese-based maintenance strategy for companywide equipment management program emphasizing operator involvement in equipment maintenance, continuous improvement in equipment effectiveness, and measurement of overall equipment effectiveness (OEE).

Traceability Traceability is characterized by a number of essential elements: a) an unbroken chain of comparisons going back to a standard acceptable to the parties, usually a national or international standard; b) measurement of uncertainty; the measurement uncertainty for each step in the traceability chain must be calculated according to defined methods; and c) must be stated so that an overall uncertainty for the whole chain may be calculate and have documentation for each step in the chain performed according to documented and generally acknowledged procedures. The results must equally be documented.

Tradesperson Alternative to "craftsperson." A skilled maintenance worker who has typically been formally trained through an apprenticeship program. TMEI likes to think of craftspeople and tradespeople as our MVPs—today's most valuable people for all types of maintenance operations around the world.

Transmission lines A gas pipeline that transports large quantities of highly pressurized natural gas over long distances.

Transportation The movement by a pipeline operator of natural gas owned by another party, typically a distribution company or end-user. Transportation service is a type of tariff many gas companies offer to large users who desire to purchase their gas from someone other than the local distribution company (LDC).

Teratology The process of monitoring the condition of equipment through the analysis of properties of its lubricating and other oils. Typically conducted through the measurement of particulates in the oil, or the measurement of the chemical composition of the oil (spectrographic oil analysis). Commonly used for monitoring the condition of large gearboxes, engines, and transformers, amongst other applications.

Tight gas Natural gas produced from relatively impermeable rock. Getting tight gas out usually requires enhanced technology applications like hydraulic fracturing. The term is generally used for reservoirs other than shale.

Total recordable rate (TRR) The total recordable rate is a measure of the rate of recordable cases, normalized per 100 workers per year. The factor is derived by multiplying the number of recordable injuries in a calendar year by 200,000 (100 employees working 2000 h per year) and dividing this value by the total man hours actually worked in the year.

Total shareholder return (TSR) Represents share price appreciation and

dividends returned to shareholders over a period. It is calculated as follows:  $[(stock\ price\ at\ the\ end\ of\ the\ period) - (stock\ price\ at\ the\ start\ of\ the\ period) + (dividends\ paid\ during\ the\ calculation\ period) <math>\div$  (stock\ price\ at\ the\ start\ of\ the\ period)].

Total system support (ToSS) The composite of all considerations needed to assure the effective and economical support of a system throughout its programmed life cycle.

Transmission Transmission is the process of moving gas from producing regions or storage fields to major consuming areas.

- Compression is the process of increasing the pressure of the gas moving through a pipeline, so that more gas can be moved a further distance. Large pipelines may operate in the range of 3,000 psi and be up to 60" in diameter.
- Compressor is the device used to add pressure to the gas moving through the pipeline. Compressors are typically powered by natural gas engines and are rated in hundreds or thousands of horsepower per compressor.

Troubleshooting Locating or isolating and identifying discrepancies or malfunctions of equipment and determine the corrective action required.

Turnaround time Interval between the time a repairable item is removed from use and the time it is again available if full serviceable condition.

Turnover Measurement on either numbers of parts or on monetary value that evaluates how often a part is demanded versus the average number kept in inventory. For example, if two widgets are kept in inventory and eight are used each year, then the turnover is 8/2 = 4 times per year. In monetary terms,

turnover is cost of inventory sold/average cost of inventory carried.

Unconventional reservoirs Reservoirs with permeability so low (generally less than 0.1 millidarcy) that horizontal hydraulically fractured stimulated wells or other advanced completion techniques must be utilized to extract hydrocarbons at commercial rates. Shale reservoirs such as the Eagle Ford and Barnett, as well as tight reservoirs like the Bakken and Three Forks, both are examples of unconventional reservoirs.

Undeveloped acreage Acreage on which wells have not been drilled or completed to a point that would permit the production of commercial quantities of oil and gas regardless of whether or not the acreage contains proved reserves.

Unit The joining of interests in a reservoir or field to provide for development and operations without regard to separate property interests. Also, the area covered by a unitization agreement.

Unplanned maintenance Maintenance done without planning or scheduling; could be related to a breakdown, running repair, or corrective work; any maintenance activity for which a predetermined job procedure has not been documented, or for which all labor, materials, tools, and equipment required to carry out the task have been not been estimated, and their availability assured before commencement of the task.

Unscheduled maintenance (UM) Emergency maintenance (EM) or corrective maintenance (CM) to restore a failed item to usable condition.

Up In a condition suitable for use.

Uptime The time that an item of equipment is in service and operating.

Usage Quantity of items consumed or necessary for product support. Usage is generally greater than the technical failure rate.

Useful life The maximum length of time that a component can be left in service, before it will start to experience a rapidly increasing probability of failure. The useful life determines the frequency with which a scheduled restoration or a scheduled discard task should be performed.

Utilization The proportion of available time that an item of equipment is operating. Calculated by dividing equipment operating hours by equipment available hours. Generally expressed as a percentage.

Value engineering A systematic approach to assessing and analyzing the user's requirements of a new asset, and ensuring that those requirements are met, but not exceeded. Consists primarily of eliminating perceived "non-value-adding" features of new equipment.

Variance analysis Interpretation of the causes for a difference between actual and some norm, budget, or estimate.

Vibration analysis The process of monitoring the condition of equipment, and the diagnosis of faults in equipment through the measurement and

analysis of vibration within that equipment. Typically conducted through handheld or permanently positioned accelerometers placed on key measurement points on the equipment. Commonly used on most large items of rotating equipment, such as turbines, centrifugal pumps, motors, gearboxes etc.

Warranty Guarantee that an item will perform as specified for at least a specified time, or will be repaired or replaced at no cost to the user.

Warranty claims Replacement or reimbursement due to bad parts or equipment from a vendor or original equipment manufacturer (OEM). Sunken gold treasure within most maintenance storerooms where warranty claims never get identified and sent back to the item vendor or OEM. For the most part, it is not the CMMS's fault!

Waterflood An improved oil recovery technique that involves injecting water into a producing reservoir to enhance movement of oil to producing wells.

Wear out Deterioration as a result of age, corrosion, temperature, or friction that generally increases the failure rate over time.

Wet gas Produced gas that contains natural gas liquids.

Working interest The right granted to the lessee of a property to explore for, produce and own oil, gas or other minerals. The working interest owners bear the exploration, development, and operating costs.

Workload The number of labor hours needed to carry out a maintenance program, including all scheduled and unscheduled work and maintenance support of project work.

Work order (WO) A unique control document that comprehensively describes the job to be done; may include formal requisition for maintenance, authorization, and charge codes, as well as what actually was done. The prime document used by the maintenance function to manage maintenance tasks. It may include such information as a description of the work required, the task priority, the job procedure to be followed, the parts, materials, tools and equipment required to complete the job, the labor hours, costs and materials consumed in completing the task, as well as key information on failure causes, what work was performed etc.

Work request The initial request for maintenance service or work usually as a statement of the problem. The work request provides the preliminary information for creation of the work order. Depending on the cost and scope of a work request an approval process may be required before the work order is created, planned, and scheduled. The prime document raised by user departments requesting the initiation of a maintenance task. This is usually converted to a work order after the work request has been authorized for completion.

X-maintenance Extreme maintenance challenges: Illustrates four key stages that as assets age and new assets are also added, the total maintenance requirements increase often without a corresponding increase in staffing levels.

#### **Challenge One:**

**Maintain Existing Assets** 

### **Challenge Two:**

Improve , Enhance
Existing Assets to
Achieve Environmental,
Regulatory Compliance or
Create Additional
Production Capacity

#### **Challenge Three:**

Renovate or Modify/ Overhaul Existing Assets with Capiital Funds and Maintain Additions

#### **Challenge Four:**

Add New Assets and Assume Increased Scope of Work as All Assets Get Older and Older

## Four Maintenance Challeges:

Growing Maintenance Requirements Often Must Be Faced Without Additional Craft Resources Zero-based budgeting An accounting strategy that, as related to maintenance, is the charge back of all maintenance work to the customer and is based on a computed shop rate per hour plus parts and rental equipment if required.

# Appendix C

## Maintenance Planner/Scheduler or Maintenance Coordinator: Position Description, Job Evaluation Form

\_

**Position Questionnaire** 

# Position Title: Maintenance Planner/Coordinator

Date: mm/dd/yyyy

Number of Associates with same title in Department:

Department: Maintenance Operations

Reports to: Maintenance Manager

Is this a new position? X Yes No

- 1. Primary purpose and function of position. Please explain in two or three sentences. Provides overall maintenance planning and scheduling support to include contract maintenance and the planning of repairs and overhauls during scheduled shutdowns, turnarounds, and outages (STO) in support to engineering. Provides close interaction and support to storeroom operations and is responsible for maintaining the site's preventive maintenance program. Serves as a primary resource for computerized maintenance management system (CMMS) implementation and the maintenance of all related databases.
- 2. Duties and responsibilities. List in order of importance the major duties that are performed and normally assigned to the position. Indicate the percentage of time spent on each duty. Please add additional sheets if needed.

\_

| % of time       |   |
|-----------------|---|
| 5               | 1. Coordinates maintenance work order (MWO) system, processing of MWOs, a       |
| 5               | 2. Reviews MWOs to confirm priorities with manufacturing operations and main    |
| 10              | 3. Develops labor estimates for planned work and establishes schedules based or |
| Table Continued | •   |

-

#### % of time

Table Continued

| 4. Develops and maintains a current backlog summary of maintenance repairs ar     |
|---|
| 5. Develops and coordinates modernization of current stores area into an organiz  |
| 6. Determines material and spare parts availability prior to scheduling. Works wi |
| 7. Develops job plans and standard repair practices during planning process. Cor  |
| 8. Evaluates requirements for contract maintenance against existing craft capabil |
| 9. Ensures that information on contract maintenance repairs, overhauls, and all r |
| 10. Responsible for coordinating the PM/PdM review team for review and updat      |
|   |

-

#### % of time

| 2 | 11. Supports scheduling PdM technology application such as oil analysis/infrared, etc. a   |
|---|--|
| 5 | 12. Develops and provides data (MTTR/MTBF) and recommendations for improving e             |
| 2 | 13. Coordinates with plant operations staff to establish PM/PdM, lubrication, and parts    |
| 5 | 14. Responsible for supporting implementation and administration of a future computer      |
| 2 | 15. Provides support to updating engineering drawings and coordinates cross-referencing    |
| 2 | 16. Works closely with the maintenance manager, all craft supervisors, and manufacturing   |
| 5 | 17. Serves as the primary support to the maintenance manager in developing performan       |
| 5 | 18. Performs other related duties and special projects as assigned. a. Provides training a |
|   |  |

3. Briefly describe any special functions performed in addition to normal responsibilities.

Serves as a key internal resource for effective CMMS implementation, supports utilization of all CMMS system modules, and supports training of internal users on a new CMMS system.

| Are the special functions   | above perform   | ned?  |   |   |
|---|---|---|---|---|
| ✓ Weekly Mor  | nthly (   | Quarterly   | Other   |   |
| 4. Office machines and  | derical skills i  | needed to perf  | orm in the position                                 | 1:  |
|   | PI  | ease check on   | e:  |   |
|   | Daily   | Weekly  | Occasionally  | Special Training Required   |
| Typing  |   | _   |   | ·   |
| Dictation   |   |   |   |   |
| 10-key  |   |   |   |   |
| Personal computer   |   | *   |   | ( <del>4)</del>   |
| ✓ Windows office  | _   |   | a   | MS project & access DB  |
| Other CRTs  |   |   |   | Basic knowledge of<br>energy mgmt system  |
| Graphics package and document management system   |   |   | <u> </u>  |   |
| ✓ Programming/CMMS  |   |   | <u> </u>  | Future CMMS   |
| Should understand how con  5. What level of education   | work orders to<br>well as is bein                                   | o this system. Og<br>g able to use ot                   | Capability to use CM<br>hers such as Crystal.       | w to load deferred maintenance<br>IMS Report Writer is helpful as<br>Report Writer. |
| Less than high scho   | CONTRACTOR CONTRACTOR A   | _   |   | To the Barrier B.   |
| College degree  | (OI   | =   | school diploma/equ<br>nced degree                   | vaient  |
| ✓ Certification in pla<br>estimating and sche   |   |   |   | s multi-skilled crafts background   |
|   |   | ш   |   |   |
| a. Needs good craft ba<br>planning of maintenan<br>b. Needs formal mainten<br>c. Must have good comp<br>d. Must be able to develo | ekground (prefe<br>ce work across<br>ance planning &<br>uter skills | erably multi-er<br>multiple trade a<br>c scheduling tra | aft experience) for<br>reas<br>ining and on the job | technical knowledge to support<br>training as well.                                 |
| 6. In detail, give an exan  | ple of an indep   | endent decisio  | n made in this posi                                 | ion?  |
| Work backlog level hi     Contract maintenance     contractor, recommence.     This position may reco                             | work is of poor<br>I new contractor                                 | quality - this p  | osition reschedules<br>Is with holding paym         |   |
| 7. Does this position mal   |   | ations to:  Vendors                                     | ✓ Cours   | e of action   |

| 8. Is this position supervised?  Yes No  |   |
|--|---|
| What amount of supervision and technical?  |   |
| Shop floor supervisors are available on the floor/depo   | artment at all times for technical support  |
| ✓ Maintenance manager is available only when needed  | 0.000   |
| 9. Does this position have supervisory responsibilities?   | X Yes No  |
|  | groups, First-line supervisors<br>gns work to individual craft person)  |
| ✓ Review work ✓ Work schedules   |   |
| Performance reviews _recommends _approves/handles  |   |
| Handles disciplinary problems _recommends _approves/handles  |   |
| List position titles supervised: i.e., Possible on size of operatio  | on .  |
| Storeroom Attendant if<br>there is a direct<br>responsibility for stores   |   |
| -Data Entry-Admin Person   | _   |
|  |   |
| This position allows the maintenance department to operate in of a high stressed reactive environment. It provides direction to operation. It ensures availability of parts and materials at right for proactive planned. When performed correctly this position to a minimum of 5 equivalent craft positions for each planne increase asset uptime resulting in greater output and greater pro- | n a planned and controlled environment instead<br>to storeroom operations in some case for a small<br>ht time, right quantity, right place and best price<br>in can help achieve craft productivity gains equal<br>to position. This position is also in a role to help |
| 11. What kinds of errors <u>could</u> happen in this position?   |   |
| There are four main areas a) Lost capacity on plant operations<br>man hours and c) excess spares parts inventory cost and d) exc<br>net inventory.   | equipment, b) low productivity of maintenance<br>cessive obsolete parts on hand and high costs of   |
|  |   |
| How would such errors ordinarily be checked or discovered?   |   |
| Maintenance metrics via a system such The Reliable Maint<br>excessive downtime of critical equipment (low OEE), high % em  |   |
| low PM and Schedule compliance will all show clearly any nega  |   |
| Direct feedback from associates, maintenance manager, first-lir<br>staff   | ne maintenance supervisors and plant operations   |
|  |   |

#### What would happen if an error is not caught?

Nothing catastrophic, but this position support a business approach to physical asset management and allows a progression toward continuous improvement for the maintenance of valuable plant assets (both human capital & plant equipment)

#### 12. What "people" contact does this position have? Mode Seven Cut Beaut Dr. (I-2x week) Inhana, letter. dailys work): in person) Other departments All In person, Stores (maint) via a PC All Vendors: Contractor's Staff General public Auditors on occasion Govt/state agencies What level of contact (clerical, administrative, managers, Vice Presidents, etc.)? High level of contact with first-line maintenance supervisors and maintenance manager Regular contact with plant manager, operations manager, VP Operations and other plant operations personnel needing information or maintenance service Give an example of such contacts: Coordinate scheduling of repairs or PM tasks where asset must be scheduled out of service for repair or PM Has major input on deciding the level of repairs made. This person may be asked along with Maintenance Leader to review deferred jobs for shutdowns (STO type work) with STO Project Manager and STO team ADDITIONAL INFORMATION: Please describe any other aspects of the position that are important and have not been covered above. This person can provide valuable information such as which vendors/contractors are performing to the company's performance standards based on actual performance and reliability data. This person can have major economic impact affecting such things as craft utilization, the cost of maintenance repairs and parts, timely repair service and status of work being requested by operations. TASK LIST: Please check the appropriate section for each task on the following checklist. Indicate whether or not the task is required for the position and the degree to which it is required: NOT REQUIRED, OCCASIONALLY REQUIRED, FREQUENTLY REQUIRED. (Occasionally is defined as irregular or infrequent intervals.) If a task statement does not exactly fit the position, change the statement by crossing out or adding additional words. Design and determine performance report, layout, format and retrieve data for finished report 1 Proofread and correct errors Have experience to operate power equipment, power tools or perform general maintenance Conduct specialized training sessions related to CMMS to educate department or company associates Operate computer peripheral equipment Set up and type financial reports or statistical tabulations Compose department memos without supervisor approval

Set up appointments independently, schedule meetings, conferences and/or make travel

arrangements and reservations

#### TASK LIST (continued) Maintain confidential records and files and handle confidential correspondence Open, sort and distribute incoming mail. Date stamp papers and documents Answer telephone, screen and place calls, and refer callers to appropriate parties Gather and analyze data to prepare complex reports Audit records for accuracy and make appropriate corrections Investigate accidents/injuries to determine cause Receive and welcome visitors and refer them to appropriate parties 7 Write and test complex computer programs 1 Prepare and process expense accounts Maintain status of inventoried maintenance parts & supplies and requisition new parts & 1 Monitor department overtime, sick leave, vacations and holidays Maintain, sort and update mailing lists and labels Handle work requests, complaints, or inquiries from callers/customers Prepare, process and verify invoices, bills and/or receipts Coordinate work to complete, process and trace purchase orders Gather and tabulate data; compile routine reports as directed by supervisor Record and verify entries in CMMS data base Balance ledger accounts and reconcile accounting statements Arrange for equipment repairs via planning process Maintain records of cash receipts and disbursements Prepare complex legal documents Photocopy, collate, punch and/or bind documents Compile routine reports for federal, state and local agencies 1 Extract, tabulate, and summarize information for periodic or special reports Interpret and enforce Company policies and procedures 1 Manually key in and verify data and correct errors 1 Negotiate prices with vendors Troubleshoot equipment for problems or repairs Support maintenance manager in researching, analyzing and prepare budget for department or 1 Unload/load materials, unpack cartons Compose department memos to be reviewed by supervisor Manipulate computer control switches on console panels, storage devices, readers, printers and punches according to detailed instructions Type and proofread legal documents Research problems by reconstructing past repairs as related to RCM/RCA team work. 1 Council associates or managers on performance related issues Assist others in the company with computer, and CMMS questions Write basic computer programs as directed by supervisor File, retrieve, assemble and distribute records, papers documents and reports 1 Make non-routine decisions without a supervisor Make decisions that impact bottom line of company

| Immediate supervis   | er a fermion     | ,                 |                                    |                     |
|----------------------|------------------|-------------------|------------------------------------|---------------------|
| This position        | >                |                   |                                    |                     |
| Any direct reports t | o this position  | <b>—</b>          |                                    |                     |
| Associate's printed  | name             |                   | Phone extension                    |                     |
| Associate signature  | <u> </u>         |                   | Date completed                     |                     |
| 72150 - 250 I XXX    |                  |                   | VISOR SECTION                      |                     |
| I have reviewed th   | e contents of th | his questionnaire | and feel it is an accurate and con | plete representatio |

# Appendix D

# Charter: Format for a Leadership Driven-Self-Managed Team at GRIDCo Ghana

\_

Ralph W. Peters, and Franklin Takyi, The Maintenance Excellence Institute International, Ghana

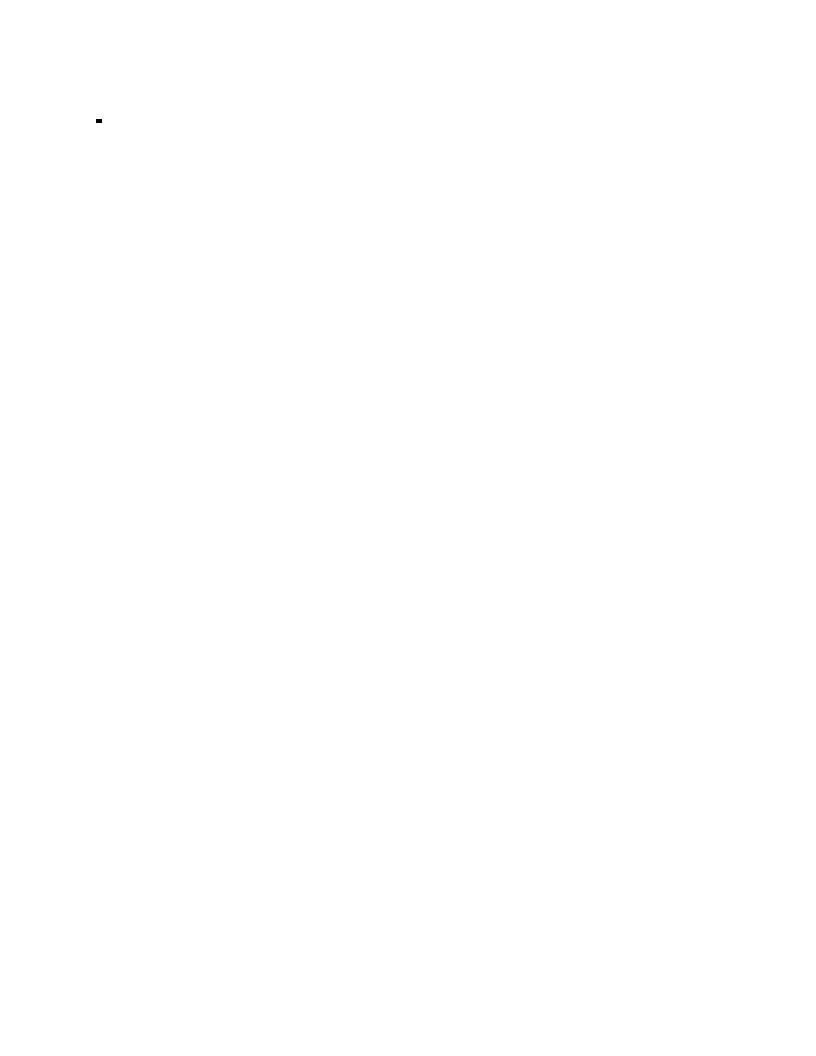
#### The GRIDCo CMMS Selection and Best Practices Implementation Team-Draft January 14, 2014

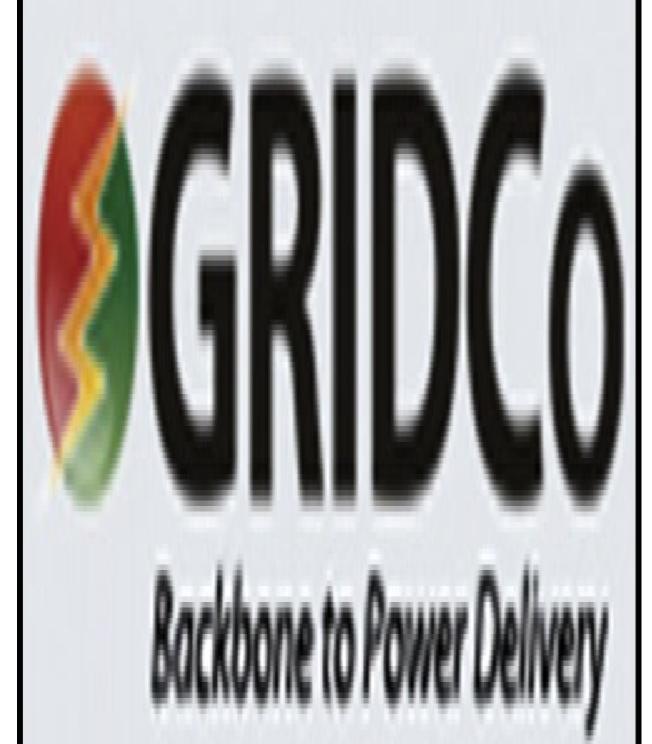
- -
- -
- 1. Purpose: To provide senior guidance to CMMS (computerized maintenance management system) sele
- 2. Expectations (sponsor's): a. Team will incorporate the 5 steps of the "Action Cycle" into their work p
- 3. Importance of this project to GRIDCo: a. Customers are serviced faster and more efficiently to restor

**Table Continued** 

- 4. Team skills: a. All GRIDCo areas represented will work have process experience. Combined years of
- 5. Scope: The scope of the parts team will include making decision on top CMMS to purchase and defir
- 6. Deliverables: a. Team charter b. Increased power transmission delivery on existing system and new s

| GRIDCo's r | recommended team members: draft                         |  |
|------------|---|--|
| Team spons | sor: Mr. Norbert Anku Responsibilities: • Clarity purpo | ose and expectations • Agree with tean |
|            |   |  |
|            |   |  |
|            |   |  |



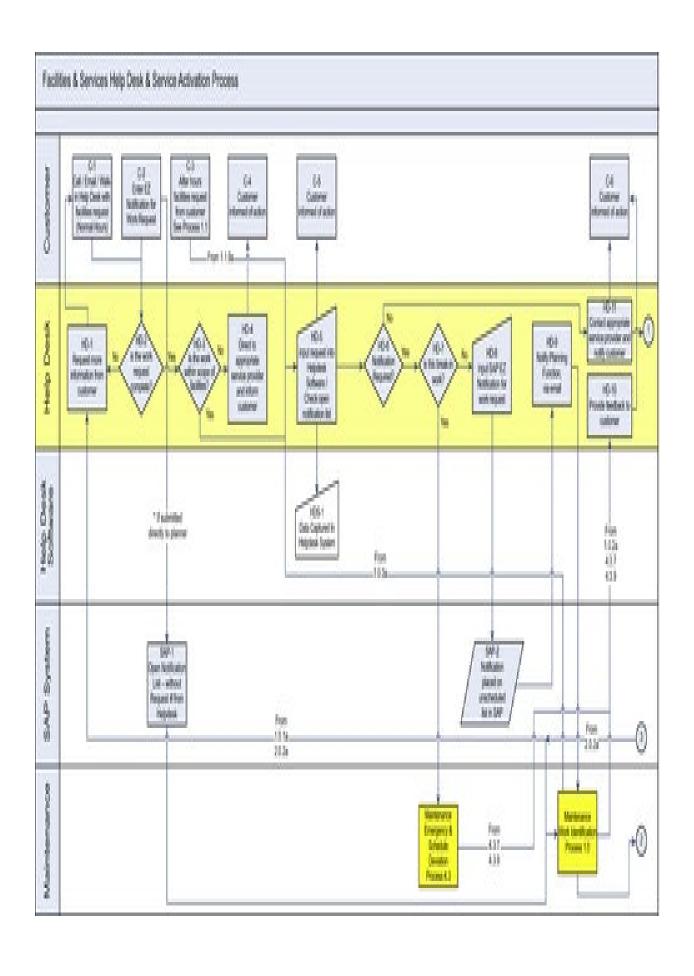


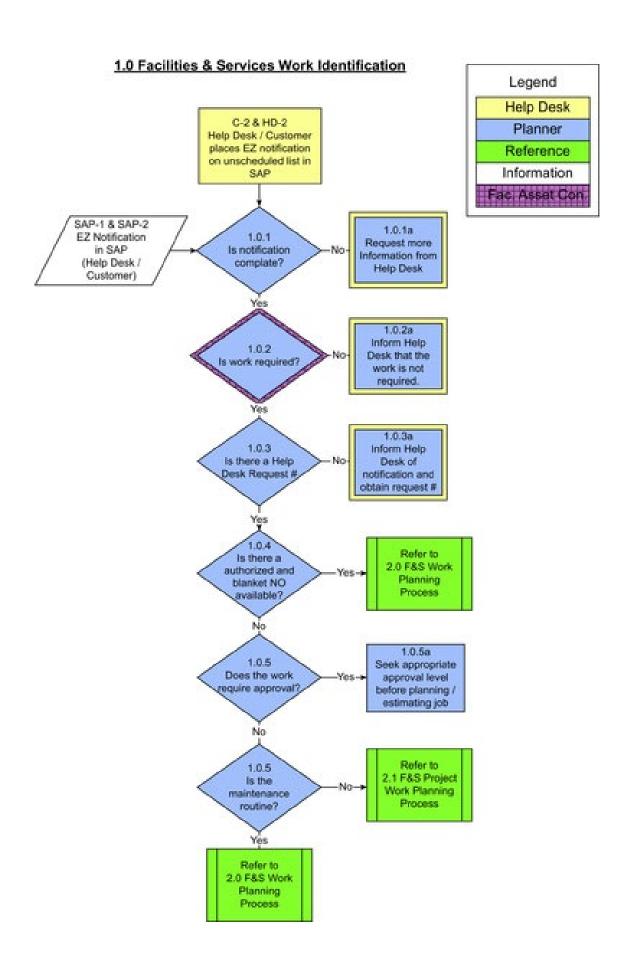


# Appendix E

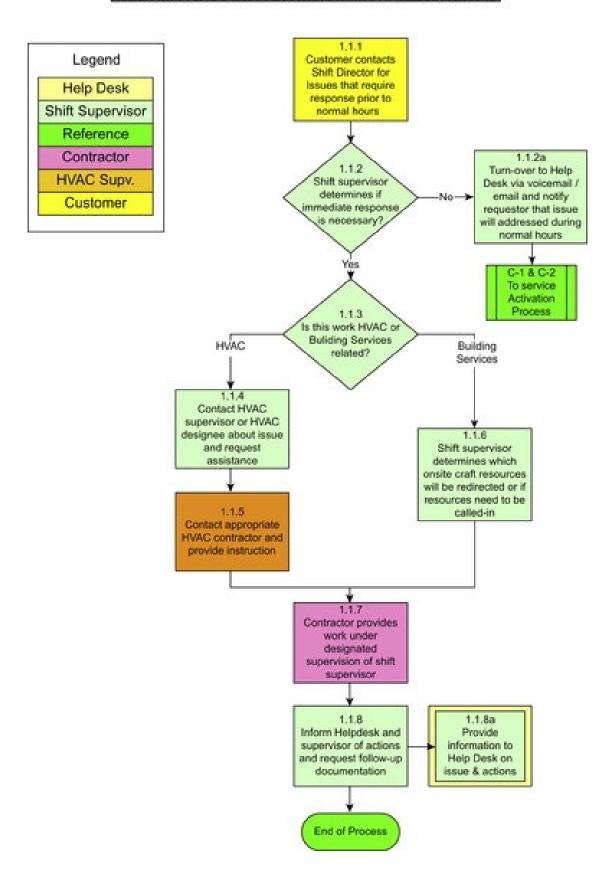
**Case Study–Process Mapping for a Refinery** 

\_

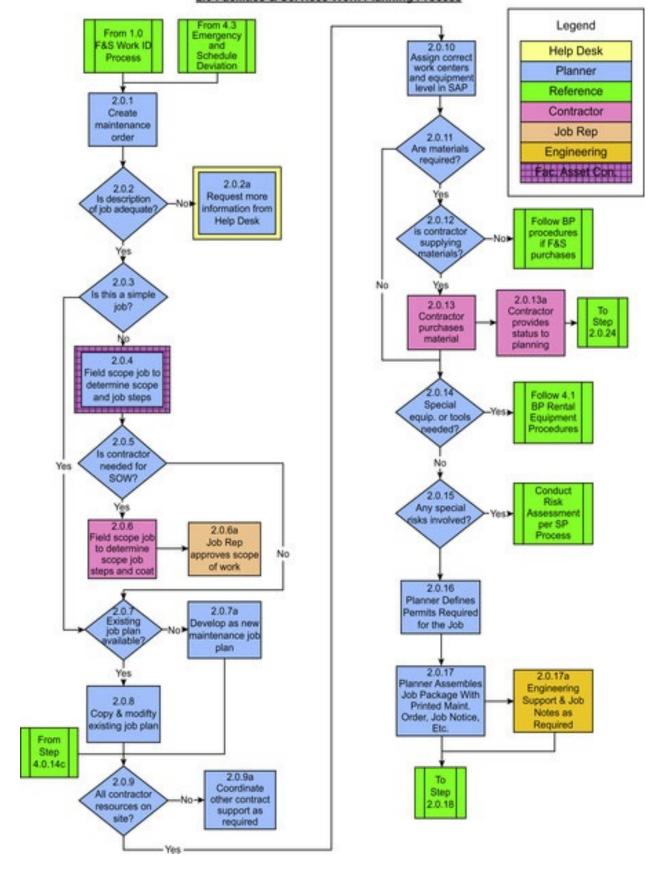




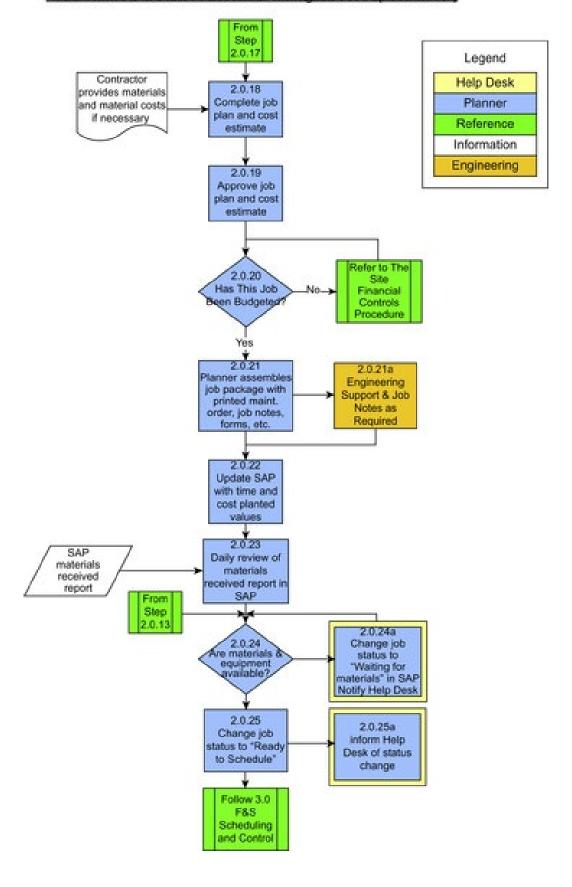
#### 1.1 Facilities & Services Work Identification - After Hours



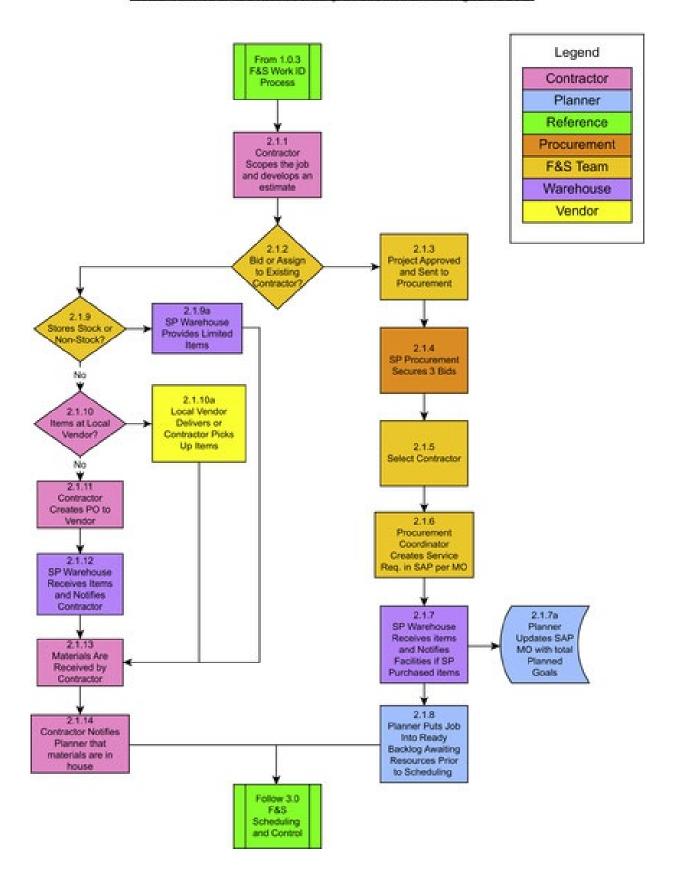
#### 2.0 Facilities & Services Work Planning Process



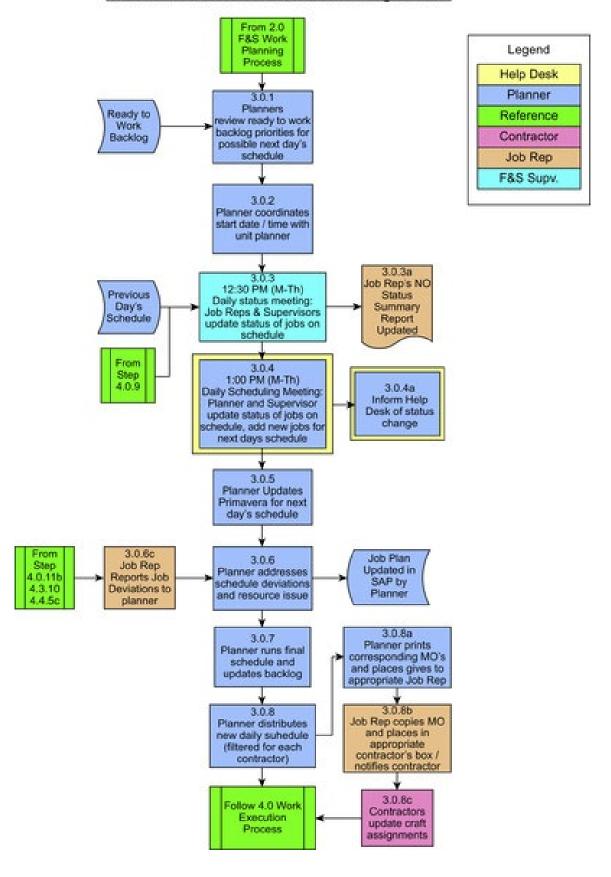
#### 2.0 Facilities & Services Work Planning Process (Continued)



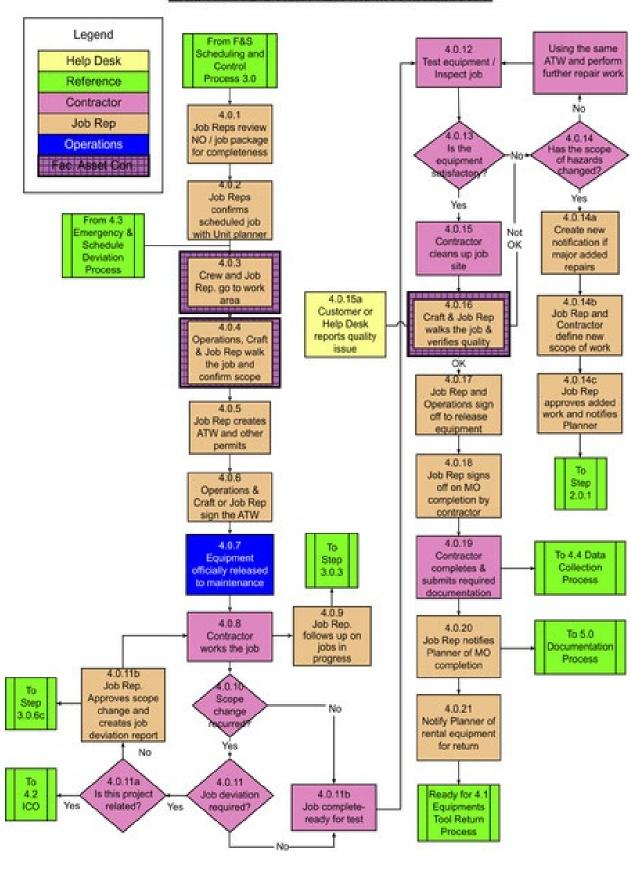
#### 2.1 Facilities & Services Project Work Planning Process



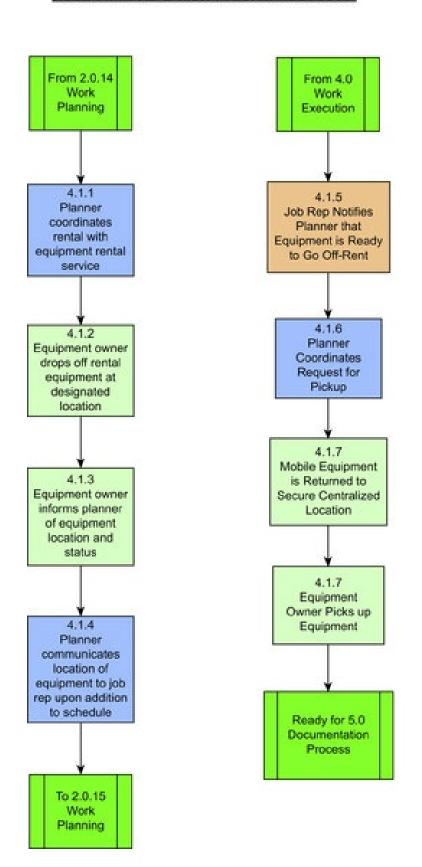
#### 3.0 Facilities & Services Work Scheduling Process

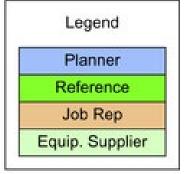


#### 4.0 Facilities & Services Work Execution Process

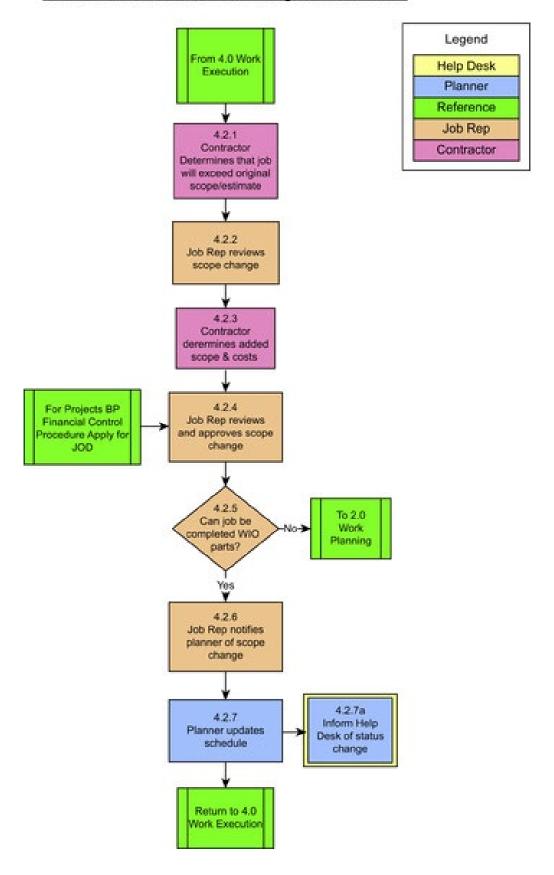


#### 4.1 Facilities & Services Rental Process

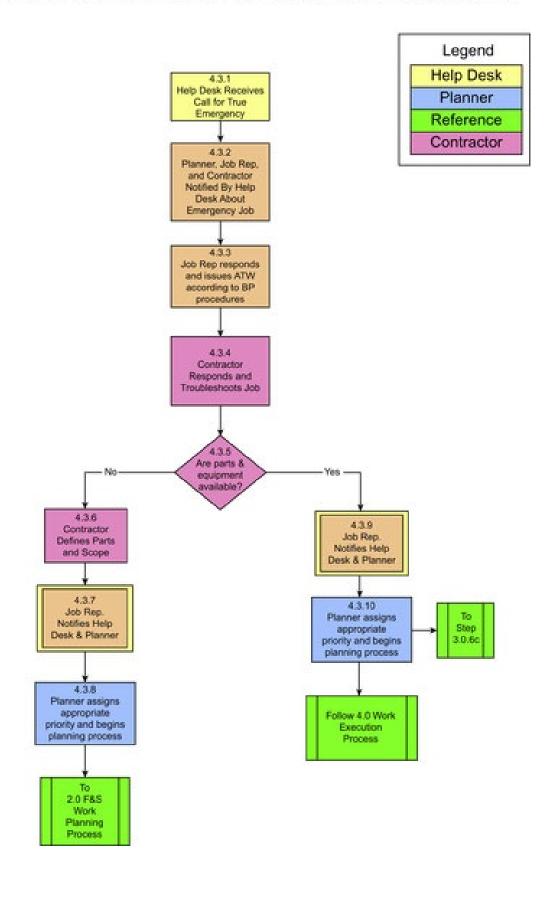




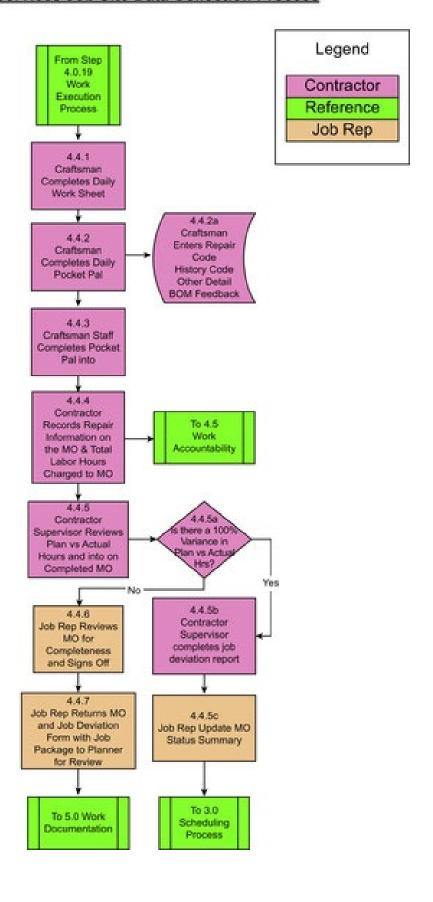
#### 4.2 Facilities & Services Job Change Order Process



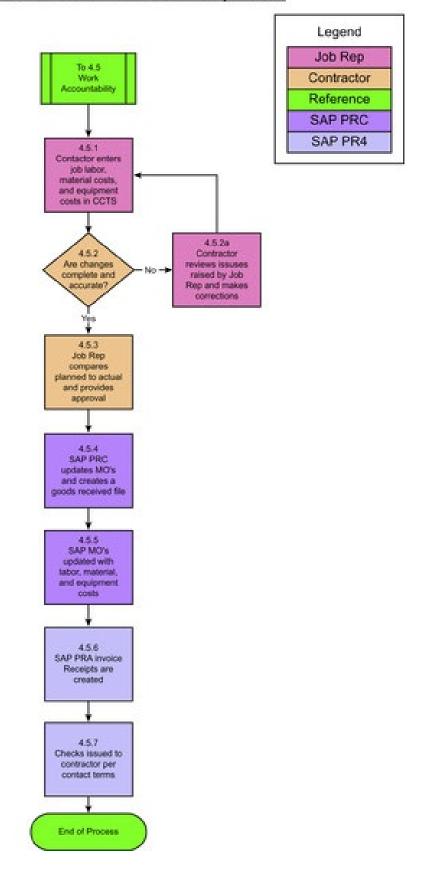
#### 4.3 Facilities & Services Emergency Break-In & Schedule Deviation Process

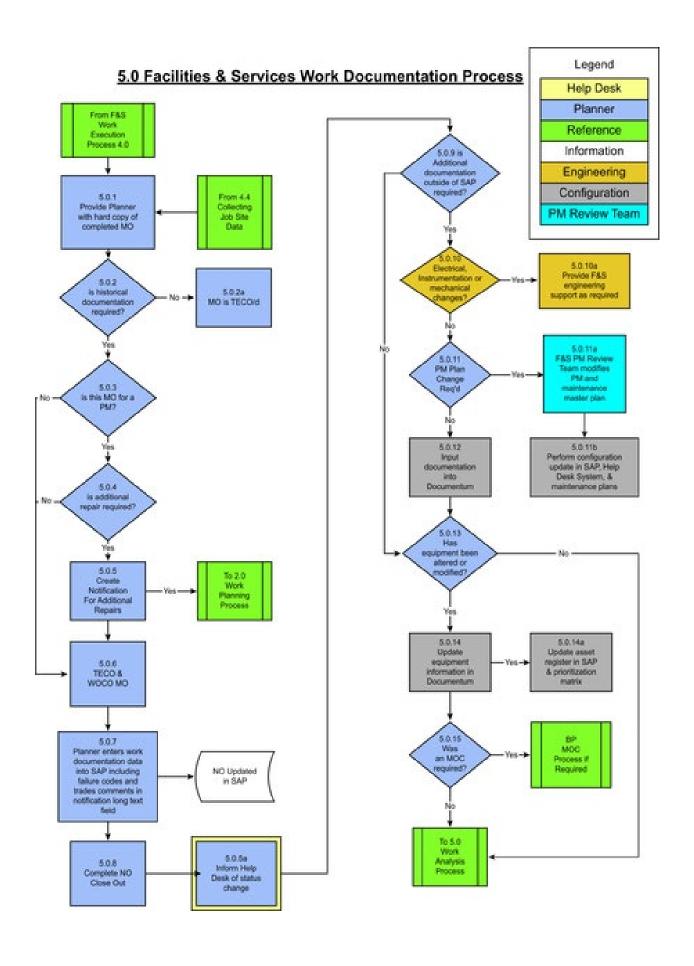


#### 4.4 Facilities & Services Job Site Data Collection Process

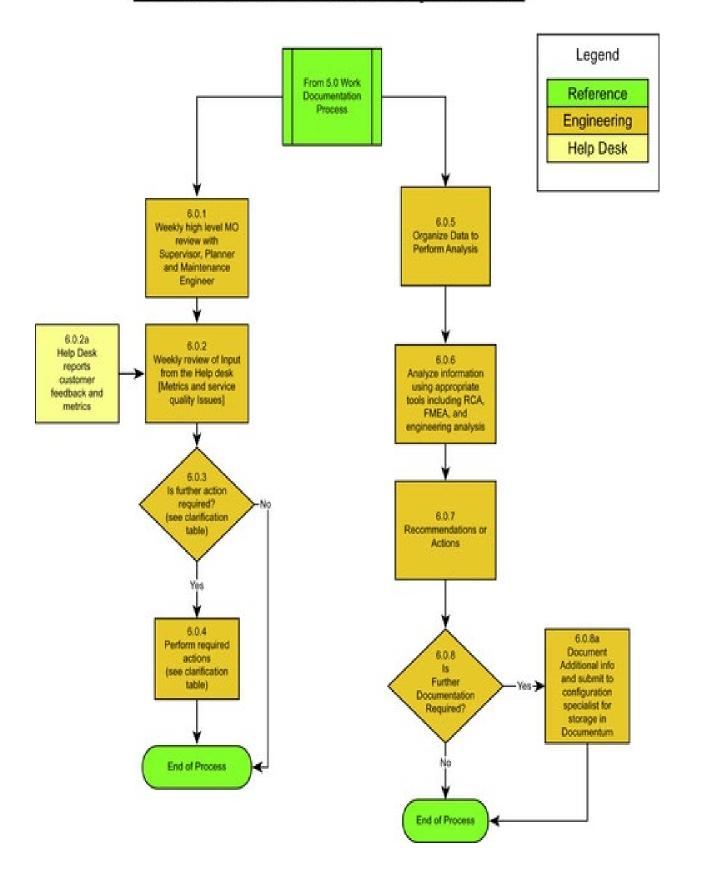


#### 4.5 Facilities & Services Contractor Work Accountability Process





## 6.0 Facilities & Services Work Analysis Process



## Appendix F

## The CMMS Benchmarking System

-

### **Introduction**

Today's information technology for computerized maintenance management offers the maintenance leader an exceptional tool for asset management and for managing the maintenance process as an internal business and "profit center." However, maintenance surveys and assessments conducted by The Maintenance Excellence Institute International and others validate that poor utilization of existing maintenance software is often a major improvement opportunity.

We will now review each of the nine major categories from the CMMS Benchmarking System and provide key recommendations on each of the 50 benchmark items for getting your computerized maintenance management system (CMMS) implementation started on the right track from day one.

## **CMMS Data Integrity**

1. Equipment (Asset) History Database: The equipment database represents one of the essential databases that must be developed or updated as part of implementing a new CMMS. It requires that a complete review of all equipment be made to include all parent/child systems and subsystems that will be tracked for costs, repairs performed, etc. The work to develop or update this database should begin as soon as possible after the data structure of the equipment master

file for the new CMMS is known.

The equipment master information for a piece of equipment (parent/child), manufacturer, serial number, equipment specs, and location will all need to be established. If the installation and removal of components within certain process type operations requires tracking by serial number and compliance to process safety management requirements, then these equipment items will have to be designated in the equipment database.

If an equipment database exists as part of an old CMMS, then now is the time to review the accuracy of the old equipment database before conversion to the new system. Conversion of the new equipment master database into the new system should be done only after a thorough and complete update of the old database has occurred. Once the new equipment master database has been converted to the new CMMS, a process to maintain it at an accuracy level of 95% or above should be established.

2. Spare Parts Database: The spare parts database represents another key database that must be developed or updated as part of implementing a new CMMS. For operations not having a parts inventory system, this will require doing a complete physical inventory of spare parts and materials. All inventory master record data for each item will need to be developed based on the inventory master record structure for the new CMMS and loaded directly to the inventory module.

Operations that have an existing spare parts database should take the time to do a complete review of it before conversion. Typically, this will allow for purging the database of obsolete parts and doing a complete review of the inventory master record data. This can be a very time-consuming process, but it allows the operation an excellent chance to finally take the time to revise part descriptions, review safety stock levels, reorder points and vendor data, and start the new CMMS with an accurate parts inventory database.

3. Bill of Materials: One key functional capability of CMMS is to provide a

spare parts listing (bill of materials) within the equipment module. This requires researching where spare parts are used and linking inventory records with equipment master records that are component parts of an equipment asset. This function would also add, change, or delete items from an established spares list or copy a spares list to another equipment master record. In addition, this feature would copy all or part of a spares list to a work order job plan and create a parts requisition or pick list to the storeroom.

The process of establishing a spares list is time-consuming and would involve only major spares that are currently carried in stock. Most CMMS systems have the capability to build the spare parts list as items are issued to or purchased for a piece of equipment. It is recommended that an equipment bill of materials be established, but the conversion of equipment master data can take place without this information being available. Because a bill of materials for spare parts is so beneficial for planning purposes, it is recommended that the process to identify key spares in the equipment master be a priority area.

4. Preventive Maintenance Tasks/Frequencies: The preventive and predictive maintenance (PM/PdM) database is another key database necessary for establishing a "Class A" installation. If a current PM/PdM database is present, then it is recommended that the existing procedures be reviewed and updated before conversion to the new system. If the existing PM/PdM database has been updated continuously on the old system, then conversion can probably occur directly from the old to the new PM/PdM database; however, this will depend on the PM/PdM database structure of the new system.

It is recommended that in the very early stages of a new CMMS benchmark/selection process that the status of the current PM/PdM program be evaluated. If a process for the review/update of PM/PdM procedures has not been in place, then it is very important to get something started as soon as possible. This provides an excellent opportunity to establish a team of experienced craftspeople, engineers, and maintenance supervisors to work on PM/PdM procedures to review, to update task descriptions, and frequencies, and to ensure that all equipment is covered by proper procedures.

- 5. Maintaining Parts Database: After a new CMMS is installed, it is highly recommended that one person be assigned direct responsibility for maintaining the parts database. This person would have responsibility for making all additions and deletions to inventory master records, changing stock levels, reorder points and safety stock levels, and changing any data contained in the inventory master records. This person could also be designated responsibility for coordinating the development of the spares list if this information is not available. This person would be responsible for recommending obsolete items on the basis of the monitoring of usage rates or because of equipment being removed from the operation. The practice of having one primary person assigned direct responsibility for the inventory master records can help ensure that parts database accuracy is 95% or greater.
- 6. Maintaining Equipment Database: It is also highly recommended that one person be assigned direct responsibility for maintaining the equipment database. This person would be responsible for making all changes to equipment master records. Information on new equipment would come to this person for setting up parent/child relationships of components in the equipment master records. Information on equipment being removed from the operation would also come to this person to delete equipment master records. Coordination between this person and the person responsible for the parts database would be required to ensure that obsolete parts were identified and/or removed from the inventory system because of removal of equipment.

#### **CMMS Education and Training**

7. Initial CMMS Training: One of biggest roadblocks to an effective CMMS installation is the lack of initial training on the system. Many organizations never take the time up front to properly train their people on the system. Shop-level people must gain confidence in using the system for reporting work order information and knowing how to look up parts information. The CMMS implementation plan should include an adequate level of actual hands-on training on the system for all maintenance employees before the "go-live" date. It is important to invest the time and expense to "train the trainers" who can, in

turn, assist with the training back in the shop. Many organizations set up "conference room pilots" where the CMMS software is set up and training occurs with actual data using CMMS vendor trainers or in-house trainers. It is highly recommended that competency-based training be conducted so that each person trained can demonstrate competency in each function they must perform on the system.

- 8. Ongoing CMMS Training: The CMMS Implementation Plan must consider having an ongoing training program for maintenance and storeroom personnel. After the initial training, there must be someone in the organization with the responsibility for ongoing training. If a good "trainer" has been developed within the organization before the go-live date, then this person can be the key to future internal training on the new system. Ongoing training can include one-on-one support that helps to follow up on the initial training.
- 9. Initial CMMS Training for Operations Personnel: The customers of maintenance must gain a basic understanding of the system and know how to request work, check the status of the work requested, and understand the priority system. During implementation, operations personnel need to get an overview of how the total system will work and the specific things they will need to do to request work. If the organization has a formal planning and scheduling process, then they will also need to know the internal procedures on how this will work.
- 10. CMMS Systems Administrator/Backup Trained: It is important that each site have one person trained and dedicated as the systems administrator with a backup trained whenever possible. This person will typically be from information services and have a complete knowledge of system software, hardware, database structures, and interfaces with other systems as well as report-writing capabilities. The systems administrator will also have responsibility for direct contact with the CMMS vendor for debugging software problems and for coordinating software upgrades.

#### **Work Control**

11. Work Control Function Established: A well-defined process for requesting

work, planning, scheduling, assigning work, and closing work orders should be established. The work control function will depend on the size of the maintenance operation. Work control may involve calls coming directly to a dispatcher who creates the work order entry and forwards the work order to a supervisor for assignment. The work request could also be forwarded directly to an available craftsperson by the dispatcher for execution of true emergency work.

Work control can also be where work requests are forwarded manually or electronically to a planner who goes through a formal planning process for determining the scope of work, craft requirements, and parts requirements to develop a schedule. PM/PdM work would be generated and integrated into the scheduling process. The status of the work order would be monitored, which might be in progress, awaiting parts, awaiting equipment, awaiting craft assignment, or awaiting engineering support, etc. A work order backlog would also be maintained to provide a clear picture of the work order status.

Effective work control provides systematic control of all incoming work through to the actual closing of the work order. The work control process should be documented with clearly defined written procedures unique to each maintenance operation.

- 12. Online Work Request Based on Priorities: Requesting work online represents an advanced CMMS functional capability in which the customer enters the work request directly into the system on a local area network or via e-mail. Online work requests would include basic information about the work required, equipment location, the date the work is to be completed by, the name of the requestor, and the priority of the work. This information would go to the work control function where the jobs would be planned, scheduled, and assigned based on the overall workload. The requestor would have the capability to track the status of their jobs online and even give final approval that the work was satisfactorily completed.
- 13. Work Order System Accounts for 100% of Craft Hours: All craft work should be charged to a work order of some type. Accountability of labor

resources is an important part of managing maintenance as an internal business. Quick reporting to standing work orders can be established for jobs of short duration within a department or for the reporting of noncraft time such as meetings, delays in getting the equipment to work on, training, and chasing parts.

14. Backlog Reports: Maintaining good control of the work to be done is essential to the maintenance process. Having the capability to visually see the backlog helps to effectively plan and schedule craft resources.

The CMMS reporting system should provide the capability to show the backlog of work in several ways:

-

| • By Type of Work | • By Overdue Work Orders |
|-------------------|--------------------------|
| • By craft        | • By parts status        |
| • By department   | • By priority            |

- 15. Priority System: A Class A CMMS installation will have in place a priority system that allows for the most critical repairs to get done first. An effective priority system adds professionalism to the maintenance operation and directly supports effective planning and scheduling. There are two basic systems for establishing priorities:
- Straight numeric priority (1, 2, 3, 4, 5, etc.), in which each priority level is defined by a definition such as Priority 1: a true emergency repair that affects safety, health, or environmental issues.
- RIME system: This system combines the criticality index of the equipment (10 highest to 1 lowest) with the criticality of the work type (10 highest to 1 lowest) to compute the ranking index for maintenance expenditures (RIME) priority number. The RIME priority number equals the equipment criticality index multiplied by the criticality number of the work type.

#### **Budget and Cost Control**

- 16. Craft Labor, Parts, and Vendor Support Costs: The equipment history file should provide the source of all costs charged to the asset. Here, it is important to ensure that all labor is charged to the work orders for each asset and that parts are charged to the respective work orders.
- 17. Budget Status-Operating Departments: Operating departments should be held accountable for their respective maintenance budgets. With an effective work order system in place for charging of all maintenance costs, the accounting process should allow for monitoring the status of departmental budgets. One recommended practice is for maintenance to be established as a zero-based budget operation and that all labor and parts be charged back to the internal customer. This practice helps ensure accountability for all craft time, parts, and materials to work orders.

- 18. Cost Improvements Due to CMMS: The effect of a successful CMMS installation should be reduced costs and achieving gained value in terms of greater output from existing resources. The CMMS team should be held accountable for documenting the savings that are achieved from the new CMMS and the maintenance best practices that evolve. The areas that were used to justify the CMMS capital investment (e.g., reduced parts inventory, increased uptime, and increased craft productivity) should all be documented to show that improvements did occur.
- 19. Deferred Maintenance Identified: It is important that maintenance provides management with a clear picture of maintenance requirements that require funding for the annual budget. Deferred maintenance on critical assets can lead to excessive total costs and unexpected failures. Benefits from CMMS will provide improved capability to document deferred maintenance that must be given priority during the budgeting process each year.
- 20. Life-Cycle Costing Supported: A complete equipment repair history provides the basis for making better replacement decisions. Many organizations often fail to have access to accurate equipment repair costs to support effective replacement decisions and continue to operate and maintain equipment beyond its economically useful life. As a result, the capital justification process then lacks the necessary life-cycle costing information to support replacement decisions.

#### **Planning and Scheduling**

21. Planning and Scheduling: This maintenance best-practice area is essential to better customer service and operations as well as greater utilization of craft resources. For most maintenance operations with 25–30 craftspeople, a full-time planner can be justified. The CMMS system functionality must support the planning process for control of work orders, backlog reporting, status of work orders, parts status, craft labor availability, etc. The planning and scheduling function supports changing from a "run to failure strategy" to one for proactive, planned maintenance.

- 22. Planned Work Increasing: The bottom-line result for the planning process is to actually increase the level of planned work. The percentage of planned work should be monitored and included as one of the overall maintenance performance metrics. In some organizations with effective PM/PdM programs, the level of planned work can be in the 90% range or more.
- 23. Craft Utilization Measured and Improving: Effective planning and scheduling is essential to increasing the level of actual hands-on wrench time of the craft work force. Improving craft utilization allows more work to get done with current staff by eliminating noncraft activities such as waiting for equipment, searching for parts, and scheduling the right sequence for different crafts on the job.
- 24. Work Schedules Available: One key responsibility of the planning process is to establish realistic work schedules for bringing together the right type craft resources, the parts required, the equipment to be repaired or serviced, and having the time available to complete the job right the first time. The actual schedule may only start with a 1-day schedule and gradually work up to scheduling longer periods of time. Work schedules provide a very important customer service link with operations that helps to improve overall coordination between maintenance and operations.
- 25. Spare Parts Status Is Available: One of the most essential areas to support effective planning is the maintenance storeroom and the accuracy of the parts inventory management system. Jobs should not be put on the schedule without parts being on hand. The planner must have complete visibility of inventory-on-hand balances, parts on order, and the capability to reserve parts for planned work.
- 26. Scheduling Coordination with Operations: As the planning function develops, there will be improved coordination with operations to develop and agree upon work schedules. This may involve coordination meetings near the end of each week to plan week end work or to schedule major jobs for the upcoming week. Direct coordination with operations allows maintenance to review PM/PdM schedules or to review jobs where parts are available to allow the job to be scheduled based on operations scheduling equipment availability.
- 27. True Emergency Repairs Tracked: Many organizations really focus on reducing true emergency repairs, which create uncertainty for operations

scheduling and contribute to significantly higher total repair costs than planned work. Improved reporting capabilities of an effective CMMS will allow for better tracking of emergency repairs, document causes for failures, and assist in the elimination of the root causes for failures.

# **Maintenance Repair Operations Materials Management**

The overall area of maintenance repair operations (MRO) parts and materials procurement, storage, inventory management, and issues represents another best-practice area that often needs major work when implementing a CMMS and developing a Class A installation. Many organizations never take the time to set up a well-planned and controlled storeroom operation and often find out that their parts database is a weak link needing major updates before it can truly be effectively used.

- 28. Inventory Management Module: The work order module must be fully integrated with an accurate parts inventory management module to charge parts back to work orders, to check parts availability status for planned work, to reserve parts, and to check the status of direct purchases. A Class A CMMS installation will develop, maintain, and fully utilize the inventory module and ensure that it is fully integrated with the work order module.
- 29. Inventory Cycle Counting Established: Inventory accuracy should be one of the key metrics for MRO materials management, and it can best be accomplished by cycle counting rather than annual physical inventories. Most CMMS systems will allow for your own criteria to be developed, such as doing an ABC analysis of inventory items (based on either usage value or frequency of issue) and then scheduling of periodic counts for each classification of inventory item that you want to cycle count. For example, A items would be counted more frequently than B and C items. The real value of cycle counting is that it is a continuous process that creates a high level of discipline and allows for

inventory problems and adjustment to be made throughout the year rather than once after the annual inventory.

- 30. Parts Kiting: This best-practice area is key to the planning process and can evolve over time as the planning process matures to the point of being able to give the storeroom prior notification on the parts required for planned jobs. Controlled staging areas are set for parts that are either pulled from stock or received from direct purchases.
- 31. Electronic Parts Requisitioning: This functional capability can provide paperless work flow for requisitioning of parts directly from maintenance to the storeroom for creation of a pick list for the item or go to purchasing to create a purchase order for a stock item or direct purchase. In some cases, electronic requisitioning might go directly to the vendor using e-commerce capability.
- 32. Critical Spares Identified: Critical spares (or insurance items), which may be a one-of-a-kind, high-cost spare, are often a part of the parts inventory system. It is recommended that these items be classified and identified in the item master record as such. This practice will help to separate these items from the regular inventory management process and identify them as a separate part of the total inventory value that has been fixed. Critical spares should also be identified in the spares list for the equipment they have been purchased for.
- 33. Reorder Notification Process: The capability to determine when and what to reorder on the basis of a review of stock-level reorder points is an important feature for a Class A installation. A recommended reorder report should be generated periodically and reviewed for validity as well as for any future needs that may not be reflected in current on-hand balances. On the basis of a final review of the recommended reorder report, electronic requisitioning then could occur directly to purchasing.
- 34. Warranty Information: Many organizations fail to have a process in place to track warranty information and, in turn, they incur added costs by not being able to get proper credit for items under warranty. Tracking specific high-value parts or components and specific equipment under warranty should be a CMMS functionality of the equipment master or the inventory item master database. The system should provide a quick reference and alert to the fact that the item is still under warranty and that a follow-up claim to the vendor is needed.

#### **Preventive/Predictive Maintenance**

- 35. PM/PdM Change Process: This best-practice area simply ensures that PM/PdM procedures are subject to a continuous review process and that all changes to the program are made in a timely manner. The CMMS system should provide an easy method to update task descriptions and task frequencies and allow for mass updating when the procedure applies to more than one piece of equipment.
- 36. PM/PdM Compliance Is Measured: One key measure of overall maintenance performance should be how well the PM/PdM program is being executed based on the schedule. Measuring PM/PdM compliance ensures accountability from maintenance and from operations. Normally, a scheduling window of 1 week will be established to determine compliance. A goal of 98% or better for PM/PdM compliance should be expected.
- 37. Long-Range PM/PdM Scheduling: As a PM/PdM schedule is loaded to the system, peaks and valleys may occur for the actual scheduling because of frequencies of tasks coming due at the same time period. The CMMS system should provide the capability to level load the actual PM/PdM schedule and to view upcoming PM/PdM workloads to assist in the overall planning process.
- 38. Lubrication Services: Lubrication services, tasks, frequencies, and specifications should ideally be included as part of the PM/PdM module. A continuous change process for this area should also be put in place as well as an audit process established to ensure all lube and PM/PdM tasks are being performed as scheduled.
- 39. CMMS Captures Reliability Data: The elimination of root causes of problems is the goal rather than just more PM/PDM. One important feature of a "Class A" installation is being able to capture failure information that can in turn be used for reliability improvement. This requires that a good coding system for defining causes for failures be developed and that this information be accurately entered as the work order is closed.

40. Complete PM/PDM Task Descriptions: PM/PdM task descriptions often provide vague terminology to check, adjust, inspect, etc. and do not provide clear direction for specifically what is to be done. Task descriptions should be reviewed periodically and details added that to the level that a new crafts person would understand exactly what is to be done and be able to adequately perform the stated task.

#### **Maintenance Performance Measurement**

- 41. Equipment Downtime Reduction: Another key metric for measuring overall maintenance performance is increased equipment uptime. The improvement in this metric is a combination of many of the previously mentioned best practices all coming together for improved reliability. Downtime due to maintenance should be tracked and positive improvement trends should be occurring within a Class A installation.
- 42. Craft Performance: Two key areas affecting overall craft productivity are craft utilization (wrench time) and craft performance. Measurement of craft performance requires that realistic planning times be established for repair work and PM tasks. A standard job plan database can be developed for defining job scope, sequence of tasks, special tools listing, and estimated times. The goal is measurement of the overall craft work force and not individual performance. Planning times are also an essential part of the planning process for developing a more accurate picture of work load and to support scheduling of overtime and staff additions.
- 43. Maintenance Customer Service: The results of improved maintenance planning must be improved customer service. The overall measurement process should include metrics such as compliance to meeting established schedules and jobs actually completed on schedule.
- 44. Maintenance Performance Measurement Process: In this area, it is important to have a performance measurement process that includes several key metrics in each of the following major categories:

| Budget and cost    | Planning and scheduling  |
|--------------------|--------------------------|
| Craft productivity | Customer service         |
| • Equipment uptime | MRO materials management |
| • PM/PdM           |                          |

The overall maintenance performance process should be established so that it clearly validates the benefits being received from the CMMS and maintenance best-practice implementation.

#### Other Uses of CMMS

- 45. Maintenance Managed as a Business: One true indicator for a successful CMMS installation is that it has changed the way that maintenance views it role in the organization. It should progress to the point that maintenance is viewed and managed as an internal business. This view requires greater accountability for labor and parts costs, greater concern for customer service, better planning, greater attention to reliability improvement, and increased concern for the maintenance contribution to the bottom line.
- 46. Operations Understands Benefits of CMMS: There is direct evidence that operations understands that an improved CMMS is a contributor to improve customer service. The scheduling process is continuously improving through better coordination and cooperation between maintenance and operations within a Class A installation.
- 47. Engineering Changes: Accurate engineering drawings are essential to maintenance planning and to actually making the repairs. Asset documentation must be kept up to date on the basis of a formal engineering change process. Feedback to engineering must be made on all changes as they occur on the shop floor. Engineering must in turn ensure that master drawings are updated and that current revisions made available to maintenance.
- 48. Equipment Database Structure: To provide equipment history information in a logical parent/child relationship, the equipment database structure has been developed using an identification of systems and subsystems. Accessing the equipment database should allow for drilldown from a parent level to lower-level

child locations that are significant enough for equipment master information to be maintained.

- 49. Failure and Repair Codes: The reporting capability of the CMMS should provide good failure trending and support analysis of the failure information that is entered from completed work orders. Improving reliability requires good information that helps to pinpoint root causes of failure.
- 50. Maintenance Standard Task Database: Developing the maintenance standard task database (or standard repair procedures) for recurring jobs is an important part of a planner's job function. This allows for determining the scope of work and special tools and equipment and for estimating repair times. Once a standard repair procedure is established, it can then be used as a template for other similar jobs, resulting in less time for developing additional repair procedures.

#### **Summary**

Developing a Class A CMMS installation requires the combination good system functionality and improved maintenance practices. The CMMS team should begin very early during implementation with how it will measure the success of the installation. The recommendations provided here for using the CMMS Benchmarking System can help your organization achieve maximum return on its CMMS investment.

The Maintenance Excellence Institute International is fully committed to ensuring that all clients now using CMMS gain maximum value from their software investment. Maintenance organizations take an important step when they invest in software to help manage the business of maintenance. They often do not achieve maximum return on investment from CMMS software investments. One of the services from The Maintenance Excellence Institute International is to provide Scoreboard for Maintenance Excellence Assessments that includes an independent benchmark evaluation of the current CMMS installation.

#### **Purpose**

The CMMS Benchmarking System was developed to support getting maximum value from an investment in CMMS by evaluating how well existing CMMS functionality is being used. The benchmarking system provides a methodology for developing an overall benchmark rating of your CMMS installation as the baseline for determining how well CMMS is supporting best practices within the total maintenance operation. It can also be used as the baseline to measure the success of a future CMMS that is just being installed.

#### **Benchmarking Your CMMS Installation**

The CMMS Benchmarking System provides a means to evaluate and classify your current installation as either Class A, B, C, or D. A total of nine major categories are included along with 50 specific evaluation items. Each evaluation item that is rated as being accomplished satisfactorily receives a maximum score of 4 points. If an area is currently being "worked on," a score of 1, 2, or 3 points can be assigned based on the level of progress achieved. For example, if spare parts inventory accuracy is at 92% compared with the target of 95%, a score of 3 points is given. A maximum of 200 points is possible. A benchmark rating of Class A is within the 180- to 200-point range. The complete CMMS Benchmarking Rating Scale is given at the completion of the benchmarking form.

#### **Conducting the CMMS Benchmark Evaluation**

The Maintenance Excellence Institute International conducts the CMMS benchmark evaluation to provide an independent and objective evaluation. It is not to make functionality comparisons between different CMMS systems. However, it will identify gaps in functionally, best-practice needs, and support decisions on upgrades. Results from the benchmark evaluation will establish a baseline classification for your current installation. A written report with specific recommendations and a plan of action to improve your CMMS installation to the Class A level will be provided along with guidelines for using the CMMS Benchmarking System in the future as an internal benchmarking tool.

| Category number | Category description   |
|-----------------|--|
|                 | CMMS data integrity  |
| 1               | Equipment (asset) history data complete and accuracy 95% or better                   |
| 2               | Spare parts inventory master record accuracy 98% or better                           |
| 3               | Bill of materials for critical equipment includes critical spare parts denoted in tl |
| 4               | Preventive maintenance (PM) tasks/frequencies data complete for 98% of appli         |
| 5               | Direct responsibilities for maintaining parts inventory is assigned                  |
| 6               | Direct responsibilities for maintaining equipment/asset database is assigned         |
|                 | CMMS education and training  |
| 7               | Initial CMMS training for all maintenance employees                                  |
| 8               | An ongoing CMMS training program for maintenance and storeroom employee              |
| 9               | Initial CMMS orientation training for operations employees                           |

| 10 | A CMMS systems administrator (and backup) designated and trained               |
|----|--|
|    | Work control   |
| 11 | A work control function is established or a well-defined documented process is |
| 12 | Online work request (or manual system) used to request work based on prioritie |
| 13 | Work order system used to account for 100% of all craft hours available        |
|    | 1  |

Table Continued

| Category number | Category description   |
|-----------------|--|
| 14              | Backlog reports are prepared by type of work to include estimated hours require      |
| 15              | Well-defined priority system is established based on criticality of equipment, sa    |
|                 | Budget and cost control  |
| 16              | Craft labor, parts, and vendor support costs are charged to work order and according |
| 17              | Budget status on maintenance expenditures by operating departments is availab        |
| 18              | Cost improvements due to CMMS and best-practice implementation have been             |
| 19              | Deferred maintenance and repairs identified to management during budgeting p         |
| 20              | Life-cycle costing is supported by monitoring of repair costs to replacement val     |
|                 | Planning and scheduling  |
| 21              | A documented process for planning and scheduling has been established                |
| 22              | The level of proactive, planned work is monitored and documented improveme           |
| 23              | Craft utilization (true wrench time) is measured and documented improvements         |
| 24              | Daily or weekly work schedules are available for planned work                        |
| 25              | Status of parts on order is available for support to maintenance planning proces     |
| 26              | Scheduling coordination between maintenance and operations has increased             |

| 27              | Emergency repairs, hours, and costs tracked and analyzed for reduction   |
|-----------------|--|
|                 | MRO materials management   |
| 28              | Inventory management module fully utilized and integrated with work order module fully utilized and integrated with the fully utilized and integr |
| Table Continued |  |

| Category number | Category description  |
|-----------------|---|
| 29              | Inventory cycle counting based on defined criteria is used and inventory accura   |
| 30              | Parts kiting is available and used for planned jobs                               |
| 31              | Electronic requisitioning capability available and used                           |
| 32              | Critical and/or capital spares are designated in parts inventory master record da |
| 33              | Reorder notification for stock items is generated and used for reorder decisions  |
| 34              | Warranty information and status is available                                      |
|                 | PM/PdM  |
| 35              | PM/PdM change process is in place for continuous review/update of tasks/frequ     |
| 36              | PM/PdM compliance is measured and overall compliance is 98% or better             |
| 37              | The long-range PM/PdM schedule is available and level loaded as needed with       |
| 38              | Lube service specifications, tasks, and frequencies included in database          |
| 39              | CMMS provides MTBF, MTTR, failure trends and other reliability data               |
| 40              | PM/PdM task descriptions contain enough information for new craftsperson to       |
|                 | Maintenance performance measurement   |
| 41              | Downtime (equipment/asset availability) due to maintenance is measured and d      |

| 42              | Craft performance against estimated repair times is measured and documented |
|-----------------|---|
| 43              | Maintenance customer service levels are measured and documented improvement |
| Table Continued |   |

| Category number                   | Category description   |
|-----------------------------------|--|
| 44                                | The maintenance performance process is well established and      |
|                                   | Other uses of CMMS   |
| 45                                | Maintenance leaders use CMMS to manage maintenance as i          |
| 46                                | Operations staff understands CMMS and uses it for better ma      |
| 47                                | Engineering changes related to equipment/asset data, drawinş     |
| 48                                | Hierarchies of systems/subsystems used for equipment/asset       |
| 49                                | Failure and repair codes used to track trends for reliability im |
| 50                                | Maintenance standard task database available and used for re     |
| Total cmms benchmark rating score |  |

CMMS, computerized maintenance management system; PM/PdM, preventive and predictive maintenance; MRO, maintenance repair operations; MTTR, mean time to repair; MFBF, mean time between failure.

**Summary of CMMS Benchmarking Evaluation** 

| TOTAL CMMS BENCHMARK RATING SC | ORE:    |     |   |  |
|--------------------------------|---------|-----|---|--|
| CURRENT CMMS BENCHMARK RATING  | : CLASS |     |   |  |
| CMMS SOFTWARE VERSION:         |         |     |   |  |
| DATE OF CMMS INSTALLATION:     | 1 1     | - 0 | _ |  |
| BENCHMARK RATING PERFORMED BY: |         |     |   |  |
| LOCATION:                      | DATE:   |     |   |  |

## CMMS BENCHMARKING RATING SCALE: INDIVIDUAL ITEM GRADING:

CLASS A = 180 - 200 POINTS (90% +) YES = 4 points

CLASS B = 140 - 179 POINTS (70% - 89%) NO = 0 points

CLASS C = 100 - 139 POINTS (50% - 69%) Working On It = 1, 2 or 3 points

CLASS D = 0 - 99 POINTS (0 - 49%)

### EVALUATION COMMENTS:

## Appendix G

# The ACE Team Benchmarking Process Team Charter Example

-

| CHARTER for The ACE TEAM at |
|-----------------------------|
|-----------------------------|

Maintenance Strategy Team - Preliminary Review Date

Maintenance Strategy Team - Final Review

ACE Team Review Date

ACE Team Final Acceptance Date

I. Opportunity: What is the reason this team exists?

The ACE Team (where ACE means "a consensus of experts") exists to provide a well-qualified team of experienced craftspeople, technicians, and supervisors that establish benchmark repairs jobs and work content time for these jobs. The ACE Team is chartered to help develop the ACE System for establishing maintenance performance standards at each work site.

- II. Process: What are the steps to be followed, and what are the questions to be answered by this team?
- a. Orientation, charter review, and charter acceptance or modification.
- b. Ensure that all team members understand team objectives and agree on what needs to be achieved and the criticality of this initiative to the planning and scheduling process.
- c. Understand the current concepts of the ACE System as defined in the XYZ Company's maintenance planning and scheduling standard operating procedure (SOP).
- d. Understand the basics of the new XYZ system for computerized maintenance management system (CMMS)/ enterprise asset management (EAM), the characteristics, functionality, and performance.
- e. Determine the critical repair jobs that should be used as representative benchmark jobs, define key steps and elements for each benchmark job, and define any special tools, safety requirements, and other special requirements for the job.
- f. Determine ways to improve doing the jobs being analyzed as benchmark jobs considering better tools, equipment, skills, and even better predictive/preventative maintenance techniques to avoid this type of failure problem.
- g. Conduct the ACE Team process as outlined in the 10-step approach from the SOP.

- h. Develop a team consensus on work content times for all the benchmark jobs selected.
- i. Continuously improve the ACE Team process within the XYZ organization as an element of our CRI efforts.
- III. Evidence of success: What results are expected, in what periods, for this team to be successful?
- a. A sufficient number of benchmark jobs will be developed as to individual tasks and steps along with estimated work content times to complete the site's ACE Team spreadsheets.
- b. The actual period to complete the initial spreadsheets will depend on time allocated by the ACE Team at each site.
- c. ACE Teams from one site are expected to share their results with the other sites. Due to the similar nature of equipment, benchmark job write-ups and even work content times that ACE Teams have developed can be shared throughout the operation.
- d. Overall success will be determined by each planner having adequate spreadsheets that cover all construct areas as well as types of crafts work (mechanical, electrical, etc.) so that planning times can eventually be established for 80% or more of the available craft hours.
- IV. Resources: Who are the team members, team leader, and team facilitator? Who will support the team if needed? How much time should be spent both in meetings and outside of meetings? The ACE Team should consist of the following representatives:
- a. One maintenance planner: team leader
- b. One maintenance supervisor
- c. Two or three crafts representatives from Area 1
- d. Two or three crafts representatives from Area 2
- e. Two or three craft representative from Area 3

Note: Crafts representatives should rotate periodically and sufficient numbers designated so as to have at least two to three representatives from each craft area when benchmark jobs from these areas are being reviewed for job steps and estimated for work content time.

- a. The initial ACE Team meeting will be for 1 h. The team should meet initially for at least 3 h each week. This team's activities and success will be considered as part of each team member's job.
- V. Constraints: What authority does the team have? What items are outside the scope of the team? What budget does the team have?
- a. No changes to organization structure are anticipated.
- b. Benchmark job plans are to be reviewed and approved by the maintenance manager.
- c. Each team must obtain buy-in and overcome concerns from the other crafts on their estimates for benchmark jobs and repair methods recommended for each benchmark job.
- d. The team presents implementation status reports as required and any additional recommendations to the Maintenance Excellence Strategy Team.
- e. The ACE Team has the authority to recommend new and improved repair methods, new tools to help craft productivity and safety, and other ways to improve asset reliability as developed during the ACE Team process.
- VI. Expectations: What are the outputs, when are they expected, and to whom should they be given?
- a. Spreadsheets for the site that cover all crafts areas and construct types are completed.
- b. Reliable planning times are provided for benchmark jobs so that effective planning, performance measurement, backlog control, and level of PM work can be established with a high level of confidence.

- c. The ACE Team provides a steady source of continuous improvement ideas to make repair jobs safer and easier.
- d. Minutes are to be completed for all team meetings and sent to the maintenance manager and the Maintenance Excellence Strategy Team.



Figure G.1 The ACE team benchmark job analysis.

# The Methodology for Applying the ACE Team Benchmarking Process

This section outlines the methodology for applying the ACE Team Benchmarking process. This very easy-to-use procedure allows a planner/scheduler to be the central organizer of the ACE Team within an organization desiring to use this methodology for developing benchmark jobs, the use of slotting, plus allowances to develop reliable planning times for scheduling. A graphical representation of this process is included in Figure G.1.

#### A New Maintenance Work Measurement Tool from The Maintenance Excellence Institute International

A True Team-Based Approach: Here, we will outline a new and highly recommended methodology for establishing team-based maintenance performance standards, which we call reliable planning times. The ACE Team Benchmarking Process (ACE System) was developed by the author in the 1980s. It is a true team-based process that uses skilled craftspeople, technicians, supervisors, planners, and other knowledgeable people to do two things:

- 1. Improve current repair methods, safety, and quality.
- 2. Establish work content time for selected "benchmark jobs" for planners and

others to use in developing reliable planning times.

Benchmark Jobs: This is a proven process that uses "a consensus of experts," or ACE, who have performed these jobs and can also help to improve them. In turn, a relatively small number of representative benchmark jobs are developed for the major work areas/types within the operation. Benchmark jobs are then arranged into time categories ("time slots") on spreadsheets for the various craft work areas.

Spreadsheets: By using spreadsheets to do what is termed work content comparison or "slotting," a planner is then able to establish planning times for a large number of jobs using a relative small sample of benchmark jobs. This publication also provides the step-by-step process for using the ACE System. Most importantly, it will illustrate how this method supports CRI and quality repair procedures for all types of maintenance repair operations.

Nearly every CMMS allows a user to enter "planned" or "standard" hours on a work order, and then report on actual versus planned hours (the craft performance element of Overall Craft Effectiveness (OCE)) when the job is complete. This holds true for both preventive and corrective maintenance work orders, as well project type work for renovation, major overhauls, and capitalized repairs. Most do not use this for one main reason; they do not have reliable planning times or standard hours available.

Determining the standard hours an average maintenance technician will require to complete a task under standard operating conditions provides everyone involved with a sense of what is expected. The standards provide management with valuable input for backlog determination, manpower planning, scheduling, budgeting, and costing. Labor standards also form the baseline for determining craft productivity and labor savings for improved methods.

The ACE System Supports Continuous Reliability Improvement: Maintenance work, by its very nature, seldom follows an exact pattern for each occurrence of the same job. Therefore, exact methods and exact times for doing most maintenance jobs cannot be established as they can for production-type work. However, the need to have reliable performance measures for maintenance planning becomes increasingly important as the cost of maintenance labor rises and the complexity of production equipment increases.

To work smarter, not harder, maintenance work must be planned, have a reasonable time for completion, use effective and safe methods, be performed with the best personal tools and special equipment possible, and have the right craft skill using the right parts and materials for the job at hand.

Investment for Planners: With an investment in maintenance planners, there must be a method to establish reliable planning times for as many repair jobs as possible. The ACE System provides that method, as well as a team-based process to improve the quality of repair procedures.

Various methods for establishing maintenance performance standards have been used, including reasonable estimates, scientific wild average guess (SWAGs), historical data, and engineered standards such as universal maintenance standards (UMS) using predetermined standard data. These techniques generally require that an outside party establish the standards, which are then imposed upon the maintenance force. This approach often brings about undue concern and conflict between management and the maintenance workforce over the reliability of the standards.

The ACE System: A Team-Based Approach: Rather than progressing forward together in the spirit of continuous improvement, the maintenance workforce in this type of environment often works against the management program for maintenance improvement. The ACE System overcomes this

problem with a team-based approach involving craftpeople who will actually do the work that will be planned later as the planning and estimating process matures. As shown later, the ACE System is truly a team-based process that looks first at improving maintenance repair methods, the reliability of those repairs to improve asset uptime, and then secondly to establish a benchmark time the job.

Gaining Acceptance for Performance Standards: To overcome many of the inherent difficulties associated with developing maintenance performance standards, the ACE System is recommended and should be established as the standard process for modern maintenance management. Other methods, such as the use of standard data, can supplement the ACE System. The ACE System methodology relies primarily on the combined experience and estimating ability of a group of skilled craftspeople, planners, and others with technical knowledge of the repairs being made within the operation.

The objective of the ACE Team Benchmarking Process is to determine reliable planning times for a number of selected benchmark jobs and to gain a consensus and overall agreement on the established work content time. This system places a very high emphasis on improving current repair methods, continuous maintenance improvement, and the changing of planning times to reflect improvements in performance and methods as they occur. The ACE System is a very progressive method to develop maintenance performance standards through reliable and well-accepted planning times for maintenance.

The complete 10-step approach to implementing the ACE Team Process within your current planning, estimating, and scheduling can be found at www.Pride-in-Maintenance.com.

The Basic Approach: A Simple Procedure that Works

Generally, the ACE System parallels the concepts of the UMS approach. For both UMS and the ACE System, the range-of-time concept and slotting are used once the work content times for a representative number of benchmark jobs have been established. The ACE System focuses primarily on the development of work content times for representative benchmark jobs that are typical of the craft work performed by the group. An example of an actual UMS benchmark job that has been analyzed with standard data to establish work content time is included as Figure G.1.

For the example illustrated in Figure G.2, we see that through the use of UMS standard data, the eight elements of the job, including oiling of the parts, have been analyzed and assigned time values that total 1.07 h. Because the time value for this benchmark job falls within the time range of 0.9–1.5 h (see Figure G.3), it is assigned a standard work content time of 1.2 h.

What this implies is that the actual work content for this benchmark job will generally be performed within the time range for Work Group G (0.9–1.5 h) with confidence level of 95%. When we refer to "work content," the following applies.

The work content of the benchmark job excludes things such as travel time, securing tools and parts, prints, delays, and personal allowances, etc. The benchmark time that is estimated does not include the typical "make ready" and "put away" activities that are associated with the job. Therefore, a number of allowances must be added to work content time by a planner to get the actual planning time for the job being.

#### **Benchmark Analysis Sheet**

Decription: Remove and reinstall 3 oil wiper rings B.M. No: split type of air compressor 1950 cfm at 100 psi Craft: Mech Dwns: N/A No. of Men: 1 Sh. 1 of Analyst: JEB Date: Reference Unit Total Operation Description Freq. Symbol Time Time .060 1 Remove and reinstall 1 crankcase cover PWN-10-10 .030 .044 2 Remove and reinstall 2 bolts PWN-10-1 .011 3 Slide gland off and on PWN-10-7 .012 2 .024 4 Unfasten 3 garter springs and refasten PWN-10-8 .023 6 .138 .216 5 Remove and reinstall 9 wiper ring PWN-10-9 .012 18 segments .360 6 Fit 9 ring segments to piston rod PWN-5-2 .040 7 Clean 12 springs and rings PWN-8-1 .016 .192 8 Oil 12 parts PWN-3-9 2 squirts per pint .0023 + .0012(N2) .0023 .002 N2 = number of application .0012 .029 Notes: Benchmark time 1.07 Standard work group E

### Figure G.2 An example of a benchmark job analysis using UMS standard data.

### Important Note: The estimated time for a benchmark job is for pure work content time and is made under these conditions:

- 1. The right craft skills and level of competency are available to do the job.
- 2. An average skilled craftsperson, two-person team, or crew is giving 100% effort to the job—that is, a fair day's work for a fair day's pay.
- 3. The correct tools are available at the job site or with the craftsperson or crew.
- 4. The correct parts are available at the job site or with the craftsperson or crew.
- 5. The machine/process/asset is available and ready to be repaired.
- 6. The craftsperson or crew is at the job site with all of the above and proceeds to complete the job from start to finish without major interruption.

| Benc        | hmark J          | lob Description   | Benchmark Job No.: MECH-AC-5 |              |      |               |
|-------------|------------------|---|------------------------------|--------------|------|---------------|
|             |                  | reinstall 3 oil wiper rings, split type air<br>1950 cfm @100psi                                 | Craft: Me                    | chanical     |      |               |
|             |                  |   | Ref. Drawi                   | ng: AC-99    | 99   |               |
|             |                  |   | No. of Cra                   |              |      |               |
|             |                  |   | Analyst: J                   | EB/ACE T     | eam  |               |
| Line<br>No. | No. of<br>Crafts | Operation Description   | Ref.<br>Code                 | Unit<br>Time | Freq | Total<br>Time |
| 1           | 1                | Remove 2 bolts to remove crankcase cover  |                              |              |      | .10           |
| 2           |                  | Slide gland off and unfasten 3 garter springs   |                              |              |      | .10           |
| 3           |                  | Remove 9 wiper ring segments  |                              |              |      | .10           |
| 4           |                  | Clean 12 springs and rings and properly oil all 12 parts per Lube Spec #AC-2000                 | CLN-1                        |              |      | .25           |
| 5           |                  | Reinstall 9 wiper ring segments and fit to piston rod   |                              |              |      | .50           |
| 6           |                  | Slide glide on and fasten 3 garter springs  |                              |              |      | .10           |
| 7           |                  | Replace, crankcase cover and fasten with 2 bolts  |                              |              |      | .10           |
|             |                  | = Average benchmark time established to clean and all parts per lube specification noted above. | Benchma<br>Work Con          |              | for  | 1.25          |
|             |                  |   | Standard                     | Work Gr      | oup  | Е             |

#### Figure G.3 Example of an ACE team benchmark analysis.

Once a sufficient number of benchmark job times have been established for craft areas and work types, these jobs are categorized onto spreadsheets. They are established on spreadsheets by craft and task area and according to the standard work groups (Figure G.4), which represent various ranges of time. This is exactly the concept behind the UMS approach. Figure G.5 provides an example of a spreadsheet for work groups E, F, G, and H with jobs that have benchmark times of 1.2, 2.0, 3.0, and 4.0 h respectively.

A complete set of ACE Team Spreadsheets for Work Group A (0.1 h) up to Work Group T (30.0 h) is available in the forms section of this appendix.

#### **ACE System Work Groupings and Time Ranges**

Figure G.6 includes a listing of the ACE System work groupings, with the respective time ranges for each work group from A to T. Likewise, spreadsheets for Work Groups A, B, C, and D could be developed with benchmark jobs having work content time below 1.2 h. Spreadsheets for Work Groups I, J, K, and L for benchmark jobs having work content time from 5.0 to 9.0 h, respectively, could also be developed as they were needed. Figure G.7 shows the ACE System standard work groupings and time ranges for Work Group U for 32 h to Work Group CC for 68 h.

| CDACT.  | CORE   |
|---------|--------|
| CRAFT:  | 13.800 |
| ******* |        |

Task Area: Task areas would be mechanical, electrical, hydraulic, etc or by major areas such as fork lift, conveyor systems or building systems types of repairs.

|     | Group E<br>1.2 Hour | Group F<br>2.0 Hours | Group G<br>3.0 Hours | Group H<br>4.0 Hours |
|-----|---------------------|----------------------|----------------------|----------------------|
| >,9 | <1.5                | >1.5 <2.5            | >2.5<3.5             | >3.54.5              |
|     | Job Description A   | Job Description E    | Job Description I    | Job Description M    |
|     | Job Description B   | Job Description F    | Job Description J    | Job Description N    |
|     | Job Description C   | Job Description G    | Job Description K    | Job Description O    |
|     | Job Description D   | Job Description H    | Job Description L    | Job Description P    |
| NOT | B                   |                      |                      |                      |

Figure G.4 Example spreadsheets for work groups E, F, G, and H.

### **EYE BALLING SPREAD SHEET**

Code: 1313.133

Craft: Eyeballing Small Areas

TASK AREA: ESTIMATING SMALL AREAS

| TASK AREA: ESTIMATING SM      | ALL AKEAS                      |                                |                                |
|-------------------------------|--------------------------------|--------------------------------|--------------------------------|
| GROUP A                       | GROUP B                        | GROUP C                        | GROUP D                        |
| (0 sq ft) 10 sq ft (15 sq ft) | (15 sq ft) 20 sq ft (25 sq ft) | (25 sq ft) 40 sq ft (50 sq ft) | (50 sq ft) 70 sq ft (90 sq ft) |
| A1                            | B1 B2                          |                                |                                |

Figure G.5 Example spreadsheets for comparing areas of work groups A, B, C, and D.

### The ACE System Time Ranges

|               | ACE S | YSTEM TIME R                    | ANGES |
|---------------|-------|---------------------------------|-------|
| WORK<br>GROUP | FROM  | STANDARD<br>TIME<br>(Slot time) | то    |
| Α             | 0.0   | .1                              | .15   |
| В             | .15   | .2                              | .25   |
| С             | .25   | .4                              | .5    |
| D             | .5    | .7                              | .9    |
| E             | .9    | 1.2                             | 1.5   |
| F             | 1.5   | 2.0                             | 2.5   |
| G             | 2.5   | 3.0                             | 3.5   |
| Н             | 3.5   | 4.0                             | 4.5   |
| 1             | 4.5   | 5.0                             | 5.5   |
| J             | 5.5   | 6.0                             | 6.5   |
| K             | 6.5   | 7.3                             | 8.0   |
| L             | 8.0   | 9.0                             | 10.0  |
| M             | 10.0  | 11.0                            | 12.0  |
| N             | 12.0  | 13.0                            | 14.0  |
| 0             | 14.0  | 15.0                            | 16.0  |
| P             | 16.0  | 17.0                            | 18.0  |
| Q             | 18.0  | 19.0                            | 20.0  |
| R             | 20.0  | 22.0                            | 24.0  |
| S             | 24.0  | 26.0                            | 28.0  |
| T             | 28.0  | 30.0                            | 32.0  |

Figure G.6 ACE system standard work groupings and time ranges: A to T.

# ACE TEAM BENCHMARKING SYSTEM: WORK GROUPS &TIME RANGES Up to 69 Hours

| WORK<br>GROUPS | RANGES<br>FROM<br>(Hrs) | BENCHMARK TIME<br>(Slot Time) | UP TO<br>(Hrs) |
|----------------|-------------------------|-------------------------------|----------------|
| U              | 32.0                    | 34.0                          | 36.0           |
| ٧              | 36.0                    | 38.0                          | 40.0           |
| W              | 40.0+                   | 42.0                          | 44.0           |
| Х              | 44.0                    | 46.0                          | 48.0           |
| γ              | 48.0                    | 50.0                          | 52.0           |
| Z              | 52.0                    | 54.0                          | 56.0           |
| AA             | 56.0                    | 58.0                          | 60.0           |
| BB             | 60.0                    | 62.0                          | 64.0           |
| CC             | 64.0+                   | 66.0                          | 68.0           |

Figure G.7 ACE system standard work groupings and time ranges: 32 to 68 h.

# **Spreadsheets Provide Means for Work Content Comparison**

After sufficient spreadsheets have been prepared based on the representative benchmark jobs from various craft/task areas, a planner/analyst now has the means to establish planning times for many different maintenance jobs using a relatively small number of benchmark jobs as a guide for work content comparison. By using work content comparison (or slotting, as it is called) combined with a good background in craft work and knowledge of the benchmark jobs, a planner now has the tools to establish reliable performance standards consistently, quickly, and with confidence for a large variety of different jobs.

Because the actual times assigned to the benchmark jobs are so critical, it is very important to use a technique that is readily acceptable. The ACE System provides such a technique because it is based on the combined experience of a team of skilled craftspeople and others. It is their consensus agreement on the range of time for the benchmark jobs—a consensus of experts who know the mission-essential maintenance work that is to be done.

The Procedure for Using the ACE System

#### Select "Benchmark Jobs."

Review past historical data from work orders and select representative jobs that are normally performed by the craft groups. Special attention should be paid to determine the 20% of total jobs (or types of work) that represent 80% of the available craft manpower. Focus on determining repetitive jobs where possible in all craft areas.

# Select, Train, and Establish the Team of Experts (ACE Team)

It is important to select craftspeople, supervisors, and planners who as a group have had experience in the wide range of jobs selected as benchmark jobs. All craft areas should be represented in the group. In order to ensure that this group understands the overall objectives of the maintenance planning effort, special training sessions should be conducted to cover the procedures to be used, reasons for establishing performance measures, etc. A total of 6–10 knowledgeable team members is the recommended size for the team.

#### **Develop the ACE Team Charter**

At this point, it is highly recommended that a formal ACE Team charter be established as outlined in first part of this appendix. The ACE Team has an important task that will take time to accomplish. However, the task of the ACE Team will be important, and in turn their success as a team can contribute significantly to CRI and increased asset uptime.

#### Develop Major Elemental Breakdown for Benchmark Jobs

- 1. For each benchmark job that is selected, a brief element analysis should be made to determine the major elements or steps for completing the total job. Another example is shown in Figure G.3. Here, the elements of the same job that we illustrated in Figure G.2 are used, but they are arranged in a more logical sequence of the actual repair method. In this example, a standard time allowance for cleaning and oiling a small group of parts had already been established, so reference to CLN-1 task was made. This task referenced back to a standardized lube specification (#AC-2000).
- 2. This listing of the major steps of the job should provide a clear, concise description of the work content for the job under normal conditions. It is important that the work content for a benchmark job be described and viewed in terms of what is a normal repair and not what may occur as a rare exception. All exceptions, along with make-ready and put-away time, are accounted for by the planner when the actual planned time is completed.
- 3. An excellent resource to consider for doing the basic element analysis for each benchmark job is the craftspeople (ACEs) who are selected for doing the estimating or even other craftspeople within the operation. Brief training on methods/operations analysis can be included in the initial training for the ACEs. Very significant methods improvements and methods to improve reliability can be discovered and implemented as a result of this important step.
- 4. The ACE Team process must include and also lead to getting answers to the following questions:
- a. "Are we using the best method, equipment, or tools for the job?"
- b. "Are we using the safest method for doing this job?"
- c. "Are we using the best quality repair parts and materials or is this a part of our

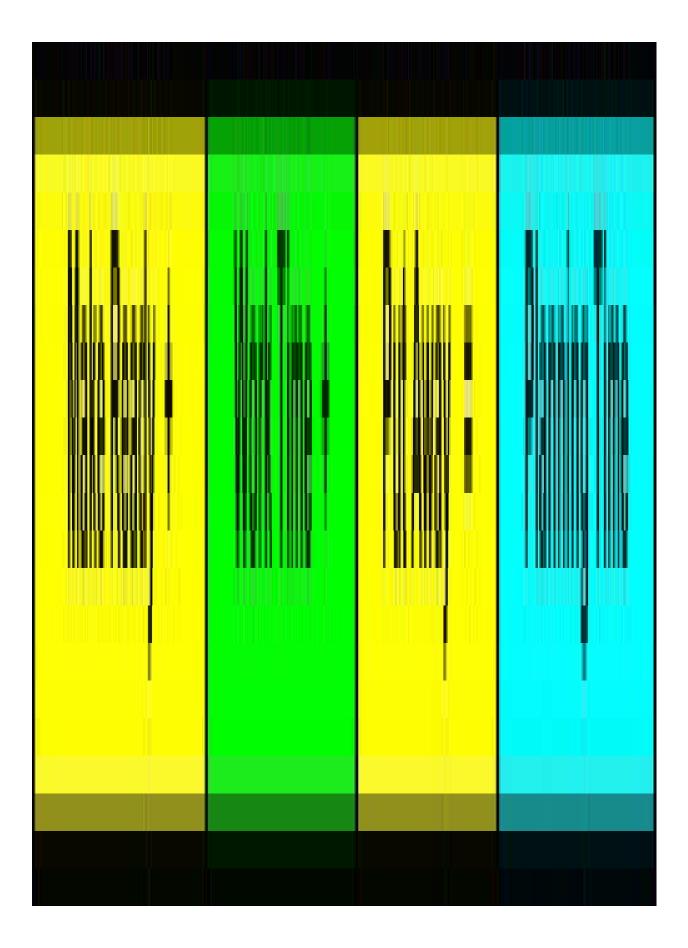
#### problem?"

- d. "What type of preventive task and/or predictive task would help identify or eliminate the root cause of the problem?"
- e. "Where can we work even smarter, not necessarily harder?"
- 5. Major exceptions to a routine job should be noted if they are significant. Generally, an exception will be analyzed as a separate benchmark job, along with an estimate of time required for such repair.
- 6. This portion of the ACE Team process ensures that the work content of each benchmark job is clearly defined so that each person/planner doing the estimating has the same understanding about the nature and scope of the job. When the benchmark jobs are finally categorized into spreadsheets, the benchmark job description information developed in this step is then used as key information about the benchmark job on the ACE Team spreadsheets.

### **Conduct First Independent Evaluation of Benchmark Jobs**

- 1. Each member of the group is now asked to review the work content of the benchmark jobs and to assign each job to one of the UMS time ranges or slots. Each member of the group provides an independent estimate, which represents an unbiased personal estimate of the "pure work content" time for the benchmark job. It is essential that each team member do an independent evaluation of each benchmark job and not be influenced by others on the team with their first evaluation.
- 2. Focus on Work Content Time: It is important here for each member of the team to remember that only the work content of the benchmark job description is to be estimated and not the make-ready and put-away activities associated with the job. This part of the procedure is concerned only with estimating the pure work content, excluding things such as travel time, securing tools and parts, prints, delays, and personal allowances, etc.

- 3. The estimate should be made for each job under these conditions:
- a. An average skilled craftsman is doing the job giving 100% effort (i.e., a fair day's work for a fair day's pay).
- b. The correct tools are available at the job site or with the craftsperson.
- c. The correct parts are available at the job site or with the craftsperson.



#### Figure G.8 Planning time elements.

- d. The machine is available and ready to be repaired.
- e. The craftsperson is at the job site with all of the above and proceeds to complete the job from start to finish without major interruption.
- 4. The work accomplished under these conditions therefore represents the "pure work content" of the job to be performed. Establishing the range-of time estimate for this pure work content is the prime objective of the first evaluation.
- 5. It is important for each ACE Team member to remember that to develop planning time requires pure work content time plus additional time allowances to cover make-ready and put-away activities associated with each job, as illustrated in Figure G.4. The make-ready time and put-away time will be accounted for as the planner adds time and allowances for these elements as the actual planning time is completed. Make-ready and put-away times are established specifically for each operation and added to the work content time to get the total planned time for the job being estimated (Figure G.8).

#### **Summarize First Independent Evaluation**

- 1. Results of the first evaluation are then summarized to check the agreement among the group as to the time range for each benchmark job. A coefficient of concordance can be computed from the results if required but normally this level of detail is not needed. A coefficient of concordance value of 0.0 denotes no agreement, while a value of 1.0 denotes complete agreement or consensus among the ACEs. Generally, a consensus can be reached by the ACE Team in one, two, or at the most three rounds of evaluations.
- 2. Define High and/or Low Estimates: Team members who are significantly higher or lower than the rest of the group for a particular benchmark job are then

asked to explain their reasons for their respective high or low estimates. They explain their reason for their estimate to the group, discussing the method, condition, or situation for their initial time estimate. This information will then be used during the second evaluation to refine the next round of time estimates from the entire group.

## **Conduct Second Independent Evaluation of Benchmark Jobs**

- 1. A second evaluation is conducted using the overall results from the first evaluation as a guide for the entire team. Various reasons for high or low estimates from the first evaluation are provided to the group prior to the second evaluation. Normally, this can be done in an open team discussion, with team members making personal notes to use in their second independent evaluation.
- 2. The second round allows for adjustment to the first estimates if the other ACE Team member's reason for a higher or lower estimated time is considered to be valid. In other words, results from the first evaluation plus reasons for highs and lows will allow each team member to reconsider their first estimate. In many cases, a review of the repair method or scope of work will be more clearly defined, causing a change to the time estimate for the second evaluation.

#### **Summarize Second Evaluation**

- 1. Results of the second evaluation are then summarized to evaluate changes or improvements in the level of agreement. The goal is a consensus among the ACEs as to the time range (Work Group) for each benchmark job. The second round should bring an agreement as to the time range.
- 2. The second independent evaluation should produce improved agreement

among the group. If an extreme variance in time range estimates still exists, further information regarding the work content, scope, and repair method for the job may be needed. Here, those with high/low estimates should again review their reasons for their estimates with the team, describing the scope of work that they see is causing differences from the rest of the team.

#### **Conduct a Third Independent Evaluation if Required**

This evaluation is required only if there remains a wide variance in the estimates among the group.

#### **Conduct a Review Session to Establish Final Results**

This session serves to finalize the results achieved and to discuss any of the high or low estimates that have not been resolved completely. A final team consensus on all time ranges is the objective of this session.

#### **Develop Spreadsheets**

1. The benchmark jobs with good work content descriptions and agreed-upon time ranges can now be categorized onto spreadsheets. From these spreadsheets, which give work content examples for a wide range of typical maintenance jobs, a multitude of individual maintenance performance standards can be established by the planner through the use of work content comparison.

2. The basic foundation for the maintenance planning system is now available for generating consistent planning times that will be readily acceptable by the maintenance workforce that developed them. Figure G.9 provides a graphical illustration of the ACE System.

The ACE Team approach combines the Delphi technique for estimating along with a proven team process plus the inherent and inevitable ability of most people to establish a high level of performance measures for themselves. As used in this application, the objective for the ACE Team process is to obtain the most reliable, reasonable estimate of maintenance-related "work content" time from a group of experienced craftspeople, supervisors and planners. This process provides an excellent means to evaluate repair method, safety practices, and even to do risk analysis on jobs that leads to improved safety practices. The ACE Team process can contribute significantly to continuous reliability.

The ACE Team approach allows for independent estimates by each member of the group, which in turn builds into a consensus of expert opinion for a final estimate. The final results are therefore more readily acceptable because they were developed by skilled and well-respected craftspeople from within the work unit. Application of the ACE System promotes a commitment to quality repair procedures and provides the foundation for developing reliable planning times for a wide range of maintenance activities (Figure G.9).

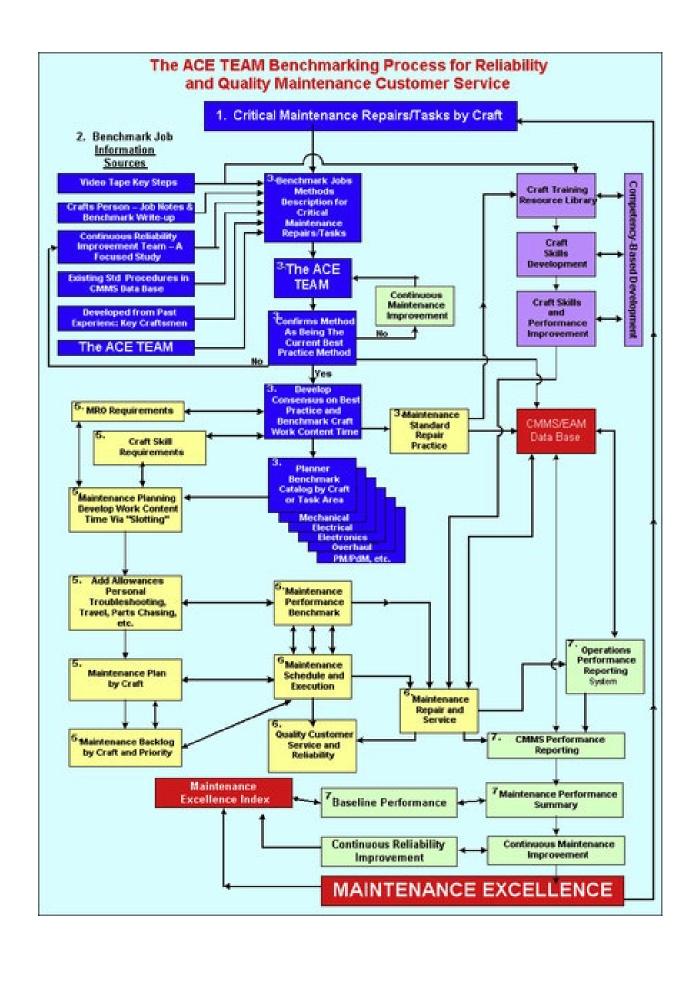


Figure G.9 The complete ACE team process.

#### **FORMS SECTION**

|             |                  | ACE TEAM Benchmark Job Ana | alysis                  |           |               |
|-------------|------------------|----------------------------|-------------------------|-----------|---------------|
|             |                  | Benchmark Job Description  |                         |           |               |
|             |                  |                            | Benchm                  | ark Job N | lo:           |
|             |                  |                            | Craft                   |           |               |
|             |                  |                            | Ref. Dra                | wing:     |               |
|             |                  |                            | No. of C                | rafts:    |               |
| J.          |                  |                            | Analyst:                |           |               |
| -           |                  |                            | Date:                   |           |               |
| Line<br>No. | No. of<br>Crafts | Operation Description      | Unit<br>Time            | Freq      | Total<br>Time |
|             |                  |                            |                         |           |               |
|             |                  |                            |                         |           |               |
|             |                  |                            |                         |           |               |
|             |                  |                            | _                       | -         |               |
| _           |                  |                            | _                       |           |               |
|             |                  |                            |                         |           |               |
|             |                  |                            |                         |           |               |
|             |                  |                            |                         |           |               |
|             |                  |                            |                         |           |               |
| ·           |                  |                            |                         |           |               |
| _           |                  |                            | -                       |           |               |
| Note        | s:               |                            | Bench<br>Time<br>Work 0 |           |               |
|             |                  |                            | Stand<br>Work 0         |           |               |

| ACE Team Spreadsheet for Work Groups A, B, C and D  CRAFT: CODE:  Task Area: |                         |                               |                     |                     |                 |  |
|--|-------------------------|-------------------------------|---------------------|---------------------|-----------------|--|
| Group A: .1 Hours<br>(0.0+) (.1  | Group B: ,<br>5) (.15+) | 2 Hours Group<br>(.25) (.25+) | C: .4 Hours<br>(.5) | Group D: .<br>(.5+) | 7 Hours<br>(.9) |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |
|  |                         |                               |                     |                     |                 |  |

| 2.0 Hours Group G: 3.0 Hours Group (2.5) (2.5+) (3.5) (3.5+) | Group F: 2.0 Hours Group G: 3.0 Hours Group |                                     |
|--|---|-------------------------------------|
|  |   |                                     |
|  | Group F: 2.0 Hours Group G:                 | 2 Hours Group F: 2.0 Hours Group G: |
|  | Group F: 2.0 Hours                          | 2 Hours Group F: 2.0 Hours          |
| F:   | Group                                       | 2 Hours Group                       |

| (0.0) | (5.5+) (6.5) (6.5+) (8.0) | (5.5) (5.5+) (6.5) (6.5+) (8.0) |
|-------|---------------------------|---------------------------------|
|       |                           |                                 |
|       |                           |                                 |

| ACE Team Spreadsheet for Work Groups M, N, O and P  CRAFT: CODE:  Task Area: |   |  |  |  |  |                                       |
|--|---|--|--|--|--|---------------------------------------|
|  |   |  |  |  |  | Group M: 11.0 Hours<br>(10.0+) (12.0) |
|  | 8 |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |
|  |   |  |  |  |  |                                       |

| CRAFT:                   | ACE 1           | eam Sprea             | dsheet fo           | r Work Gr           | oups Q, R,           | S and T             |                                       |  |  |  |  |
|--------------------------|-----------------|-----------------------|---------------------|---------------------|----------------------|---------------------|---------------------------------------|--|--|--|--|
| Task Area:               |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
| Group Q: 19.0<br>(18.0+) | Hours<br>(20.0) | Group R: 2<br>(20.0+) | 2.0 Hours<br>(24.0) | Group S:<br>(24.0+) | 26.0 Hours<br>(28.0) | Group T:<br>(28.0+) | Group T: 30.0 Hours<br>(28.0+) (32.0) |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |
|                          |                 |                       |                     |                     |                      |                     |                                       |  |  |  |  |

# Appendix H

# Shop Load Plan, Master Schedule and Shop Schedules: Example Forms and Steps on How to Use

\_

# **Shop Load Plan**

Sample Form: Shop Load Plan. Figure H.1 is a sample shop load plan form. The computerized maintenance management system (CMMS) used by the center should support computer-aided scheduling, including interactive manpower and other resource scheduling and schedule balancing. The shop load plan should be automated as a standard report in the CMMS. A single database should support all three levels of scheduling (i.e., shop load plan, master schedule, and shop schedule) in a networked system. Although it is possible to examine the shop load plan on a video display terminal, the practical limitations on the number of lines and columns that can be displayed at one time makes a printout on wide paper convenient for use by managers.

Data Elements. The following data elements are shown on the shop load plan. The information either is contained in the CMMS database or is derived from the CMMS database. The information is defined below as an aid to understanding the schedule format. The only item that should require entry in the scheduling process is for the scheduling period. The rest of the information is based on other data entered in the CMMS during the work reception and planning process or is extracted from other databases, such as labor accounting.

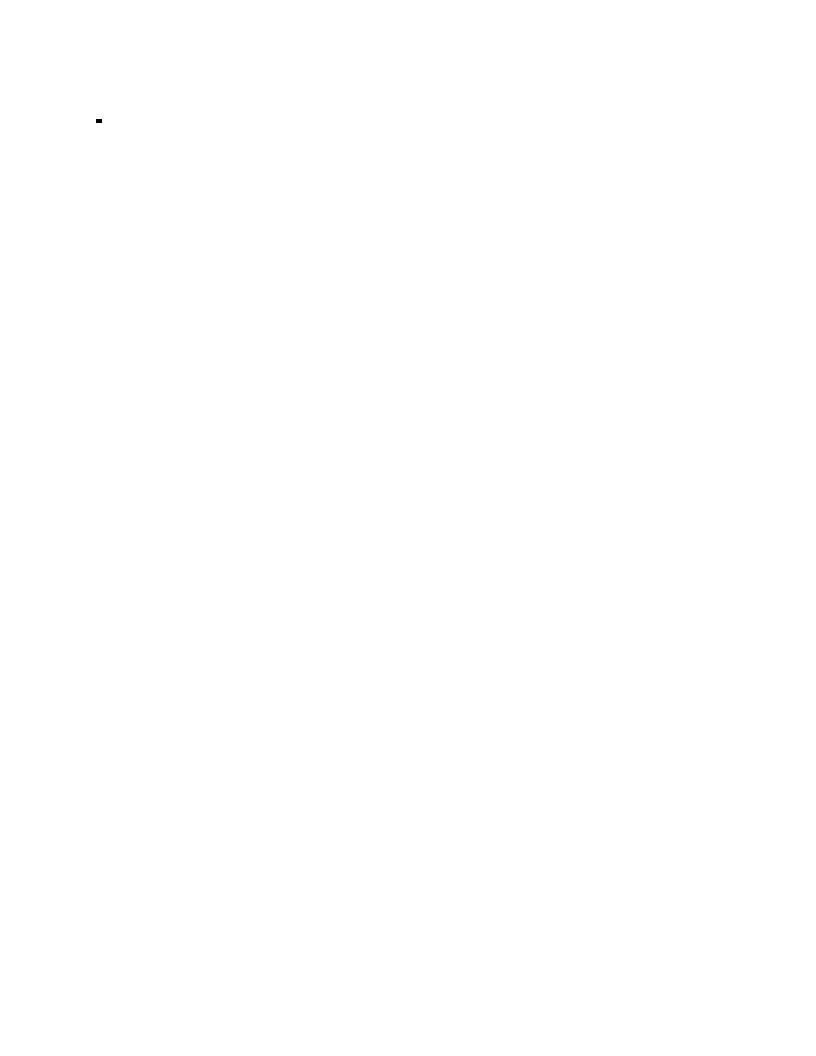
\_

| 1 | Period covered             | The time period this schedule considers. Norm |
|---|----------------------------|---|
| 2 | Shop                       | The shop or craft group being scheduled, such |
| 3 | Number of employees        | The average number of employees available in  |
| 4 | Gross work hours available | The total number of work hours available in e |
| 5 | Adjustments                | The number of work hours that will not be ava |

Table Continued

| 6  | Net work hours available                           | The net work hours available in each   |
|----|--|--|
| 7  | Trouble call (TC) ticket level of effort (LOE)     | The number of hours allocated by sh    |
| 8  | Preventive maintenance (PM) scheduled              | The number of hours for scheduled l    |
| 9  | Predictive testing and inspection (PT&I) scheduled | The number of hours for scheduled I    |
| 10 | Scheduled, Recurring                               | The number of hours by shop for oth    |
| 11 | Total LOE scheduled                                | Total hours committed to items 7, 8,   |
| 12 | Carryover from prior period:                       | Work scheduled or started in the price |
| 13 | Available to schedule                              | Net work hours available (item 6) les  |
| 14 | Work order number (WO#)                            | Work order number for each work or     |
| 15 | Description  | An entry giving a short title for each |
| 16 | Requested start date (RSD)                         | Requested start date for the work orc  |
| 17 | Required completion date (RCD)                     | Required completion date for the wo    |
| 18 | Priority (PRI)                                     | Priority of the work order.            |
| 19 | Material status indicator (MAT)                    | Normally, this block contains the dat  |
| 20 | Work hours   | The estimated work hours for the wo    |
| 21 | Total  | The total labor hours for the work or  |

| 22 | Labor | Estimated total labor cost for the wo |
|----|-------|---------------------------------------|
| 23 | Mtl   | Estimated total material cost for the |
| 24 | Other | Estimated total other cost for the wo |
| 25 | Total | The total cost for the work order.    |



| El           | RIOD COVERED:                  | (I)  |           |       |       |      |    |    | 1  | SH | OP | L  | Al | ) P | LA | N  |     |      |       |     |        |     |   |   |
|--------------|--------------------------------|------|-----------|-------|-------|------|----|----|----|----|----|----|----|-----|----|----|-----|------|-------|-----|--------|-----|---|---|
|              | SPECIFIC WO                    |      | WORKHOURS |       |       |      |    |    |    |    |    |    |    |     |    |    | Ost | 131  |       |     | HIMAKS |     |   |   |
| . >          |                                |      |           | (2) 5 | K)P o | ØI   | 01 | 93 | 04 | 95 | 06 | 97 | a  | 99  | 10 | 20 | 39  | loui |       |     |        |     |   |   |
|              | No of Employees G              | 1    |           |       | m     |      |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        |     |   |   |
| AVAILABILITY | Cross Workhours Areal. (4      | 1    |           |       |       |      |    |    |    |    |    |    |    |     |    |    | Г   |      |       |     |        |     | Г |   |
|              | Algorithmis (1                 |      |           |       |       |      |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        |     |   |   |
| 1            | Net Workhoun Avail (           | 1    |           | M     |       |      |    |    |    |    |    |    |    |     |    |    |     |      |       | 18  | 7.0    | ľ   |   |   |
| wo           | DESCUPTION                     | 150  | RCD       | 191   | MAT   | 01   | 40 | 45 | 04 | 45 | 96 | 47 | 4  | 99  | 10 | 20 | 30  | led  | labor | M   | Ohr    | Top |   |   |
| 1            | TC106 (                        | 1    | -         |       |       |      | -  | H  | H  |    | -  | -  | -  |     |    |    |     |      | -     | H   | -      | H   | 0 |   |
|              | PM Scheduled g                 |      |           |       |       | -    | -  |    | -  |    |    |    | -  |     |    |    | -   |      |       | H   | -      | H   | - | _ |
| WORK FORCE   | PT&I Scheduled (F              |      |           |       |       |      |    |    |    |    |    | -  |    |     |    |    |     |      | -     | H   |        | H   |   |   |
| 0.0          | Scheduled, Recurrence (        | 1    |           |       |       |      |    |    |    |    |    |    | _  |     | _  |    |     |      | -     | H   |        | -   |   |   |
|              | Total LOE, Scheduled, etc. (   | 11)  |           |       |       |      |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        |     |   |   |
| 18           | Carry-over from Prior Period ( | 6    |           |       |       | Г    | Г  | Г  | r  | Ī  |    |    | T  |     |    |    |     | _    |       | H   |        | t   | t |   |
|              | AVAILABLE TO SCHEDULE (        | U)   |           |       |       | Ī    |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        |     |   |   |
| (14)         | (15)                           | (16) | (II)      | (11)  | (11)  | (28) |    |    |    |    |    |    |    |     |    |    |     | (II) | (2)   | (1) | (24)   | (25 |   |   |
|              | flat specific work order       | s]   |           |       |       |      |    |    |    |    |    |    | Ī  |     |    |    | Т   |      |       | Г   | Г      | T   | Т |   |
|              | (as many lasts as week         | 4    |           |       |       |      |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        | T   | T |   |
|              |                                |      |           |       |       | 3    |    |    |    |    |    |    |    |     |    |    |     |      |       |     |        |     | T |   |
|              |                                |      |           |       |       |      |    |    |    |    |    |    |    |     |    |    |     | П    | -     |     |        | T   | T |   |
|              |                                |      |           |       |       |      |    | 8  |    |    |    |    |    |     |    |    |     |      |       |     |        | Г   |   |   |
|              |                                |      |           |       |       |      |    |    |    |    |    |    |    |     |    | Г  |     |      |       |     |        |     | Т |   |
|              |                                |      | Г         |       |       | -    |    |    |    |    | T  |    | Г  |     |    |    |     | Г    |       |     | Г      | T   | T |   |

#### Figure H.1 Sample form: shop load plan.

# **Instructions for Use: Shop Load Plan**

- 1. Normally, the shop load plan is prepared covering a quarter. However, shop load plans should be prepared and maintained looking 18 months into the future. The last period should include all work that is in an estimated and approved but unscheduled status. A center also may wish to extract a short-term (next month) and a midterm (following two months) shop load plan for closer work scheduling and management. After final approval of a work order, it is assigned to a shop load plan. Normally, this level of scheduling is done by a senior maintenance planner, not in the shop's organization. This starts the work performance phase and triggers material acquisition to ensure that the required material is available for the assigned start period. Approved work orders remain in the shop load plan until completed or canceled.
- 2. The primary purpose of the shop load plan is to provide for the orderly scheduling of work in accordance with the center's mission priorities, to assist in resource scheduling and management, and to provide senior managers with information on pending work. It also provides a valuable tool for evaluating the workforce skill mix against workload requirements. If the shop load plan consistently shows a significant amount of overscheduling or unscheduled backlog in a shop coupled with underscheduling in another shop, realignment of workforce assets from the underscheduled to the overscheduled shop may be in order.

#### **Master Schedule**

Sample Form: Master Schedule. Figure H.2 is a sample form for a master

schedule. The master schedule is based on the shop load plan. However, its focus is on scheduling work performance to a specific week and tracking material status of work orders that are due for master scheduling in the future according to the current and approaching shop load plans. Normally, master schedules are prepared covering 6–10 weeks into the future. Jobs with long lead-time material requirements may be scheduled further in the future. Of special interest is the Work Orders Waiting Material section. This is used to highlight the material status of work orders waiting material that need to start during the master schedule period covered.

Data Elements. The following data elements are shown on the master schedule form. As with the shop load plan, the information either is contained in the CMMS database or is derived from the CMMS database by manipulation and calculation. The data elements are defined below as an aid to understanding the schedule form. The only data that should require entry in the scheduling process are for the period during which the work order is being scheduled (normally, the specific workweek). The rest is based on other data entered in the CMMS during the work reception and planning process, the material management process, or extracted from other databases such as labor accounting.

-

| 1               | Period covered      | The time period this schedule considers. Normally   |
|-----------------|---------------------|---|
| 2               | Shop                | The shop or craft group being scheduled (e.g., shop |
| 3               | Number of employees | The average onboard manpower in each shop durin     |
| Table Continued |                     |   |

| 4  | Gross work hours available | The total number of work hours in each shop available during   |
|----|----------------------------|--|
| 5  | Adjustments                | The number of work hours that will not be available for faci   |
| 6  | Net work hours available   | The net available work hours for facilities maintenance work   |
| 7  | TC LOE                     | The level of effort (the number of hours) allocated for jobs,  |
| 8  | PM scheduled               | The numbers of hours for scheduled PM work.                    |
| 9  | PT&I scheduled             | The number of hours for scheduled PT&I work.                   |
| 10 | Scheduled and recurring    | The number of hours for other scheduled or recurring work.     |
| 11 | Total LOE scheduled        | Total hours committed to items 7, 8, 9, and 10.                |
| 12 | Available to schedule      | Net work hours available (item 6) minus item 11. This is the   |
| 13 | WO#                        | Work order number for each specific work order listed.         |
| 14 | Description                | Entry giving a short title for each work order. Also, the num  |
| 15 | RSD                        | Requested start date for the work order.                       |
| 16 | RCD                        | Requested completion date for the work order.                  |
| 17 | PRI                        | The work order priority rating.                                |
| 18 | MAT                        | Material status indicator. Normally, this entry is the date on |
| 19 | Total                      | Total labor hours for the shops.                               |
|    |                            |  |

| 20 | Labor | Expended labor hours. The total labor hours used or schedul    |
|----|-------|--|
| 21 | Mtl   | Cumulative material cost of material used for work order.      |
| 22 | Other | Cumulative costs of other than labor and material used for the |
| 23 | Total | Cumulative total cost.   |
|    |       |  |

### **Instructions for Use: Master Schedule**

1. The master schedule is used to direct and coordinate the execution of work in the shops. It provides the coordinating linkage between the shops on jobs involving more than one shop and it highlights the material status of pending work orders. Normally, it is maintained under the direction of the shop supervisor working in close coordination with the shop supervisors and the maintenance planners. Work is scheduled by assigning it to a specific workweek; the automation program used should perform all necessary calculations, including computing estimated carryover work and resources expended (or projected to be expended) up to the period under consideration.

| PERI                          | OD COVERED: (1)                 |      |      |      |      |    |           |      |      | Ŋ   | (A)  | STI  | ER  | SCI | HE | )U | E   |       |       |              |      |          |         |
|-------------------------------|---------------------------------|------|------|------|------|----|-----------|------|------|-----|------|------|-----|-----|----|----|-----|-------|-------|--------------|------|----------|---------|
| SPECIFIC WORK/ITEM            |                                 |      |      |      |      |    | WORKHOURS |      |      |     |      |      |     |     |    |    |     |       |       | USED TO-DATE |      |          | REMARKS |
| è                             |                                 | -    | (2)  | 3    | OP 2 | 01 | 02        | 03   | u    | 65  | 06   | 07   | OI. | 09  | 10 | 20 | ))) | Total |       |              |      |          |         |
| Zw2                           | No. of Employees (3)            |      |      | W.   |      |    |           |      | П    | П   | T    | П    |     |     |    |    |     | -3    |       |              |      |          |         |
| WORK<br>FORCE<br>AVAILABILITY | Gross Workbours Avail (4)       |      |      |      |      |    |           |      |      |     | Ī    |      |     |     |    |    |     |       |       |              |      |          |         |
| 2 T T                         | Adjustments (5)                 |      |      |      |      |    |           |      |      |     | Ī    |      |     |     |    |    |     |       |       |              |      | 10       |         |
| 3                             | Net Workhours Avail. (6)        |      |      | 7    |      |    |           |      |      |     |      |      |     |     |    |    |     |       |       |              |      | 16       |         |
| WOJ                           | DESCRIPTION                     | 850  | D/Th | 1001 | wit  | 60 | 40        | 20   | - T  | 76  | a. I | er 1 |     | -   | 15 | -  |     | 7.44  |       |              |      | la cal   |         |
| 4.65                          | TCLOE (f)                       | -    | RCD  | PRI  | MAT  | 01 | 62        | 03   | (4   | 05  | 06   | Ø7   | 01  | 09  | 10 | 20 | 30  | Total | Labor | Mil          | Ohe  | Total    |         |
| ėΗ                            | PM Schedule (B)                 |      |      |      |      | -  | -         |      | Н    |     | -    |      |     | -   |    | =  | -   |       |       | -            | -    | H        |         |
| WORK FORCE                    | PT&I Schedule (9)               |      |      |      |      | -  |           | -    |      |     | +    | -    | -   |     |    |    | -   |       | -     |              | -    | $\vdash$ |         |
| 2 ×                           | Scheduled and Recurring (18)    |      |      |      |      |    | -         | -    |      |     | +    | +    | -   |     |    |    |     |       |       | -            | -    | H        |         |
| 06 -                          | Total LOE, Scheduled, etc. (11) |      |      |      |      | -  | -         | -    | H    |     | Ŧ    | -    | -   |     |    |    |     | _     | -     | -            | -    | Н        |         |
|                               | AVAILABLE TO SCHEDULE (C        |      |      |      |      | -  | -         |      | H    |     | +    | +    | -   | -   | -  | _  |     |       | -     |              | H    | Н        |         |
| (13)                          | (14)                            | (15) | (14) | (11) | (18) |    | F         | -    | H    |     | +    |      | -   |     |    |    |     | (15)  | (36)  | (21)         | (22) | (2)      |         |
|                               | (list specific work orden)      |      |      |      |      |    | Т         |      | П    |     | T    |      |     |     |    |    |     |       |       |              |      |          |         |
|                               | (in many lines as needed)       | Т    | T    | П    |      |    | Г         | Г    | П    |     | 7    | 1    |     |     |    |    |     |       |       |              |      |          |         |
|                               |                                 |      |      |      |      |    |           |      |      |     | T    |      |     |     |    |    |     |       |       |              |      | П        |         |
|                               |                                 |      |      |      |      |    | Γ         |      |      |     | T    |      | ī   |     |    |    |     |       |       |              | Т    | П        |         |
|                               |                                 |      |      |      |      |    |           |      |      |     | J    |      |     |     |    |    |     |       |       |              |      |          |         |
|                               | Not hown overlander scheduled   | 14   |      |      |      |    |           |      |      |     | I    |      |     |     |    |    |     |       |       |              |      |          |         |
|                               |                                 |      | Ξ    |      |      |    |           |      |      |     |      |      |     |     |    |    |     |       |       |              |      |          |         |
| _                             |                                 |      | _    |      |      |    | W         | 8X.0 | WDE: | 3.1 | AITE | NG)  | (AT | KIA |    |    | _   | _     | _     | _            | _    | _        |         |
| _                             | (as many lines as needed)       |      | _    |      |      |    |           |      |      |     | 4    |      |     | Н   |    |    |     |       |       |              |      |          |         |
|                               |                                 |      |      |      |      |    |           |      |      |     | 4    |      |     |     |    |    |     |       | _     |              |      |          |         |
|                               |                                 |      |      |      |      |    |           |      |      |     | 1    |      |     |     |    |    |     |       |       |              |      | Ш        |         |
| -                             |                                 | H    |      |      |      |    |           | _    | H    |     | _    |      |     | L   |    |    | _   |       |       | _            |      |          |         |
|                               | Total writing material          |      |      |      |      |    | -         |      |      |     | 4    | -    |     |     |    | _  |     |       |       |              | _    |          |         |

#### Figure H.2 Sample form: master schedule.

- 2. It is essential for the master schedule to give close attention to balancing the work to each shop to ensure that all forces are productively employed. To this end, the master scheduler will assign labor hours to each scheduled job within available manpower and job phasing requirements.
- 3. Although it is possible to examine the master schedule on a video display terminal, the practical limitation on the number of lines and columns that can be displayed at one time makes it difficult to see all work that is subject to scheduling. Accordingly, printouts on wide paper and wall-mounted scheduling boards normally are used to display job status.

# **Shop Schedule**

Sample Form: Shop Schedule. A form for a shop schedule is provided as Figure H.3. The shop schedule provides the day-to-day scheduling/assignment of workers and equipment to work orders. It is used by the shop supervisor as an aid in scheduling personnel and shared equipment assets.

Data Elements. The following data elements are shown on the shop schedule form. The information either is contained in the CMMS database or is derived from the CMMS database by manipulation and calculation. The data elements are defined below as an aid to understanding the schedule form. The only data elements that should be entered during the scheduling process are the assigned hours for each work order and employee being scheduled. The remaining data elements should be provided by the computer based on other data entered in the CMMS during the work reception and planning process, the material management process, or

# extracted from other databases. For example, hours for PM on the schedule shown be the top priority based upon level loading PM across the entire year as shown in Figure H.4.

| 1 | Period covered             | The time period this schedule considers. Norm   |  |  |  |  |  |
|---|----------------------------|---|--|--|--|--|--|
| 2 | Shop                       | The shop or craft group being scheduled (e.g.,  |  |  |  |  |  |
| 3 | Employee                   | The name or other identifier of the worker bei  |  |  |  |  |  |
| 4 | Gross work hours available | The total number of work hours available for    |  |  |  |  |  |
| 5 | Adjustments                | The number of work hours that will not be ava   |  |  |  |  |  |
| 6 | Net work hours available   | The net available work hours for each employ    |  |  |  |  |  |
| 7 | WO#                        | Work order number for each work order listed    |  |  |  |  |  |
| 8 | Description                | An entry giving a short title for each work ord |  |  |  |  |  |

**Table Continued** 

| 9   | RSD   | Requested start date for the work order.  |
|-----|-------|---|
| 10  | RCD   | Requested completion date for the work order.                                       |
| 11  | PRI   | The work order priority rating.   |
| 12  | МАТ   | Material status indicator. Normally, this is a code or symbol indicating that the m |
| 13  | Total | Total hours for all employees.  |
| 14  | Labor | Cumulative labor hours for the work order prior to this schedule period. This info  |
| 15  | Mtl   | Cumulative cost of material used for the work order.                                |
| 16  | Other | Cumulative cost of other than labor and material used for the work order. This in   |
| 23. | Total | Cumulative total cost.  |
| •   |       |   |

Instructions for Use: Shop Schedule

The shop supervisor uses the shop schedule for scheduling and managing craft personnel. It is typically prepared on a weekly basis for each day of the following week, based on jobs scheduled in the master schedule. The shop supervisor enters the hours each employee is scheduled to work on each assigned job for each day. The workforce availability is determined from leave, training, and related activities that are also scheduled through the shop supervisor. A planner/supervisor's projection of resources over a 4-week period is shown in Figure H.5. Also, a weekly schedule example with 90% of the availability is shown in Figure H.6.

| PERIOD COVERED: (1)        | SHOP SCHEDULE | For Shop (3)      |
|----------------------------|---------------|-------------------|
| SPECIFIC WORK/ITEM         | WORKHOURS     | USED REMARKS      |
| d) EMPLOYEE->              |               | out of the second |
| Gross Workhours Avail. (4) |               | 鱼展                |
| Adjustments (5)            |               |                   |
| Net Workhours Avail (6)    |               |                   |

| W0.1 | DESCRIPTION                     | RSD | RCD  | N   | MAT  |           |   |   | П |   |   |        |                     | Total | Liber | М    | Other | Total |  |
|------|---------------------------------|-----|------|-----|------|-----------|---|---|---|---|---|--------|---------------------|-------|-------|------|-------|-------|--|
| (7)  | (f)                             | 0)  | (19) | (0) | (12) | T         |   | T | П | T | П | T      | Ħ                   | (13)  | (14)  | (15) | (14)  | (17)  |  |
|      | (assigned work orden)           | T   |      |     |      |           |   | T | П | T | П | T      | П                   |       |       |      |       |       |  |
|      | (as many lines as needed)       | T   |      |     |      | $\exists$ | T | T | Ħ | T | П | T      | TT                  | T     | П     | П    |       | П     |  |
|      |                                 | T   |      | Т   |      | $\exists$ |   | T | П | T | П | +      | П                   | 1     |       | Г    |       |       |  |
|      |                                 | t   |      |     |      | 1         | Ť | T |   | T | Н | +      | Ħ                   | +     |       |      |       |       |  |
|      |                                 | t   |      |     |      | T         | Ť | t | H | Ť | Ħ | $^{+}$ | $^{++}$             | +     |       |      |       |       |  |
|      |                                 | t   | H    |     |      | $\dashv$  | + | t | Н | + | H | +      | $^{\dagger\dagger}$ | +     |       |      |       |       |  |
|      |                                 | H   | H    | -   |      | +         | Ŧ | ۰ | H |   | Н | +      | H                   | +     | H     |      | H     |       |  |
| -    |                                 | ÷   | H    | -   | H    | -         | + | ٠ | H | H | Н | $\pm$  | +                   | +     |       |      | -     | Н     |  |
| -    |                                 | +   | +    | -   | H    | +         | + | + | Н | + | Н | +      | +                   | +     | -     |      | H     | -     |  |
| -    |                                 | +   | H    | -   |      | -         | + | + | Н | + | Н | +      | ₩                   | +     | H     | H    | H     | Н     |  |
| -    |                                 | H   | H    | H   |      | -         | + | ╄ | Н | + | Н | +      | +                   | +     | H     |      | H     | Н     |  |
| _    |                                 | ÷   | -    | -   |      | _         | + | + | Н | + | H | +      | ++                  | _     |       |      | H     | Н     |  |
|      |                                 | 4   | -    | _   |      | 4         | 4 | + | Ц | 4 |   | _      | 44                  | 4     | _     |      |       |       |  |
| _    |                                 | 1   | _    |     |      |           | _ | Ļ | Ц | _ |   | _      | 1                   |       |       | L    |       |       |  |
|      |                                 |     | _    | L   |      |           |   | L | Ц |   |   |        |                     |       |       |      |       |       |  |
|      |                                 |     |      |     |      |           | 1 |   |   |   |   |        |                     |       |       |      |       | Û     |  |
|      |                                 |     |      |     |      |           |   |   |   |   |   |        |                     |       |       |      |       |       |  |
|      |                                 |     |      |     |      |           |   |   |   |   |   |        |                     |       |       |      |       |       |  |
|      |                                 |     |      |     |      |           |   |   |   |   |   |        |                     |       |       |      |       |       |  |
|      |                                 |     |      |     |      |           |   |   |   |   |   |        |                     |       |       |      |       |       |  |
|      | ket hours over lander scheduled |     |      |     |      |           |   | T | П |   |   |        |                     |       |       |      |       |       |  |

Figure H.3 Sample shop schedule.

| Total Company Service  |     |      |           |     |        |    |    |     |         |      |      |      |    |      |          |     |           |      |     |          |        |         |        |         |          |           |     |          |
|--|-----|------|-----------|-----|--------|----|----|-----|---------|------|------|------|----|------|----------|-----|-----------|------|-----|----------|--------|---------|--------|---------|----------|-----------|-----|----------|
|  | to  |      | NO.       |     |        | 77 | Ħ. | Tit | 1.1     |      |      | 1.1. |    |      |          | TT  | 1000      | 100  | TIT | 1.1.     | T.T.   | 1.1     | 77.7   | 1.1     | 77       | 11.1      | Tit | 111      |
|  | F   | +    | ₩         | +   | -      | ÷  | H  | H   | ++      | +++  | ++   | ++   | -  | -    | ÷        | -   | ++        | ++   | H   | ++       | ++     | ++      | ++     | H       | ÷        | -         | ++  | +++      |
|  | H   | - 10 | н         | +   | W      | +  | H  | +   | M       | ++   | ++   | W    | +  | 1    | +        | +   | +         | ++   | W   | ++       | M      | $^{++}$ | V      | +       | +        |           | ++  |          |
| 20,5100  | -   |      | $\mapsto$ | +   | - 6    | +  |    | ++  | Ť       | ++   | ++   | - A  | +  | , já | -        |     | <b>)</b>  | ++   | ×   | ++       | M.     | ₩       | - Ö    | +       | +        | <u> </u>  | ++  |          |
| 14,4000  | -   | - 8  | Н         |     |        | -  |    | ш   | -       | -    | -    | -    |    |      |          | Ħ   | 4         | -    | н   | -        | -      | ш       | - 2    | $\perp$ | -        |           | -   |          |
| STATE OF THE PARTY | -   |      | 4         | _   | -      | +  | ш  | ш   | -       | 11   | ++   | ш    |    |      | ш        | 1 0 | $q \perp$ | 11   | ш   | 44       | ш      | ш       | -      | ш       | _        | ш         | ш   | 111      |
|  | -   |      | П         |     |        |    |    | П   | ш       |      |      | Ш    |    |      |          |     |           |      | П   | ш        | ш      | П       |        | Ш       |          |           |     |          |
|  |     | N    | П         | П   | - 30   | 7  | ×  | П   | X       | П    | Н    | X    | П  | X    |          |     |           | П    | M   | ŒΕ       | M      | П       | X      | П       | Т        | X         |     | X D      |
| ***  |     | ×    | П         | т   |        | Ŧ  | т  | П   | X       | т    | т    | т    | т  |      | т        | T   | 41        | т    | П   | т        | П      | П       | X      | П       | т        | П         | т   |          |
| T. Carrier   |     | 2    | Ħ         | 11  | $^{+}$ | +  | _  | Ħ   | т       | ++   | **   | ++   | _  | -    | 7        |     | 4         | **   | Ħ   | **       | ++     | Ħ       | п      | Н       | +        | 111       | 77  | ***      |
|  |     | -    | Ħ         | ++  | -      | +  | H  | Ħ   | ++      | ++   | ++   | ++   | +  |      | 1        |     | -         | -    | Ħ   | ++       | ++     | Ħ       | ++     | Ħ       | +        | -         | ++  | ++1      |
| 200  |     | 10   | H         | +   | M      | +  | T. | +   | W       | ++   | ++   | M    | +  | M    | +        | +   | *         | ++   | M   | ++       | M      | Ħ       | V      | +       | +        | W T       | +   |          |
|  | -   | 2    | H         | +   |        | +  | H  | -   | ¥       | ++   | ++   | -    | +  | -    | -        |     | *         | -    | ä   | -        | Α.     | ₩       | X      | ++      |          | -         | ++  | 4        |
| ***  | -   |      | Н         | н   | -      | +  |    | Н   | -       | +    | ++   | ++   | +  |      | 1        | +   | +         | 44   | H   | ++       | ++     | H       | -      | +       | +        | +         | ++  | -        |
| ****   | -   |      |           |     |        |    |    | ш   | 11      | 44   | 44   | 11   |    |      |          | 1 2 | 4         | ш    | ш   | 11       | ш      | ш       |        | $\perp$ | -        |           |     |          |
| -  | -   |      | П         |     |        |    | Ш  | Ш   | П       |      |      |      |    |      |          |     | П         |      | П   | Ш        | Ш      | П       |        |         |          |           |     |          |
|  |     |      |           |     |        |    |    |     | M       |      |      | M    |    | X    |          | H   |           |      | M   |          | X      |         | X      |         |          | ×         |     |          |
| 27/2000  | -   |      |           |     | 17 18  |    |    |     | *       |      |      |      |    |      |          |     |           |      | 11  |          |        | П       | ×      |         |          |           |     |          |
| Tally Server   |     | ¥    |           |     |        |    |    |     |         |      |      |      |    |      |          | 18  |           |      |     |          |        | П       |        |         |          |           |     |          |
|  | -   |      |           |     | 11 3   |    |    | П   | 11      |      |      | 11   | т  |      |          | T   |           |      | 77  |          |        | П       |        | П       |          |           | 77  |          |
| -  |     | +    | M         | +   | -      | +  |    | M   | +       | 1    | ++   | 11   | -  |      | X        | ++  | V         | ++   | +   | 4        | 1      | +       | 1      | +       | +        | W         | ++  | X        |
| Total Control  |     | +    | 慘         | +   | -      | -  | +  | n.  | +       | X    | ++   | +*   | -  |      |          | ++  | 8         | ++   | ++  | ++       | H      | +       | 18     |         | +        | -         | ++  |          |
|  | +   | -    | X         | +   | -      | +  | +  | ++  | ₩       | -    | ++   | ++   | -  |      | H        | ++  | <b>*</b>  | ++   | ₩   | ++       | ++     | ₩       | + 4    |         | +        | +++       | ++  | -        |
| 77.500   |     |      | щ         | +   | +      | +  | -  | H   | ₩       | ++   | ++   | ++   | -  |      | -        | ++  | 4         | -    | ₩   | ++       | +      | +       | -      |         | +        | $\mapsto$ | ++  |          |
| -  |     |      | ш         | ш   | -14    | 1  | ш  | ш   | 44      | 44   | -    | 14   | L  |      | 4        | ш   | 11        | _    | щ   |          | 1      | ш       | 1      | ш       | +        | 111       | -   |          |
|  |     |      | X         |     |        |    |    | ×   | ш       | ¥    |      | 1.0  |    |      | X.       | ш   | X         | ш    | П   |          |        |         | -      |         | 1        | X         | Ш   | X        |
| ***  | 1   |      | X         |     |        |    |    | П   | ш       | - 20 |      |      |    |      |          |     | ×         |      | П   |          |        | П       |        |         | Т        |           | ш   |          |
| Adhibana.  | 100 |      | Ż         |     |        |    |    | П   | П       | П    | П    | П    |    |      | 11       | Ш   | M         | П    | П   | Ш        |        | П       |        |         |          |           | П   |          |
| SERVICE SERVICE  |     |      | П         | П   | П      |    | П  | П   | т       | T    | ш    | П    | т  |      | П        | т   |           | т    | П   | 11       | т      | П       |        |         | т        | ш         | т   |          |
| 20.500   |     |      | M         | 11  |        | 4  | т  | M   | 77      | X    | _    | T    |    |      | X        | ##  | 101       | 11   | Ħ   | 4        |        | Ħ       | 73     | 7       |          | W         | 77  | X        |
| Add Associate  |     | +    | X         | ++  | -      | +  | -  | m   | ++      | -    | ++   | ++   |    | -    | -        | ++  | Š         | -    | Ħ   | **       | 1      | +       |        | 7       | +        | -         | ++  | •        |
|  | 1   | +    | 憿         | ++  | ++     | +  | H  | H   | ++      | -    | ++   | ++   | +  | -    | H        | ++  | 10        | ++   | ++  | ++       | ++     | H       | +*     | +       | +        | +++       | ++  | +++      |
|  | H   | +    | A         | ++  | -      | +  | -  | ₩   | ++      | ++   | ++   | ++   | +  | -    | +        | ++  | 1         | ++   | ₩   | ++       | ++     | $^{+}$  | ++     | ++      | +        | +++       | ++  |          |
|  |     | +    | b         | н   | -      | -  | н  | v   | ₩       | M    | ++   | +    |    | -    | V        |     | 44        | -    | н   | +        | 1      | Н       | +4     | +       | +        | W         | -   | W        |
| Address:   |     | 1    |           | н   | -      | 4  | ш  | ж.  | ++      | ğ    | ++   | 11   | 4  |      | <u> </u> | +   | ě         | -    | 11  |          | 10     | 44      | $\Box$ |         | +        | - 23      | ++  | <b>X</b> |
| 1015000  | -1  |      |           |     |        |    |    |     | $\perp$ | - 30 |      |      |    |      |          |     | 11        |      | Ш   |          |        |         |        |         |          |           |     |          |
| Add to the last  |     |      | X         |     |        |    |    | П   | П       |      | Ш    | Ш    |    |      |          |     | X         | ш    | П   | ш        | П      | П       |        |         |          |           | ш   |          |
| terior .   |     | П    | П         | П   |        | Т  | Ш  | П   | Ш       | П    | П    | П    | П  | Ш    | П        | Ш   |           | П    | П   | П        |        | П       | П      | П       | Т        |           | Ш   |          |
|  |     |      |           |     |        | X  |    | П   |         |      |      | П    | K  |      |          |     | 1 5       |      | П   |          |        | X       |        | X       |          |           |     |          |
| Library .  |     | т    | П         |     | _      | т  | т  | П   | 77      | 77   | 7    | т    | т  |      | т        | 77  | 175       | 7    | П   | т        | $^{-}$ | П       | 77     |         | т        | ш         | 77  |          |
| 10.100   |     |      |           | F   | +      | +  |    | #   | ##      | + *  | 1    | ++   | ٠  |      | +        | Ħ   |           |      | +   | **       | Ħ      | Ħ       | ++     |         |          | 1         | ++  | 111      |
|  |     | +    | Ħ         |     | ++     | +  | +  | +   | ++      | ++   | ++   | ++   | +  | +    | +        | ++  | Ħ         |      | ++  | ++       | ++     | ++      | ++     | +       | +        | +++       | ++  | +        |
|  |     | 4    | ++        | V   | -      | +  | V  | ++  | X       | ++   | 10   | ++   | +  | ¥    | H        | W   | ++        | M    | ++  | 1        | +      | +       | 4      | +       | <b>V</b> | +++       | M   | ++-      |
|  |     | X    | ₩         | -   | +      | +  | 4  | ++  | -       | ++   | ×    | ++   | -  | 4    | Н        | -   | ++        |      | ++  | - 1      | 4      | ++      | ×      | +       |          | +++       | -   | +        |
| Sally Section  |     |      | ₩         | Ž   | -      | +  | н  | H   | ₩       | ++   |      | ++   | -  |      | Н        | ₩   | ₩         | Ž    | +   | ++       | 1      | н       | ++     |         | 4        | -         | ++  |          |
| Military.  |     | 4    | ш         | -   | -      | +  | ш  | Ш   | ш       |      | -    |      | L  | ш    |          | ш   | ш         | X    | ш   | 44       | Ш      | ш       |        | ш       |          |           | Ш   | -        |
|  |     |      | П         |     |        |    |    | П   | П       |      |      |      |    |      |          | П   | П         | 10.1 | П   | П        | П      | П       |        | П       |          |           | П   |          |
| 575 5700   |     | X    |           | X   |        |    | X  | П   | X       |      | X    |      |    | X    |          | X   |           | ¥    | П   | <u>.</u> |        |         | X      |         | X        |           | X   |          |
| Add Arrest   |     |      | П         | M   |        |    |    | П   |         |      | X    |      |    |      |          |     |           | X    |     |          |        |         |        |         | Z.       |           |     |          |
| 10.00  |     | т    | Ħ         |     | П      | T  |    | П   | Ħ       | 11   |      | 11   | Т  |      | Т        | T   | П         | X    | Ħ   | 11       |        | П       |        |         |          |           | T   |          |
| -  |     |      | Н         |     |        | т  |    | Ħ   |         | 11   |      | **   |    |      |          | Ħ   | Ħ         |      | Ħ   | 77       | П      | П       | 11     | 77      |          | 11        | Ħ   | -        |
|  |     |      | +         |     |        | 1  | +  | V   | ++      | +    |      | 13   | t  |      | V        | ++  | 13        |      |     |          |        | H       | ++     | X       | +        | X         | ++  | 1        |
|  |     |      | H         | +   | ++     | -  | +  | 0   | Ħ       | ++   | +    | ++   |    |      | 0        | ++  | +*        | +    | ۲   | -        | 3      | -       | ++     | -       | +        | -         | ++  | ğ        |
| 101/100  |     | -    | +         | +   | -      | +  | +  | 0   | ++      | +    | ++   | ++   | +  | -    | 4        | +   | +         | ++   | ₩   | ++       |        |         | ++     | +       | +        | +++       | +   | -        |
| ***  | H   | 1    | H         | +   | -      | +  | 4  | X   | ++      | ++   | ++   | ++   | +  |      | Н        | ++  | #         | ++   | +   | ++       | 1      | 44      | ++     | +4      | +        | 14        | 44  | 11       |
| ***  | ш   |      | Ш         | Ш   |        |    |    |     | Ш       | 11   |      |      | L  |      |          | Ш   | Ш         |      | Ш   |          |        | Ш       |        | Ш       | $\perp$  |           | Ш   |          |
| 10 have  |     |      |           |     |        |    |    | X   | П       |      |      |      |    |      |          | П   |           |      | П   | 1        |        |         |        | M       |          | X         | П   | ¥        |
| Militaria  |     |      |           |     |        | 1  |    | X   |         |      |      |      |    |      | V.       |     |           |      |     |          |        |         |        |         |          |           |     |          |
| 15.500   |     |      | П         |     |        |    |    |     | П       |      | 1 11 |      |    |      |          |     | T         |      | T   |          | TS     |         |        | П       |          |           |     |          |
|  |     |      |           | - 6 |        |    |    |     |         | 1 1  |      |      | 11 |      |          |     | 4 1       | 1 1  | -   |          |        |         |        | 10.00   |          |           |     |          |

ď

Figure H.4 Sample PM leveling and planning by shop area.

| Week           | commencing | 04-Jul-05   | 11-Jul-05 | 18-JJI-05 | 25Jul-05 |
|----------------|------------|-------------|-----------|-----------|----------|
| Operating unit | Craft      | week 1      | week 2    | week 3    | week 4   |
| Area 1         | Mech       | 8 M         | 7 M       | 6 M       | 5.5 M    |
|                | Elec       | 4.5 E       | 5 E       | 3 E       | 4 E      |
|                | Inst       | 1.5 1       | 2 1       | 0         | 3 1      |
| Area 2         | Mech       | 10 M        | 9 M       | 12 M      | 7 M      |
|                | Bec        | 5.5 E       | 3.5 E     | 7 E       | 4 E      |
|                | Inst       | 3 1         | 3 1       | 3 1       | 25       |
| Area 3         | Mech       | 0           | 1.5 M     | 0         | 1 M      |
|                | Bec        | 0           | 0.5 E     | 0         | 1 E      |
|                | Inst       | . 0         | 0.5 1     | 0         | 0        |
| Area 4         | Mech       | 7 M         | 8.5 M     | 7 M       | 10 M     |
|                | Elec       | 4.5 E       | 5 E       | 5 E       | 5 E      |
|                | Inst       | 25          | 2 1       | 2 1       | 1.5      |
| etc            | Ш.,        |             |           |           |          |
| Weekly totals  | Mech       | 25.0 M      | 26.0 M    | 25.0 M    | 23.5 M   |
|                | Elec       | 14.5 E      | 140 E     | 15.0 E    | 14.0 E   |
|                | Inst       | 7.0 1       | 7.5 1     | 5.0 1     | 7.0 1    |
| Monthly totals | Mech       | 99.5 Mech   | anical    |           |          |
|                | Elec       | 57.5 Electr | ical      |           |          |
|                | Inst       | 26.5 Instru | mentation |           |          |

Figure H.5 Sample 4-week shop look-ahead of resources by trade type (mechanical. Electrical, and instrumentation).

| Crew:                              | BA04            | Manufactu           | ring Enginee          | ring        | Week S                                 | tarting:                     | 20                         | June 2005  |
|------------------------------------|-----------------|---------------------|-----------------------|-------------|--|------------------------------|----------------------------|------------|
| Craft:                             | ММ              | Mechanica           | ı                     |             |  |                              |                            |            |
| Operating u                        | nit: Coating    | room 7              |                       |             | Avaita                                 | ote on : W                   | ednesday                   | 22nd       |
| W/O number<br>Job descriptio       | Work type<br>in | W/O status          | Equipment 10          | GMP/SA fleg | Window                                 | Target Start<br>Sched, Start | Labour hrs<br>Duration hrs | Crefternen |
| 241483<br>OHARA COA<br>BYPASS DUC  |                 | WSOH<br>N/PROCEDUR  | 11130<br>£ 30884)     | GMP NR      | 60                                     | 14-JA/05<br>20-JA/05         | 1.00<br>0.75               | john jound |
| 241 604<br>OHARA COA<br>MECHANICAL |                 | WSOH<br>RAYGUN (PRO | 11130<br>CEOURE 30884 | GMP NR      | 20                                     | 14-Janos<br>20-Janos         | 225<br>200                 | 20km 20mma |
| 241465<br>Ohara coa<br>Mechanical  |                 | WSOH<br>OCEDURE 308 | 11130                 | CMP NR      | 60                                     | 14-JA-05<br>20-JA-05         | 325<br>300                 | rectan     |
| 241 667<br>OHARA COA<br>COATING SO | T-1000 1000 100 | WSOI<br>ELS PROCED  | 11130<br>JREXXIII     | GMP NR      | 60                                     | 14-Jan 05<br>20-Jan 05       | 0.75<br>0.50               | ressas     |
|                                    | issued for this |                     |                       | Area tel    | otal labou<br>al duratio<br>otal labou | n hours :                    | 125<br>6.25<br>125         |            |
| NON CHA                            | ICE ARLE HOL    | IRS                 |                       | ) Brow      | kdown uff                              |                              | с                          |            |
| Tr                                 | eining ellower  |                     | ([pnining]            | ١ ا         | otal labou                             | r hours :                    | 180                        |            |
|                                    | Admin / Meetin  | <b>σ</b> : <u>6</u> | [Admin]               | Areil       | able labou                             | r hours:                     | 200                        |            |
| Houlth and                         | Safety activit  | les:                | [Satety]              | '           | ercentage                              | louded:                      | 90                         | *          |
| 513975 - I                         | Workshop ti     | me:                 | — <sup>[900]</sup>    |             |  |                              |                            |            |
| Productio                          | n support at 2  | 5%:                 | [Shop]                |             |  |                              |                            |            |

Figure H.6 Sample weekly maintenance work schedule at 90% loading.

# Appendix L

# **Routine Planner Training Checklist**

\_

The purpose of this document is to ensure new planners are trained on all aspects of planning/scheduling a maintenance order in SAP/P3.

#### **Personal Details**

-

| Name:             | Employee Number:             |
|-------------------|------------------------------|
| Position:         | Team/Work Group:             |
| Level:            | Performance/Functional Unit: |
| Team Leader Name: |                              |

\_

# **Section 1 (Basic)**

-

| Activity   |
|--|
| Work identification  |
| Retrieve approved notifications from notification backlog                                      |
| Ability to review/edit notification for needed corrections                                     |
| Understand the RIME system and how to edit to assign (provide employee with the RIME document) |
| Planning/Estimating  |
| Create maintenance order from approved notification  |
| • Explain the job note process   |
| • Review reusable job plan process (creation, use, retrieval, etc.)                            |
| • Review tasking process in SAP  |
| • Review PM activity field in SAP  |
| Review revision coding system in SAP for EBB purposes  |
| Provide copy of revision codes used for EBB  |
| Table Continued  |

| Acti | ivity  |
|------|--|
| • F  | Review estimating process (supply employee with the fluor estimating template)         |
| • (  | Generation of WCC associated with the ISSOW  |
| Ap   | pproval process  |
| • E  | Explain cost approval process EBB  |
| • P  | Provide employee with the different levels of approval per work process flow process   |
| • E  | Explain approval process for opportunity contractors                                   |
| • P  | Provide CWR to employee for approval to use tier 2 and Tier 3 contractors, if required |
| Ini  | itiating approved work   |
| • F  | Forward cost estimate to cost analyst  |
| • I  | nform employee which cost analyst is assigned to his area of responsibility            |
| • (  | Order needed materials and rental equipment per job requirements                       |
| • K  | Know how to search SAP identified materials  |
| • k  | Know how to search material by use of BOM  |
| • k  | Know how to use the VAM system   |
| • k  | Know how to create a free text requisition   |

| Know how to use the total control system  |
|---|
| Have employee set up in the total control system  |
| • Inform employee of their assigned procurement coordinator and procurement associate             |
| Scheduling  |
| • Review backlog  |
| • Review the different planner groups   |
| • Facilitation of weekly/daily scheduling meetings. Provide employee with meeting agenda document |
| Assignment of scheduled work  |
| Pre for Execution   |
| Generation of CWR for opportunity contractors once they have been approved                        |
| Table Continued   |

| Activity  |
|---|
| • Minimum requirements for job packages. Provide employee with job package requirement document |
| Scope Change  |
| Review JCO process and supply employee with JCO form  |
| Post Execution  |
| Returning of rental equipment, materials, and repair items                                      |
| • Entry of history in SAP   |
| Close maintenance orders to maintenance   |
| Revision of reusable job plan if required   |
| Update of BOM if required   |
|   |
|   |

BOM, bill of materials; VAM, vendor agreement manager; EBB, events based Budgeting; RIME, ranking index of maintenance expenditures; PM, preventive maintenance; ISSOW, integrated risk management and safety system; WCC, work control center; JCO, job control order; CWR, corrective work order.

#### **Section 2 (SAP)**

-

#### Activity

SAP user menu

- How to access maintenance systems (logistics, plant Maintenance, Maintenance processing, etc.)
- · Adding and deleting favorites
- Renaming and organizing favorites

Creating notification

- Know the difference between Maintenance request and malfunction report
- Entering short and long text
- Assigning functional location
- Assigning main work centers
- Assigning the priority. Explain how RIME is assigned and give copy of RIME document

| TILL C. et al.  |  |  |
|-----------------|--|--|
| Table Continued |  |  |
|                 |  |  |

| Activity  |
|---|
| Closing Out/Documenting work history  |
| Know how to capture and input history of work performed and condition of repair                           |
| Know how to close a notification in conjunction with closing out an MO                                    |
| Creating maintenance order  |
| Know how to create a maintenance order from a notification  |
| Understand the different order types and assignment   |
| • Understand the different PM Activity type codes and assigning the one that best fits the description of |
| Transferring long text from the notification to the MO  |
| Understanding and assigning revision codes for EBB. Furnish employee with EBB list                        |
| Using the radial buttons in the control tab to identify emergency/break-in or planned jobs.               |
| Selecting approver in the partner field of the MO   |
| Tasking operations  |
| Operation activity number   |
| • Work centers  |
| • Short and long text   |
|   |

| Craft number (number of craft per operation)   |
|--|
| Duration hours of operation  |
| Material procurement   |
| Search for SAP-identified materials in the component field   |
| • Search material through the use of the VAM system. Explain what the VAM is, how it is used, and wh   |
| Create requisition from beginning to end (ex. assigning purchasing group, vendor, offset material date |
| Search for material via BOM  |
| • How to request a BOM to be added in SAP  |
| Table Continued  |

**Activity** Scheduling • Know the different planner group codes used for status of work orders and scheduling (ex. 124 = daily Reusable job plans • Have a basic understanding of how to create, edit, and assign reusable job plans (job templates) Closing of MO • See notification closeout and document work history Notifications/Maintenance orders/Order operations • Understand how to create, modify, and execute variants • Know how to use "current function" for viewing layouts • Know how to transport reports form SAP to excel

\_

BOM, bill of materials; VAM, vendor agreement manager; EBB, events based Budgeting; MO, maintenance order.

## Sign Off

| Date | Employee Signature | Team Leader Signature |
|------|--------------------|-----------------------|
|      |                    |                       |

## **Index**

-

Note: Page numbers followed by, "f" and "t" indicate, figures and tables respectively.

## Α

A Strategy for Developing a Corporate-Wide Scoreboard, 43

ACE (a consensus of experts)

system

basic approach, 246–251

benchmark jobs, 251

See also ACE benchmark jobs

performance standards, gaining acceptance for, 246

review session, 254

spreadsheets, developing, 254

team charter, 252

team-based approach, 245-246

team of experts, 251–252

time ranges, 249, 250f–251f

work content comparison, 249–251

work content time, 253, 253f

work groupings, 249, 250f-251f

Team Benchmarking Process™, 19, 69, 91, 208–211, 242, 255f

benchmark jobs, 245

constraints, 243

continuous reliability improvement, 245

evidence of success, 242

expectations, 243

investment for planners, 245

maintenance work measurement tool, 244-246

methodology for applying, 244

note, 243

resources, 243

spreadsheets, 245

team-based approach, 244

ACE benchmark jobs

benchmark jobs, 251

elemental breakdown for, 252

first independent evaluation of, 253

second independent evaluation of, 254

third independent evaluation of, 254

ACE system work groupings and time ranges, 459–460

spreadsheets, 460f

work content comparison, means for, 461–462

for work groups, 468f–470f

standard work groupings, 461f

10-step procedure, 462

planning time elements, 464f

ACE team benchmarking process

analysis sheet, 458f

complete team process, 466f

example process, 459f

job analysis, 455f, 467f–468f

maintenance work measurement tool, 455–457

methodology for, 455–457

planning time elements, 464f

10-step procedure, 457–459

Adjusted averages, 241

Adjustment/alignment, 387

Allowances

application of, 260f

for determining total planned time, 258f

miscellaneous, 259f

personal, fatigue and delay, 259f

American Petroleum Institute (API), 372

Analysis paralysis scheme, 73

Anticline, 372

Applications parts list, 372

Apprentice, 372

Aquifer, 372

Area maintenance, 372

Asset care, 372

Asset list, 372

Asset management, 372

Asset number, 372

Asset register, 372

Asset utilization, 372

Assets, 372

criticality, 237t–240t

history, 103f, 103t, 120

management, definition of, 11

numbering structure, 140t

tracking, 279

Availability, 372

Available hours, 372

Average life, 372

Backlog, 92, 92, 372

calculating weeks of, 164f

definition of, 158

integrity, maintaining, 162f–163f

job status codes, 164f

maintenance resources with, balancing, 163f

management, 159f

monitoring, 162f

ready, 92, 96, 158

reports, 118

total, 91, 96, 158

trends, monitoring, 163f

Bar code, 373

Barrel (BBL), 373

Barrel of oil equivalent (BOE), 373

Baseline information, preassessment checklist for, 60–64

craft labor rates/overtime history, 61

craft skills development, 61

maintenance budget and cost accounting, 61

maintenance storeroom, 62

MRO purchasing operations, 62

organization charts/job descriptions, 61

predictive maintenance, 39–40, 47–48, 57, 61–62

preventive maintenance, 39–40, 47–48, 57, 61–62

reliability centered maintenance, 61-62

total productive maintenance, 61–62

work control, 62

work orders, 62

Basin, 373

Bathtub curve, 154f

Being stationary, effects of, 280–281, 280f

Benchmark(ing), 40–45, 40f, 373

analysis sheet, 248f

baseline value assignment, 54–55

definition of, 40–41

evaluation criteria, format of, 55, 57f

external, 44

functional, 42

internal, 43

international, 44

jobs, 245–246, 251

analysis, 247f

elemental breakdown for, 252

first independent evaluation of, 253

independent evaluation of, 253

second independent evaluation of, 254

third independent evaluation of, 254

levels of, 285f

maintenance, 40f

performance, 41–42

process, 42

results, 54

strategic, 41

Bill of materials (BOM), 109-110, 373

Bitumen, 373

Blanket work orders, 92

Bohai Bay, China, 381

Borehole, 373

Bowers, Terry, 36

Breakdown, 373

Breakdown maintenance, 298, 373

British thermal unit (BTU), 373

Budget, 120

status-operating departments, 121

Built-in test equipment (BITE), 373

Business vacation, 373

 $\mathbf{C}$ 

Calibrate, 373

Call-out, 373

CAPEX, 373

Capital, 373

Carbon capture and storage (CCS), 373

Carbon dioxide equivalents (CO2e), 373

Carbon intensity, 373

Carbon sequestration, 373

Carbon sink, 374

Carlin, Joel, 36

Carrying costs, 374

Casing, 374

Cause of failure, 201

Central maintenance, 374

Centum cubic feet (CFF), 374

Change out, 374

Checkout, 374

Chief maintenance officer (CMO), 3, 374

as maintenance leader, 3-4

pride in ownership, 5

City gate stations, 374

Clean, 374

Closed-loop-type organization, 184f

CMMS benchmarking system, 374

budget and cost control, 443

data integrity, 439–441

bill of materials, 440

equipment (asset) history database, 439

maintaining equipment database, 441

maintaining parts database, 440

preventive maintenance tasks/frequencies, 440

spare parts database, 439–440

education and training, See CMMS education and training

evaluation, 448–452, 449t–452t

installation, 448

maintenance performance measurement, 446–447

maintenance repair operations materials management, 444-445

planning and scheduling, 443–444

preventive/predictive maintenance, 445-446

purpose, 448

uses of, 447 work control backlog reports, 442 function established, 442 online work request based on priorities, 442 priority systems, 442–443 work order system, 442 CMMS education and training initial training, 441 for operations personnel, 441

ongoing training, 441

systems administrator/backup trained, 441

Coal bed methane (CBM), 374

Code, 374

Commodity code, 374

Communication, and leadership, 22

Competitive benchmarking, 41-42

Completion, 374

Component, 375

Component number, 375

Compound annual growth rate (CAGR), 375

Compressed natural gas (CNG), 375

Compression, 405

Compressor, 405

Computerized maintenance management system (CMMS), 14–15, 42–43, 71, 79–80, 82, 87, 92, 241, 285, 305, 307, 375, 439, 471

backlog reports, 118

benchmark evaluation, conducting, 101–120

bill of materials, 109–110

captures reliability data, 134

cost improvements due to, 121

craft hours, work order system accounts for, 118

data integrity, 103t

for developing maintenance operation as profit center, 143

education and training, 112t

equipment database, maintaining, 111–112

equipment history database, accuracy of, 103-104

initial training, 112

ongoing training, 112–113

online work request based on priorities, 118

operations personnel, initial training for, 113

operations understands benefits of, 141

parts database, maintaining, 110–111

preventive maintenance tasks/frequencies, 110

priority system, 120

spare parts database, accuracy of, 107–108

systems administrator/backup trained, 113

uses of, 140t

work control, 114, 114t, 115f-117f

Condensate, 375

Condition monitoring, 375

Conditional probability of failure, 375

Condition-based maintenance (CBM), 375, 389

Conditioning, 387 Confidence, 375 Configuration, 375 Configuration data, 278 Consequence of failure, 224 Construction trade estimates, 241 Consumables, 375 Contingency, 375 Continuous reliability improvement (CRI), 73, 74f, 76, 82–83, 245, 375 Contract acceptance sheet, 376 Contract maintenance, profit and customer-centered, 2–3

Contractor management, 181, 199f, 299

Convenience work, 160f

Conventional resources, 376

Coordination, 167, 168f, 170f, 376

Core competencies, for maintenance, 8

Core requirement, for maintenance,  $\boldsymbol{8}$ 

Corrective maintenance (CM), 376

Cost

avoidance, 71

center, 1–2

control, 120

improvements due to CMMS, 121

life cycle, 122

Craft availability, 376

Craft labor, 121

resources, 69–70, 71f, 76

Craft leaders, 376

PRIDE in Excellence within, 29–30

PRIDE in Maintenance and Construction within, 36–37

PRIDE in Maintenance within, 31–35, 32f, 34f

Craft performance (CP), 71–72, 77, 79–85, 87–88, 139, 241

Craft productivity, 69–71, 85–87, 447t

improved by planning and scheduling, 276f

Craft service quality (CSQ), 26, 72, 77, 82–84

Craft utilization (CU), 68–70, 70f, 76–79, 376

measuring and improving, 128, 128f

Craftsperson, 377

Crescent-Xcelite Plant

leadership buy-in, obtaining, 59-60

operating goals, 57–60

Critical, 377

Critical equipment, 377

Critical path method (CPM), 377

Critical spare, 377

identifying, 132, 133f

Criticality, 377

Crossdocking, 377

Customer-centered benefits, of planning and scheduling, 1-10

Cycle count, 377

Cycle counting, 131, 131f

Data integrity, 103t

Data migration, 99

Davis, Rodney, 36

Dead stocks, 378

Defect, 378

Deferred maintenance, 5–6, 12–13, 120–121, 378

DELPHI technique, 254

Demand, 378

Detailed planning, 207–222

Deterioration rate, 378

Developed acreage, 378

Developed reserves, 378

Development well, 378

Direct cost savings, 71

Direct costs, 378

Directional drilling, 378

Discard task, 378

Disposal, 378

Distribution line, 378

Distribution system, 378

Do it now (DIN) work, 160f

Down, 378

Downtime (DT), 278, 282, 378

Drilling rig, 378

Dry gas, 378

Dry hole, 378

Economic life, 378–379

Economic order quantity (EOQ), 379

Economic repair, 379

Economically producible, 379

Educated guesses, 241

Effective planning, benefits of, 9

Effectiveness factor, 68, 68f, 72

Efficiency, 12

Electronic parts requisitioning, 132, 132f

Elke system, 298

Emergency maintenance, 379

Emergency maintenance task, 379

Emergency work, 161–162

Emotional intelligence, 26

Empowerment, 23

Engineering change, 379

Engineering change notice (ECN), 379

Engineering support, 187f

Engineering work order, 379

Enhanced oil recovery (EOR), 379, 383

Environmental assessment, 379

Environmental consequences, 379

Equipment configuration, 379

Equipment

database structure, 141, 141f

downtime reduction, 139

failure patterns, 154f

history, 208

history database, accuracy of, 103-104, 110-111

records, 207–208

Equipment maintenance strategies, 379

Equipment repair history, 379

Equipment use, 379

Estimated plant replacement value, 379

Estimated ultimate recovery (EUR), 379

Estimating, 11–14, 19

Estimating index, 379

Everhart, Robbie, 36

Examination, 379

Execution, 27

Expediting, 379

Expense, 380

Expensed inventory, 380

Expert system, 380

Exploratory well, 380

External benchmarking, 44

Facilities Management Excellence™, 45

Failsafe, 380

Failure analysis, 380

See also Failure modes, effects, and critical analysis (FMECA)

Failure cause, 380

See also Failure mode

Failure coding, 380

Failure consequences, 380

Failure effect, 380

Failure finding interval, 380

Failure finding task, 380

Failure mode, 380

Failure modes and effects analysis (FMEA), 151f, 343t–345t, 380

of reliability-centered maintenance, 145–156

Failure modes, effects, and critical analysis (FMECA), 380

Failure pattern, 381

Failure rate, 381

Failure reporting analysis and corrective action system (FRACAS), 343t–345t

Failure, 380

Farm-in, 381 Farm-out, 381 Fault tree analysis (FTA), 381 Feedback, accepting, 23 Field, 381 Fill rate, 381 First in still here (FISH), 381 First in-first out (FIFO), 381, 385 Flaring, 381

Floating production, storage, and offloading (FPSO), 381

Forecast, 381

Formation, 382 Forward workload, 382 Fossil fuel, 382 Frequency, 382 Front-end engineering and design (FEED), 382 Fugitive emissions, 382 Function, 382 Functional benchmarking, 42 Functional failure, 382

Functional levels, 382

Functional maintenance structure, 382

Functional test, 387

Gained value, 71

Gantt chart, 382

Gas cost recovery (GCR), 382

Gathering lines, 393

Gathering system, 382

General support equipment (GSE), 382

Generic benchmarking, 42

Global warming potential (GWP), 382

Golden rule, 30, 30

Go-line, 382

Greenhouse gas, 382

GRIDCo Ghana, 420f–421f

CMMS Selection and Best Practices Implementation Team-Draft, 417

leadership driven-self-managed team at, 419

| ٦ | Г | 1 |
|---|---|---|
|   | r |   |

Hardware, 382

Health, safety, security, and environmental (HSSE) challenges, 39, 223

Healthcare Facilities Scoreboard for Maintenance Excellence, 43

Heavy oil, 383

Hidden failure, 383

High quality maintenance contractors, in-house maintenance plus, 5–6

Higher throughput, 297

Historical averages, 241

Hold for disposition stock, 383

Horizontal drilling, 383

Hot work, 383

Human capital, planning and scheduling of, 295f

Hydraulic fracturing, 383

Hydraulic fracturing fluids, 383

Hydrocarbons, 383

Identification, 383

Improved oil recovery (IOR), 383

Indirect costs, 383

Ineffective planning, 171f

symptoms of, 8–9

Infant mortality, 383

Infill wells, 383

Information resources, 53

Inherent reliability, 384

In-house maintenance plus high quality maintenance contractors, 5–6 Injection, 403 In-situ recovery, 384 Inspection plan, creating, 237t–240t Inspection, 384, 387 Insurance items, 384 Interchangeable, 384 Interface, 384 Internal benchmarking, 43 International benchmarking, 44

Interval-based, 384

Inventory, 384

cycle counting, 131, 131f

management module, 131

Inventory control, 384

Inventory turnover, 384

ISO 55000, 39-41, 45

Issues, 384

Item of supply, 384

Item, 384

Jack-up rig, 384

Job close out, 270f

Job follow up, 270f

Job packages, 90–91, 95, 211

items, 221f

planned, 211

Job plan, 95, 201, 206, 304–307

database, 201

labor needs, 305

parts, 305

permits, 305

procedures, 305

special tools and equipment, 305

specifications, 305

Job scope, 304

inspection sheet, 306f-307f

Job status codes, 164f

Joint operating agreement (JOA), 384

Just-in-time (JIT), 384

KAHADA (Keep a half a day ahead), 94

Keep full, 384

See also Shop stock

Key performance indicators (KPIs), 384

Knowing your total maintenance requirements, 386

Knuckle buster, 385

 $\mathbf{L}$ 

Labor estimating, 208–210

Labor libraries, 208

Last in-first out (LIFO), 385

Lead by example, 23–24

Lead time, 385

Leaders vs managers, 21, 22f

Leadership, 21–28

buy-in, obtaining, 59–60

communication, 22

definition of, 21

empowerment, 23

execution of, 27

feedback, accepting, 23

lead by example, 23–24

motivation, 23

opportunity, 26

patience and, 25

perseverance and, 25

personal goals, 26

place in history, believe in, 27

power, 24–25

power of optimism, 22

professional goals, 21

publicity, 22

quality, 22, 26–27

quit from, 27

respect and, 27

responsibilities, 24

self-confidence, 28

style, 25–26

success of, 27–28

vision, 21

Lease, 385

Ledger inventory, 385

Level of repair (LOR), 385

Level of services (stores), 385

Library of planning aids, 208

Life, 385

Life cycle, 297, 385

costing, 122

Life cycle analysis (LCA), 385

Life cycle cost (LCC), 385

Liquefied natural gas (LNG), 385

Local distribution company (LDC), 385, 405

Logistics engineering, 385

Logistics support analysis (LSA), 385

Lubrication services, 134

## M

Main, 385

Maintainability, 385–386

Maintainability engineering, 386

Maintenance, 386

challenges, 173, 175f–176f

contract maintenance, profit and customer-centered, 2-3

core requirement versus core competencies for, 8

costs, 168f

customer service, 139

deferred, 5-6, 12-13, 121

failure of, 313–314

indiscriminate cutting of, 85–86

managed as business, 141

organization, benefits of, 177f–178f

performance measurement process, 139t, 140, 140f

predictive, 14, 39–40, 47–48, 57, 61–62, 71, 73, 89, 92, 94–95, 95f, 128, 133t, 134

preventative, 12–14, 39–40, 47–48, 57, 61–62, 67–69, 71, 73, 89, 92–95, 95f, 110, 128, 133t, 134

profit in, 6–8, 6f

reliability centered, 61-62, 138f

standard task database, 142

storeroom, 62

strategies, development of, 224f

technical library, 207, 210f

total productive, 61–62

as traditional cost center, 1-2

winning, 388, 404

Maintenance business process improvement, 386

Maintenance business system, planner review of, 99–144

computerized maintenance management system

backlog reports, 118

benchmark evaluation, conducting, 101–120

bill of materials, 109–110

craft hours, work order system accounts for, 118

data integrity, 103t

education and training, 112t

equipment database, maintaining, 111–112

equipment history database, accuracy of, 103-104

initial training, 112

ongoing training, 112–113

online work request based on priorities, 118

operations personnel, initial training for, 113

parts database, maintaining, 110–111

preventive maintenance tasks/frequencies, 110

priority system, 120

spare parts database, accuracy of, 107-108

systems administrator/backup trained, 113

work control, 114, 114t, 115f-117f

Ranking Index of Maintenance Expenditures (RIME) system, 120–143, 120f

budget and cost control, 120

budget status-operating departments, 121

CMMS captures reliability data, 134

CMMS, operations understands benefits of, 141

complete PM/PDM task descriptions, 134

cost improvements due to CMMS, 121

craft labor, 121

craft performance, 139

craft utilization, measuring and improving, 128, 128f

critical spares, identifying, 132, 133f

deferred maintenance, 121, 121f

electronic parts requisitioning, 132, 132f

engineering changes, 141

equipment database structure, 141, 141f

equipment downtime reduction, 139

inventory cycle counting, 131, 131f

inventory management module, 131

life cycle costing, 122, 122f

long range PM/PdM scheduling, 134

lubrication services, 134

maintenance customer service, 139

maintenance managed as business, 141

maintenance performance measurement process, 139t, 140, 140f

maintenance standard task database, 142

MRO materials management, 130t–131t

parts kitting and staging, 131, 132f

parts of, 121

planned work, increasing, 128, 128f

planning and scheduling, 122, 123f–127f

PM/PdM change process, 134

PM/PdM compliance, 134

reliability centered maintenance, 138f

reorder notification process, 133

scheduling coordination with operations, 130

spare parts status, 130

true emergency repairs, tracking, 130

vendor support costs, 121

warranty information, 133

work schedules, 128, 129f

Maintenance coordinator, 308–311

Maintenance coordinator

duties and responsibilities, 409

job evaluation form, 409–413

primary purpose, 409

task list, 414f-415f, 415, 416

Maintenance engineering, 386

Maintenance excellence, scoreboard for

computerized maintenance management systems (CMMS) and business systems, 354t

continuous reliability improvement, 355t-356t

contractor management, 332t-334t

craft skills development and technical skills, 321t-322t

critical asset facilitation and overall equipment effectiveness (OEE), 356t-357t

energy management and control, 350t

health, safety, security, and environmental (HSSE) compliance, 351t-352t

maintenance and quality control, 352t

maintenance business operations, budget and cost control, 324t–325t

maintenance engineering and reliability engineering support, 351t

maintenance leadership, management and supervision, 323t

maintenance organization, administration and human resources, 319t-321t

maintenance performance measurement, 353t

maintenance strategy, policy and total cost of ownership, 316t–318t

management of change (MOC), 362t-363t

manufacturing facilities planning and property management, 334t-335t

MRO materials management and procurement, 336t-337t

operator-based maintenance and pride in ownership, 322t

organizational climate and culture, 318t–319t

overall craft effectiveness (OCE), 357t-358t

predictive maintenance and condition monitoring technology applications, 338t—339t

preventive maintenance and lubrication, 337t-338t

pride in maintenance, 366t–367t

process control and instrumentation systems technology, 349t-350t

process safety management (PSM), 362t-363t

production asset and facility condition evaluation program, 335t

reliability analysis tools, 343t–345t

reliability-centered maintenance (RCM), 339t-343t

risk mitigation, 363t–366t

risk-based inspections (RBI), 363t-366t

risk-based maintenance (RBM), 345t-349t

shop facilities, equipment, and tools, 354t-355t

shop-level reliable planning, estimating and scheduling (M/R), 328t–331t

STO and major planning/scheduling with project management, 331t–332t

storeroom operations and internal MRO customer service, 335t-336t

sustainability, 358t-359t

top leaders' support to management, 315

traceability, 359t–361t

work management and control: maintenance and repair (M/R), 325t–326t

work management and control, shutdown, turnarounds, and outages (STO), 326t–328t

Maintenance Excellence Institute International, 32, 73, 244–246

Maintenance excellence strategy team, 45–47

Maintenance leaders, 3-5, 8, 12-14, 185f, 386

distinguished from maintenance managers, 21, 22f

gambling, 1

Maintenance Leadership Team, 35

Maintenance managers, 4

distinguished from maintenance leaders, 21, 22f

Maintenance planner/scheduler

duties and responsibilities, 409

job evaluation form, 409–413

primary purpose, 409

task list, 414f-415f, 415, 416

Maintenance policy, 386

Maintenance repair operations (MRO), 115f-116f, 386, 444

materials management, 444-445

See also Maintenance repair operations materials management

parts and material resources, 53

purchasing operations, 62

Maintenance repair operations materials management, 277f, 130t–131t, 277–284

data, 278–279

spare parts ownership, 281–282

spares maintenance program, establishing, 282

spares storage, 279–281

being stationary, effects of, 280–281, 280f

exposure to environment, 279–280

storeroom function, 281

Maintenance requirements, 386

Maintenance schedule, 387

Maintenance shutdown, 387

Maintenance strategy, 387

Maintenance supervisor, 173

role of, 174, 185f–186f

Maintenance task routing file, 387

Management of change (MOC), 388

Master schedule, 474–477, 474t–475t

instructions for use, 475–477

Material library, 210

Maximum corrective time (MCT), 397

Maximum preventive time (MPT), 397

McDonald, Larry, 30

Mean active maintenance time (MAMT), 397

Mean downtime (MDT), 397

Mean time between failures (MTBF), 372, 388, 397

Mean time between maintenance (MTBM), 397

Mean time to repair (MTTR), 388, 397

Measure contractors, 91

Mercaptan, 388

Miscellaneous allowances, 259f

 $Mitigation\ measures,\ 237t-240t$ 

Model work order, 388, 402

See also Standard job

Modification, 388

Modularization, 388

Most valuable people (MVP), 388

Most valuable player (MVP), 32f

Motivation, 23

MP2, 298

MRO materials management, 388

Natural gas, 388

Natural gas liquids (NGLs), 388

Natural gas vehicle (NVG), 388

Net acres, 388

No scheduled maintenance, 388–389

See also Run-to-failure

Nondestructive testing (NDT), 388

Nonoperational consequences, 388

Nonrepairable, 388

Nonroutine maintenance, 388



Obsolescence, 389

Obsolete, 389

Odorant, 389

Oil analysis, See Teratology

Oil sands, 389

On-condition maintenance, See Condition-based maintenance (CBM)

One million barrels (MMBBL), 389

One million cubic feet (MMCF), 389

One thousand cubic feet (MCF), 389

Online work orders, 118

Operating context, 228f, 389

Operating hours, 389

Operational consequences, 389

Operational efficiency, 389

Operations leaders, defining results to, 11-20

Operator, 389

Operator-based maintenance (OBM), 389

Opportunity, 26

Optimization, 67

Order point, 389

Order quantity, 389

Original equipment manufacturer (OEM), 406

Outage, 389

Overall craft effectiveness (OCE), 12, 15–16, 72, 72f, 241, 389

calculation of, 74f

 $comparison\ with\ overall\ equipment\ effectiveness,\ 73f$ 

data collection, technology for, 87-88

elements of, 83

gained value, 85

Overall equipment effectiveness (OEE), 68, 390, 404

comparison with overall craft effectiveness, 73f

Overhaul, 390

Pareto's principle, 390

Part numbers, 390

Parts and material resources, 53

Parts inventory master, 103f, 103t, 130t–131t

Parts kitting, 131, 132f

Parts maintenance, 167–168, 169f

PASS 55: 2008, 39-40

Patience, 25

Pay-me-later syndrome, 5–6

People resources, 51

Percent planned work, 390

Performance benchmarking, 41–42

Performance factor, 68, 68f, 72

Periodic maintenance, 390

Permeability, 391

Perseverance, 25

Personal, fatigue and delay allowance (PF&D), 259f

Peters, Pete, 36

P–F interval, 1, 2f, 153f, 391

Physical asset and equipment resources, 53

Physical asset management, 1–3, 11

Pick list, 391

Planned job packages, 211

Planned maintenance, 391

Planned work, increasing, 128, 128f

Planner skills, 307

Planner worksheet, 222f

Planners/schedulers (P/S), 5, 14, 18–19, 31, 34–35

factors influencing, 191f

hiring, 89–98

position goals and relationships, 96

roles and responsibilities, 89–96

selection criteria, 96–97

needs of, 188f-189f

qualities of, 192f

ratio of crafts to, worksheet for, 190f–191f

responsibilities of, 187f–188f

right things, 179f

Planning, 11–19, 302–303

aids, library of, 208

detailed, 202, 207–222

failure of, 313–314

of human capital, 295f

ineffective, 171f

job, 304–307

profit and customer-centered benefits of, 1–10

promoted by storerooms, 182f

skills, 303

maturing process, signs of, 209f

RIME system, 122, 123f–127f

storerooms support to, 182f

times, 79–82, 84

Plant engineering, 90, 391

Plant operating goals, 57–60

Play, 391

Porosity, 391

Possible reserves, 391

Potential failure, 391

Pounds per square inch (Psi), 391

Power, 24–25

Power of optimism, 22

Predictability, 313

Predictive maintenance (PDM/PdM), 14, 39–40, 47–48, 57, 61–62, 71, 73, 89, 92, 94–95, 95f, 128, 133t, 392

change process, 134

complete task descriptions, 134, 135f-138f

compliance, 134

long range scheduling, 134

Preplanned job packages, 305

Preventive maintenance (PM), 12–14, 39–40, 47–48, 57, 61–62, 67–69, 71, 73, 89, 92–95, 95f, 128, 133t

change process, 134, 392

See also Scheduled maintenance (SM)

complete task descriptions, 134

compliance, 134

long range scheduling, 134

tasks/frequencies, 110

PRIDE in Excellence, 29–30

PRIDE in Maintenance, 31–33, 32f, 73–74, 75f, 76, 392

gaining support from craft workforce, 33–35

positive and proven approach, 33, 34f

PRIDE in Maintenance and Construction, 36–37

PRIDE in Work, 30

Priority, 392

Priority systems, 120, 159f

Proactive maintenance, 392

Proactive planned work, 180f

Probabilistic risk assessment, 392

Probabilistic safety assessment, 392

Probability of failure (POF), 223

Probable reserves, 392

Process benchmarking, 42

Process mapping, 42, 168

Process safety management (PSM), 392

Processing, 392 Processing natural gas, 393 Procurement, 393 Produced water, 393 Production, 393 Production sharing contract (PSC), 393 Productive well, 393 Productivity, 12 categories of, 67 definition of, 67–68

Profit

ability, 3

in maintenance, 6–8, 6f

optimization, 3–4

Profit and customer-centered maintenance (PCCM), 393-394

Profit-centered benefits, of planning and scheduling, 1–10

Profit-centered maintenance (PCM), 393

Project evaluation and review technique (PERT) chart, 394

Proppant, 394

Protective device, 394

Proved developed reserves, 394

Proved reserves, 394

Provisioning, 394

Publicity, 22

Purchase order, 394

Purchase requisition, 394

Purchasing benefits, 178f

Purchasing/stores, 210

Quality factor, 68, 68f, 72

Quality of leadership, 22, 26–27

Quality rate, 395

Questa, Carole, 36



Range of time concept, 246

Ranking Index for Maintenance Expenditures (RIME) system, 120–143, 120f, 159f–160f, 161, 397

benefits of, 161f

budget and cost control, 120

budget status-operating departments, 121

## **CMMS**

operations understands benefits of, 141

reliability data, 134

complete PM/PDM task descriptions, 134

cost improvements due to CMMS, 121

craft labor, 121

craft performance, 139

craft utilization, measuring and improving, 128, 128f

critical spares, identifying, 132, 133f

deferred maintenance, 121, 121f

electronic parts requisitioning, 132, 132f

engineering changes, 141

equipment

database structure, 141, 141f

downtime reduction, 139

inventory cycle counting, 131, 131f

inventory management module, 131

life cycle costing, 122, 122f

long range PM/PdM scheduling, 134

lubrication services, 134

maintenance customer service, 139

maintenance managed as business, 141

maintenance performance measurement process, 139t, 140, 140f

maintenance standard task database, 142

MRO materials management, 130t–131t

parts kitting and staging, 131, 132f

parts of, 121

planned work, increasing, 128, 128f

planning and scheduling, 122, 123f–127f

PM/PdM

change process, 134

compliance, 134

reliability centered maintenance, 138f

reorder notification process, 133

scheduling coordination with operations, 130

spare parts status, 130

true emergency repairs, tracking, 130

vendor support costs, 121

warranty information, 133

work schedules, 128, 129f

RCM++, 229, 229f-232f

Reaction time/response time, 395

Reactive planned work, 180f

Ready backlog, 92, 96, 158

Ready line, 395

Reasonable certainty, 395

Rebuild, 395

Rebuild/recondition, 395

Recompletion, 395

Recordable cases, 395

Redesign, 395

Redundancy, 395

Refinery process flow, 173, 174f–175f

Refinery work flow, 211, 212f-220f

Refinery, process mapping for

facilities and services work analysis process, 431f

facilities and services work documentation process, 437f

facilities and services work execution process, 431f

contractor work accountability process, 436f

emergency deviance and schedule deviation process, 434f

job change order process, 433f

job site data collection process, 435f

rental process, 432f

facilities and services work identification, 425f

after hours, 426f

facilities and services work planning process, 427f–428f

project work, 429f

facilities and services work scheduling process, 430f Refurbish, 395 Reliability, 395 Reliability analysis, 395 Reliability centered maintenance (RCM), 61–62, 73, 88, 138f, 145–156, 395– 396 bathtub curve, 154f decision diagram, 152f default actions, 155f elements of, 146f equipment failure patterns, 154f

failure consequences of, 152f

failure effects of, 150f

failure modes and effects analysis of, 151f

failure modes of, 149f

functional failure of, 148f–149f

functions and performance standards of, 148f

implementation of, 147f

operating context, 146

P–F interval, 153f

principles of, 146f

proactive maintenance of, 153f

Reliability engineering, 396

Reliability improvement, 29, 33

Reliability performance indicators (RPI), 397

Reliable Maintenance Excellence Index (RMEI), 17–19, 42–44, 43f, 95, 285–296, 286f–290f

customer-centered, 295f

development of, 287f, 290f-291f

human capital, planning and scheduling of, 295f

performance data collection, 295f

performance metrics and purpose, 291f–295f

profit-centered, 295f Reliable planning times, 244 ReliaSoft, 229 Remove, 387 Remove and reinstall, 387 Remove and replace, 387 Reorder notification process, 133 Reorder point (ROP), 396

Repair, 396

Repair parts, 396

See also Order point

Repairable, 396 Repetitive jobs, 202 Replaceable item, 396 Reserves, 397 Reservoir, 397 Resources, 397 Respect, 27 Responsibilities of leadership, 24

Restoration, 397

Return-on-assets, 397

Return on capital employed (ROCE), 397

Risk, 397

definition of, 223

matrix, 226f

ranking, 237t–240t

Risk-based inspection (RBI), 223–240, 397–398

equipment, 229f-230f

software, 229–232

Risk-based maintenance (RBM), 223-240, 225f-226f, 395

case study example, 232-236, 232f-236f

category 22 for, 237t–240t

factors for implementation, 227f

operating context, 228f

outline of, 225f

overview of, 227f

quantitative analysis, 228f

results, 236-240, 236f

risk matrix, 226f

Robinson, Ricky, 36

Root cause analysis (RCA), 343t–345t

Root cause corrective action (RCCA), 343t–345t

Rotable, 398

Routine maintenance task, 398

Routine maintenance work

acceptance process, 219f-220f

execution process, 219f

planning process, 215f–216f

scheduling process, 217f–218f

Routine planner training checklist

personal details, 483

basic, 483–485

SAP, 485–487

sign off, 487

Running maintenance, 398

Run-to-failure, 398

Run-to-failure strategy, 122

Safety consequences, 398

Safety stock, 398

Salvage, 398

Schedule compliance, 398

Scheduled discard task, 398

Scheduled maintenance (SM), 392, 398

Scheduled operating time, 398

Scheduled restoration task, 398

Scheduled work order, 399

Scheduling, 11–19, 257–276, 308–313, 310f

allowances, application of, 260f

compliance, 270f–271f, 273f–274f

coordination meeting, preparation for, 261f–264f

coordination required by planners for, 260f-261f

coordination with operations, 130

function, measures for, 274f-276f

guidelines for completing, 264f–270f

of human capital, 295f

job close out and follow up, 270f

key procedures for, 263f

long range PM/PdM, 134

miscellaneous allowances, 259f

non-compliance, reasons for, 271f–273f

performance, 273f–275f

personal, fatigue and delay allowance, 259f

profit and customer-centered benefits of, 1-10

RIME system, 122, 123f–127f

total planned time, allowances for determining, 258f

travel time, 258f–276f

Scope of work, 90–92, 201, 207–222

Scoping, 399

Scoreboard for Excellence, See Scoreboard for Facilities Management Excellence, Scoreboard for Maintenance Excellence

Scoreboard for Facilities Management Excellence, 43, 399

Scoreboard for Fleet Management Excellence, 43

Scoreboard for Maintenance Excellence, 13–17, 31–33, 95

baseline information, preassessment checklist for, 60-64

craft labor rates/overtime history, 61

craft skills development, 61

maintenance budget and cost accounting, 61

maintenance storeroom, 62

MRO purchasing operations, 62

organization charts/job descriptions, 61

predictive maintenance, 39–40, 47–48, 57, 61–62

preventive maintenance, 39–40, 47–48, 57, 61–62

reliability centered maintenance, 61–62

total productive maintenance, 61–62

work control, 62

work orders, 62

benchmark evaluation criteria, format of, 57f

continuous reliability improvement, 48f, 59f

current position of, determining, 47–48, 49f–50f, 52f

definition of, 41

evolution of, 45-47, 46f

external benchmarking, 44

functional benchmarking, 42

internal benchmarking, 43

maintenance benchmarking, 40f

maintenance resources, 51f

hidden resources, 53–57

information resources, 53

parts and material resources, 53

people resources, 51

physical asset and equipment resources, 53

technical skill resources, 53

1993 version of, 47f

performance benchmarking, 41–42

physical asset management strategy with, 39-66

plant operating goals, 57–60

process benchmarking, 42

rating summary comments, 56f

self-assessment, 60f

strategic benchmarking, 41

Scoreboard for Maintenance Excellence, 399–400

Secondary damage, 401

Secondary failures, 401

Secondary function, 401–402

Self-assessment, 60f

Self-confidence, 28

Selling benefits, 172f, 173, 177f

Serial number, 402

Service contract, 402

Service level, 402

Service line, 402

Serviceability, 402

Servicing, 402

Shale, 402

Shelf life, 402

Shop load plan, 471–474, 471t–472t

instructions for use, 474

Shop schedule, 477–478

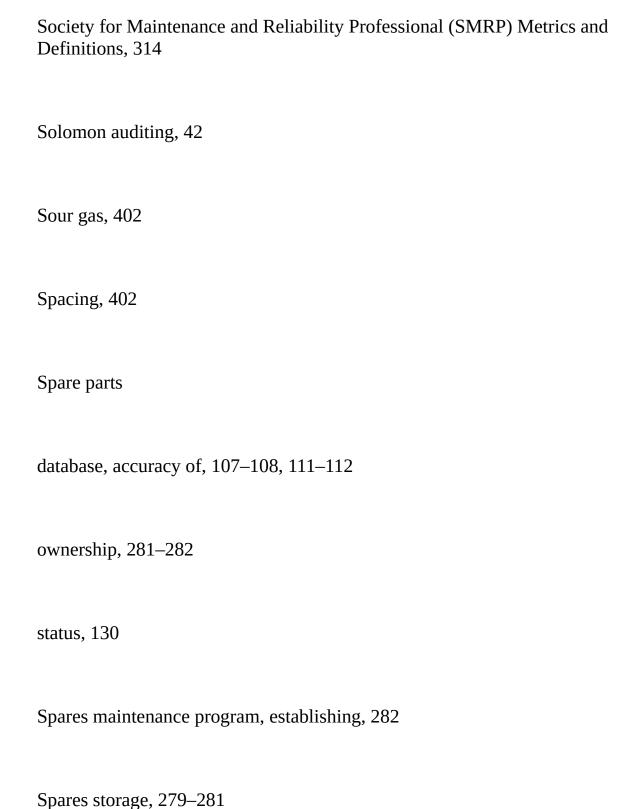
sample, 479f

4-week shop look-ahead of resources by trade type, 481f

PM leveling and planning by shop area, 480f weekly maintenance work schedule at 90% loading, 482f Shop stock, 384, 402 Short, Eddie, 36 Shutdown, 402 Shutdown maintenance, 402 Shutdown, turnaround, or outage (STO), 116f-117f, 126f-127f, 174-181, 198f, 402 Slotting, 242, 246

Social life cycle analysis (S-LCA), 402

Snea, Keith, 36



being stationary, effects of, 280–281, 280f

exposure to environment, 279–280

Spares tracking, 279

Special skills, 93

Specifications, 402

Spreadsheets, 245, 249–252, 249f–250f, 257f

developing, 254

Staffing, 168f

Standard item, 402

Standard job, 402

See also Model Work Order

Standard operating procedure (SOP), 211, 242

Standardization, 402

Standby, 402

Standing work orders, 92, 402–403

Steam-assisted gravity drainage (SAGD), 403

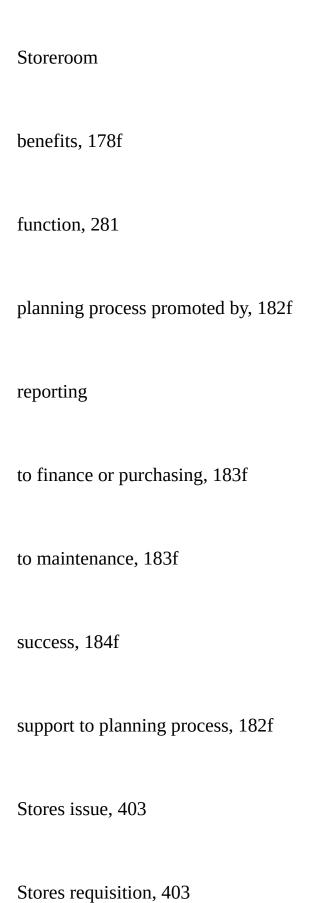
Stock keeping unit (SKU), 403

Stock number, 403

Stock out, 403

Storage, 403

Storage underground, 403



Strategic benchmarking, 41

Supply, 403

Support equipment, 404

Sustainability, 16–17, 404

Sweet gas, 403

Systems Performance Team, 36

Teamwork works, 404

Technical data and information, 404

Technical skill resources, 53

Teratology, 389, 405

Terotechnology, 404

Test and support equipment, 404

The Maintenance Excellence Institute (TMEI), 386

The Maintenance Excellence Institute International (TMEII), 12, 39–41, 43, 48–51, 59

Thermography, 404

Throwaway maintenance, 404

Thurston, Julie, 36

Tight gas, 405

Time standards for maintenance work

adjusted averages, 241

construction trade estimates, 241

educated guesses, 241

historical averages, 241

slotting, 242

universal maintenance standards, 242, 246

Top leaders, 404

defining results to, 11–20

Top management support, 297–298, 300

Total asset management, 404

Total backlog, 91, 96, 158

Total cost of ownership, 206

Total maintenance requirements (TMR), 12–13, 19, 91, 157–158, 162–165

Total operations success, 12

Total planned time, allowances for determining, 258f

Total productive maintenance (TPM), 61-62, 73, 404

Total recordable rate (TRR), 405

Total shareholder return (TSR), 405

Total system support (ToSS), 405

Traceability, 404–405

Tradesperson, 405

Transmission, 405

Transmission lines, 405

Transportation, 405

Travel time, 258f–276f

Troubleshooting, 92, 201, 387, 405

True emergency repairs, tracking, 130

TrueWorkShops™, 32

Turnaround time, 405

Turnover, 405

Unconventional reservoirs, 405–406

Undeveloped acreage, 406

Unit, 406

Universal maintenance standards (UMS), 242

Unplanned downtime, 297, 299

Unplanned maintenance, 406

Unscheduled maintenance (UM), 406

Up, 406

Uptime, 406

Usage, 406

Useful life, 406

Utilization, 406

Value engineering, 406

Value-adding investments, 4

Variance analysis, 406

Vendor support costs, 121

Vibration analysis, 406

Vision of leadership, 21

## $\mathbf{W}$

Wall, Joe, 36

Warranty, 406

claims, 406

information, 133

Waterflood, 406

Wear out, 406

Wellhead, 393

Wet gas, 406

Willis, Ed, 36

Withdrawal, 403

Work content, 246–247

comparison, 249–251

Work control, 62, 114t, 180, 193f-197f

Work identification, 212f-214f

Work order (WO), 62, 201-206, 202f-205f, 278, 407

blanket, 92

cause of failure, 201

criteria for, 206f

as prime source for reliability information, 206

processing, 213f–214f

standing, 92

Work requests, 89–90, 92, 407

Work schedules, RIME system, 128, 129f

Working interest, 407

Workload, 407

World-class wrench time, 302

Wrench time, 68–71, 76–84, 83f, 87–88, 257f, 258, 307–308, 314

definition of, 302

world-class, 302

X-maintenance, 407

Zero-based budgeting, 407

## Appendix I

## **Management of Change (MOC) Procedures Example**

\_



Health, Safety, Security and Environmental (HSSE)
Management System (HSSE MS)

## Management of Change (MOC) Procedure

Document Number: 02/GP/PJ/PR/009/A01

#### **Appendix 1 Project communications routes.**

#### Introduction

The company recognizes that changes are inevitable and initiated during the course of project development and execution; these changes may or may not have a significant impact upon environment, community, safety, integrity, cost, or schedule. Notwithstanding the severity or magnitude of the change, the processes for managing changes will be according to this document, supplemented by other procedures from the suite of change control processes, such as technical queries; deviations; environmental, social, and health/safety nonconformances; variations orders; etc.

Change management procedures are developed to ensure that changes are properly reviewed and approved by persons with the required expertise prior to implementation, to eliminate workplace hazards that could lead to injuries, equipment damage, production losses, project reputational impact, or environmental impact. Also, accountability for proper change implementation of change management review procedures will address both permanent and temporary changes. Temporary change reviews and approvals will specify the duration of the change and will require review if an extension is required. Temporary changes are to be considered in the same manner as permanent changes.

#### **Definitions and Abbreviations**

| CN               | Change notification  |
|------------------|--|
| DCC              | Document control center  |
| ESHS             | Environmental, social, and health and safety                                       |
| GM               | General manager  |
| IFIs             | International financial institutions providing finance to the projects             |
| MCC              | Management of change control coordinator   |
| PM               | Project manager  |
| PCMT             | Project construction management team, a group consisting of representatives fro    |
| RPNR             | Reassessment of project requirements in terms of project deign capacity, consum    |
| VO               | Variation order  |
| VOR              | Variation order request  |
| Deviations       | This is the formal documentation that a change not affecting the scope of work (   |
| Key areas        | The disciplines or departments that may be affected by the change and must, the    |
| Project sponsors | The company and all or any of its co-investors who hold a financial interest in th |

#### -

# Responsibilities

All members of the project team, including the company, project sponsors, contractors, and vendors, are responsible for identification, communication, and management of change. The management of change process provides the project team with an early warning of conditions that might affect one or more of the following key areas:

- Reassessment of project needs or requirements (RPNR)
- Equipment
- Materials
- Documentation (drawings, plans, specifications, procedures)
- Organizational
- Environmental, social, and health/safety
- Cost and/or schedule
- Logistics
- Security
- Other

When reviewing a potential change, it is important that each of the above key areas is considered, as each one could be influenced by, and in turn affect, others. Also, the potential changes should be circulated around the project in an expeditious manner so that a positive and prompt response can be issued to the

initiator of the change notice.

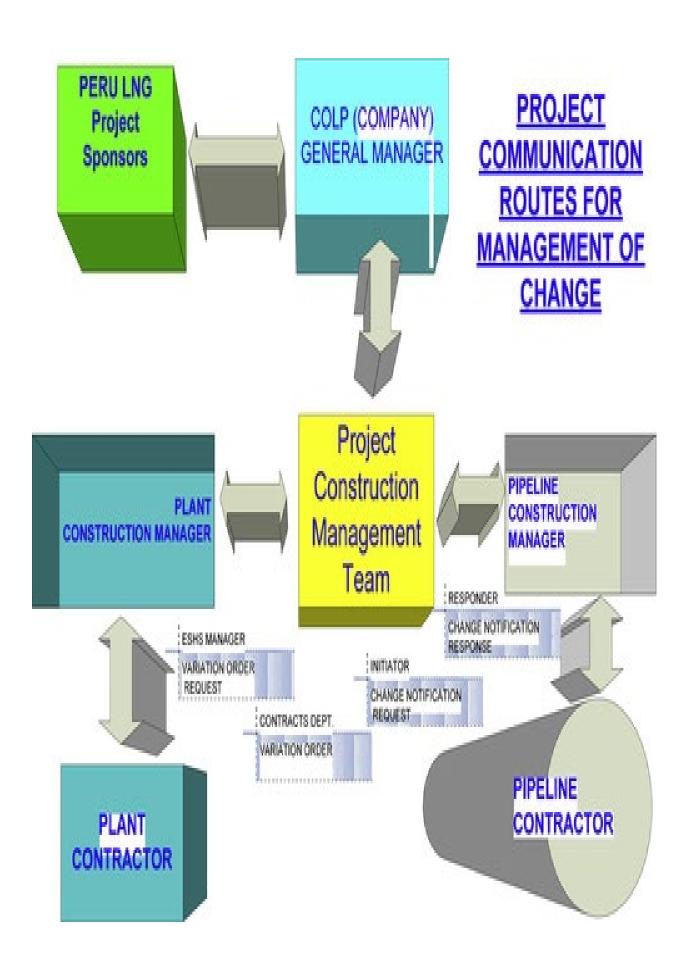
The management of change process project communication routes are illustrated in Appendix 1.

# **Accountability**

A management change coordinator (MCC) shall be appointed for the plant and pipeline construction project. The discipline of the MCC will depend on the nature of the change. Where the change affects the whole project and not just one of the functions, the construction manager shall take the lead. The responsible person shall remain the plant or pipeline construction manager even when the MCC has been delegated the task. The appointed management change coordinator shall ensure that the requirements of this procedure are followed and fully implemented.

#### **Process**

The early identification, communication, and management of change are the responsibility of all members of the project management team, contractors, and suppliers. The management of change review process is illustrated Figure I.1. Once a potential change is identified, the initiator shall advise the project construction management team via a change notification (CN) form (Figure I.2). The construction manager will then designate an MCC to complete sections 1 and 2 of the CN form and the reviewers' required part in section 3. Each CN form will have a unique number (Figure I.3).



#### Figure I.1 Management of change review process.

The change notice request form shall then be sent to all identified reviewers, and the accountable person for the plant or pipeline.

The impact with an estimate of accuracy and the forecasted effect on the schedule (days/weeks) should be added to the CN Form. Any extended comments and relevant backup documents should then be attached to and become part of the CN Form.

The reviewers shall review the data supplied and form a team; whether this is physical team that is able to meet depends on the locations of the individuals. At minimum, the team should meet, via conference call if required, to discuss each reviewer's perspective on the proposed change.

If the change notice cannot be accepted in its present form, the reviewers may request risk assessments or mitigation measures to be developed and implemented. The parties involved shall include the following:

- Initiator: the party identifying the change or initiating the MOC process
- Responsible: plant and pipeline construction managers
- Accountable: plant and pipeline project managers
- Consulted: engineering manager, health and safety (H&S) manager, environmental and community affairs manager, environmental supervisors, community affairs supervisors, security director

All parties involved can question the change. All questions must be resolved before the CN can be approved for implementation. Reviewers may reject the change if their concerns cannot be allayed through risk assessment or identified mitigation measures being implemented.

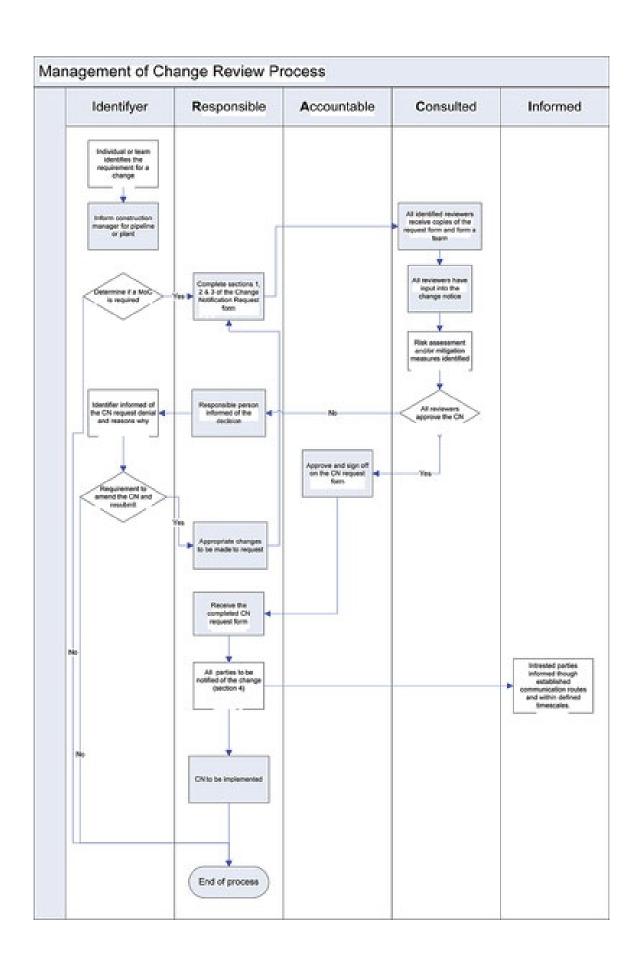


Figure I.2 Change notification form.

Note: Utilize this link to go to Form Template.

|  |  | Request F                                  | orm        | 400000   | -2007                  |  | HERE T             | 30.00                 |
|--|--|--|------------|--|------------------------|--|--------------------|-----------------------|
| Facility:  | Area:  |  |            | Equipn   | nent LD.:              | Origi  | nator:             | Date: (sampony)       |
| Description of Proposed Cha  | nge/Modificat  | tion:                                      |            | -  | CN NO:                 |  | ☐ Permanent        | ☐ Temporary           |
| ☐ Equipment  |  |  |            |  |                        |  |                    | -33                   |
| ☐ Materials  |  |  |            |  |                        |  |                    |                       |
| ☐ Documentation  |  |  |            |  |                        |  |                    |                       |
| ☐ Organization   | -  |  |            |  |                        |  |                    |                       |
| □ Elis   | -  |  |            |  |                        |  |                    |                       |
| Cost and/or Schedule   | -  |  |            |  |                        |  |                    |                       |
| Logistics  | -  |  |            |  |                        |  |                    |                       |
|  | -  |  |            |  |                        |  |                    |                       |
| Other Technics   | d Basis for th   |  |            |  |                        |  |                    |                       |
|  |  |  |            |  |                        |  |                    |                       |
| Essential & Immediate  | Пс   | nstruction                                 | Mand       | Ins  | afety Need             | Пв   | rvironmental Need  | ☐ Desimble            |
| Requires Project Shutdown o  | The second second  |  | arccu.     | ☐ Yes  | □ No                   | Description of the last of the | red Date: assurero | LT resultance         |
| Temporary Changes:   | From   |  | MM/DE      | Name .   | 100                    | _  | (Approval requi    | red for extension)    |
| Please attack: Supporting D  | ocumentation:  | (drawing                                   | s, calcul  | ations, doc  | uments, etc.)          |  |                    |                       |
|  | and Endorser   |  | -          |  |                        |  | 200                |                       |
| SOCIEDE 21 BOYDON I  | and Engorser   | MARCHINE .                                 |            |  |                        |  |                    |                       |
|  |  |  | nroved     | T  | Signature              |  | Date               | Comments              |
| Participants   | Req'd  |  | proved     | No   | Signature              | Ŧ  | Date               | Comments              |
| Participants<br>Operations   |  | Ap   | proved     | No<br>No   | Signature              | Ŧ  | Date               | Comments              |
| Participants Operations First Line Management Maintenance  |  | Yes Yes                                    | proved     | No<br>No   | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety   |  | Yes Yes Yes                                | proved     | No<br>No<br>No                                     | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment   |  | Yes Yes Yes Yes                            | proved     | No<br>No<br>No<br>No                               | Signature              | Ī  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment Engineering   |  | Yes<br>Yes<br>Yes<br>Yes<br>Yes<br>Yes     | proved     | No<br>No<br>No<br>No                               | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect  |  | Yes Yes Yes Yes Yes Yes Yes Yes Yes        | proved     | No<br>No<br>No<br>No<br>No<br>No                   | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting  |  | Yes    | proced     | No<br>No<br>No<br>No<br>No<br>No<br>No             | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other  | Reg'd  | Yes    |            | No<br>No<br>No<br>No<br>No<br>No                   | Signature              |  | Date               | Comments              |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other  | Req'd  | Yes    |            | No<br>No<br>No<br>No<br>No<br>No<br>No             | Signature<br>Regulator |  |                    | Comments<br>crs Group |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod. Accounting Other Section 4: Notificat  | Reg'd  | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No             | Regulator              |  | Lená               |                       |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 4: Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P&   | Reg'd  Grow/Updates  PL2  Ired  ID's  nyouts/ Gener  | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 41 Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EHS Management System  | Reg'd  Gons/Updates PL2  red  ID's nyouts/ Gener   | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 4: Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EHS Management Systee Contingency Plan   | Reg'd  Gons/Updates PL2  red  ID's nyouts/ Gener   | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 4: Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EHS Management Systee Contingency Plan Construction Procedures                                 | Reg'd  Gons/Updates PL2  red  ID's nyouts/ Gener   | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other  Section 4: Notificat Partners  Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EHS Management System Construction Procedures Training                                       | Reg'd  Gons/Updates PL2  red  ID's nyouts/ Gener   | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 4: Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EHS Management System Contingency Plan Construction Procedures Training Standing Order / Rules | Reg'd  Gons/Updates PL2  red  ID's nyouts/ Gener   | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená               | ers Grosep            |
| Participants Operations First Line Management Maintenance Safety Environment Engineering Inst / Elect Prod Accounting Other Section 4: Notificat Partners Updates Requi File(s) Drawing(S) - PFD's, P& SLD's, Plot Plans/La Arrangements Major Equipment / I SD Key EPIS Management System Contingency Plan Construction Procedures Training                       | Reg'd  Re | Ap Yes | il fanager | No<br>No<br>No<br>No<br>No<br>No<br>No<br>No<br>No | Regulator              |  | Lená: Assigned Re  | ers Grosep            |

#### Figure I.3 MOC decision tree.

# **Common Justifications for a Change**

The most common justifications for changes are listed on the CN form and include the following:

\_

| NO.             | Type of issue | Description   |
|-----------------|---------------|---|
| 1.              | RPR change    | Partners require a technical scope change.                      |
| 2.              | ESHS          | The change will potentially affect the health and safety of per |
| Table Continued | •             |   |

| NO. | Type of issue    | Description   |
|-----|------------------|---|
| 3.  | Functional       | The facilities cannot function/be operated/be maintained as required wi   |
| 4.  | Constructability | The facilities cannot be fabricated or constructed as designed or specifi |
| 5.  | Statutory        | The change is necessary to comply with legislation or other mandatory     |
| 6.  | Schedule         | The schedule may be at risk if the change cannot be accommodated.         |
| 7.  | Procurement      | Supplier cannot meet previous commitments and obligations.                |
| 8.  | Security         | Exposure to security risk is increased/decreased.                         |

# **Routing of the CN**

The assignment of file numbers to CN forms shall be responsibility of the company's MCC. The CN form, with any associated reference documents, is raised and signed by the originating entity; this shall include details of estimated costs and schedule impact.

The impact with an estimate of accuracy and the forecasted effect on the schedule (days/weeks) should be added to the CN. Any extended comments and relevant backup documents should then be attached to the CN and become part of the CN.

All CNs are to be signed by the technical authority who then forwards to the company's MCC, who shall, in turn, facilitate the required company signatures.

Subsequently, the MCC then passes the CN around the project for input (if applicable), on the key areas by each of the following company departments:

- Construction management
- Environment and social
- H&S department (for H&S issues)
- Other personnel, if applicable, for specialist topics

• Project management, and above, where financial authorities are exceeded

It should be noted that at any of the above reviews, the basis of the CN can be rejected/questioned; these must be resolved if the CN is to be approved for action or formally rejected.

When fully approved, the company's MCC enters details and forwards copies of the CN and attachments to the project manager, CN originator, and company's document control center.

#### **Distribution of the CN**

The construction management team CCC will issue both approved and rejected CNs to the Company's CCC, DCC, and the CN originator.

# **Changes Originating from a Project Sponsor**

All communications received by the project management team shall be checked for any change in the key areas of the project or the level of involvement of any of the project sponsors. If these communications on changes are received by telephone, the originator is to be requested to confirm the change in writing, preferably by letter.

All requests for changes received from a Sponsor are to be logged and managed by project change control coordinator and a notification sent to the originator that the change is being reviewed. A summary of all changes shall be circulated to all sponsors with the monthly report.

# **Changes Originating from a Contractor**

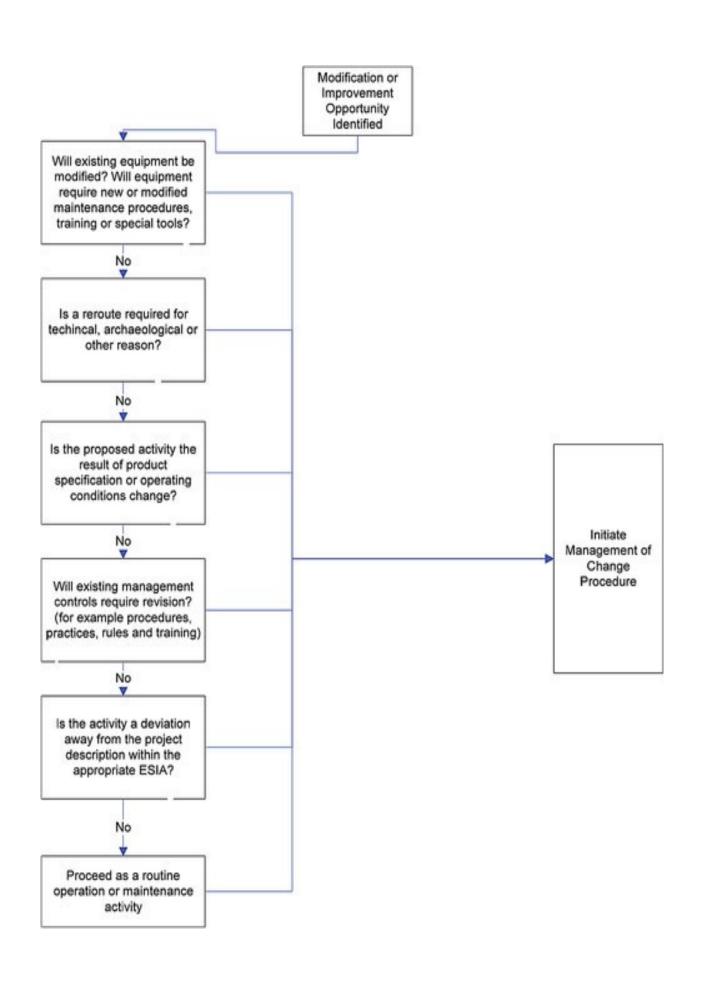
Changes originating from a contractor are to be reviewed by the company project management team and if valid, will be converted to a CN by the company's CCC and processed in accordance with this procedure.

# **E&S Rating Criteria**

Management of change from an environmental and social perspective must be tested against the following rating criteria to adequately classify the effects of the change on community and environment:

- Changes to the execution strategy and methodology that have the potential to affect implementation of key mitigation measures agreed through the ESIA process and other commitments,
- Contract deviation requests that have the potential to affect environmental and social mitigation measures or the functioning of the E&S management system
- Design changes initiated by either company or the construction contractors and subcontractors that have the potential to impact the ability for the project to meet project adopted environmental and social standards (e.g., emissions, discharges, noise, vibrations, water use constraints, etc.)<sup>1</sup>
- Changes to pipeline route, access roads, or any other site affecting the project footprint minimization objectives

- Changes to locations for temporary facilities (pipe storage yards, camps) to those contained in the ESIA (e.g., camp location not covered by ESIA or project description)
- New activities that have not been assessed as part of the ESIA process
- Route changes
- Major changes to construction planning, such as an introduction of additional spreads and implications on training and resources and community issues



# **Classes of Change for E&S Impact**

\_

| Significance ranking | Description   |
|----------------------|---|
| Class I: Major       | Changes include project activities or facilities with potential impacts on the    |
| Class II: Moderate   | Changes requiring a development or other project activity outside of the ESI      |
| Class III: Minor     | Changes to the plant, marine facilities, quarry, pipeline, accesses, construction |

# **Resulting Actions**

Each affected party initiates its own change implementation process following approval of the change. For the incorporation into the plant design and construction, the plant PMT will ensure that contractors have incorporated the change technically and commercially by reviewing the appropriate drawings (e.g., P&IDs, layouts) and invoices. Plant project controls manager will also notify finance and accounting of the change if it affects project cost or timing. This is similar for the pipeline.

Upon receipt of the signed/approved CN, the MCC shall advise the project manager(s) of the outcome so that work may proceed accordingly. Any instruction to a contractor is to be made in writing through the company contracts administration department following the contract variation order request (VOR) and variation order (VO) procedures.

## **Advising Partners of Change**

Partners are consulted with via the Technical and Management Committee members as an "affected party" on major changes. Partners are advised about all changes in accordance with the shareholder agreements. Communication with partners is via the general manager.

# **Advising Regulators of Change**

Regulators are consulted with (via plant permit coordinator) and their approval sought (as part of the change impact assessment process) if the change affects information previously used for obtaining permits.

Once a decision is made to incorporate the change, revised documentation will be submitted and new permits obtained (if necessary) prior to implementation of the change at the plant site.

# **Advising Lenders of Change**

The lenders shall be notified of significant changes depending upon the significance and scope of the change, and in particular those changes with associated potential environmental and social impacts. The changes could include, for example:

- Pipeline right-of-way reroutes
- Construction methodology
- Location and details of infrastructure and temporary facilities (access roads, camps, pipe storage yards, borrow and spoil sites)
- Design specifications and operating specifications, including emissions
- Any change that potential differs, or goes beyond, from what was described in the ESIA and other project definition documents

Decisions regarding the notification method will be based on the three-tiered change classification structure described above. The MCC views all proposed

changes and is in the best position to ensure that each change is assigned a significance ranking. The change control coordinator should liaise with company's environment and social manager for advice on the appropriate ranking assignation.

Lenders will be specifically notified on changes that fall into Class I due to E&S reasons. Notification of other changes will be in accordance with the loan agreements reached with the company.

Communication with lenders of a Class I E&S change is the responsibility of the company's environmental and social manager. Consequently, any Class I change needs to be immediately reported to company's environmental and social manager (the MCC coordinator is responsible for this reporting).

## **Updates Required**

On completing and approving the CN, the reviewers will assist the MCC in identifying all the documentation and processes that require updating and revising. The document number, date action was assigned, and responsibility shall be completed on the CN request form. The MCC shall follow up until all actions are closed.

- <sup>1</sup> Key environmental and social mitigation measures include but are not limited to the following:
- 1. Seasonal and geographical construction constraints (e.g., environmentally sensitive areas, culturally sensitive areas)

- 2. Key reinstatement safeguards ensuring
- a. Minimization of project footprint
- b. Protection of buffer zones and pinchpoints (water bodies and wetlands)
- c. Protection of the long-term viability of topsoil (either the seed bank and soil structure)
- d. Erosion and sedimentation control
- e. Pollution prevention
- f. Biorestoration to restore natural habitat
- g. Limits on open ROW (width or length)
- h. Limits on open trench
- 3. River crossing mitigation measures, including special method statements
- 4. Measures that ensure disruption to communities along ROW is minimized (disruption by construction workers, traffic, construction activities, location and timing, infrastructure impacts)
- 5. Construction contractors fail to meet objectives, targets, or key performance indictors
- 6. Special ROW stabilization measures (including special protection for geohazard areas)

-

# **Appendix J**

# **Risk Management**

\_

| Project N                   | ame:       | : Project X |        |          |     |
|-----------------------------|------------|-------------|--------|----------|-----|
| Location:                   | Area ABO   |             |        |          |     |
| Business Unit/Program Area: |            |             | LMNDiv | ision    |     |
| Project Sponsor: Nancy W    |            |             |        |          |     |
| Project Manager: Joe P      |            |             |        |          |     |
| Date:                       | 08/21/2014 |             |        | Version: | 1.5 |

#### Introduction

# **Purpose and Objectives**

Risk management is the systematic process of identifying, analyzing, and responding to project risks. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives. A risk management plan defines how a project team will handle risks to achieve that goal.

#### **Risk-Related Definitions**

There are several terms used in risk management that we need to define to ensure clear communications.

#### Risk

An uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives. Risk is often a measure of the inability to achieve overall project objectives within defined project requirements and constraints and has three components: (1) the probability of occurrence, (2) the impact of the risk on the program, and (3) the time horizon during which the consequences

will occur if the risk is not mitigated.

# **Probability of Occurrence**

The following table defines the probability of occurrence (Table J.1).

# **Risk Impact**

The following table defines the risk impact categories and terms. For positive risks, consider the opposite of the impact description. The examples would remain the same except having a positive impact to the project (Table J.2).

#### Risk Score

The risk score is a value calculated that is the product of probability of occurrence and impact. You use the score to compare risks as part of the risk prioritization process. Table J.3 is the matrix used to develop the risk score. The values range from 1 (very low exposure) to 50 (very high exposure). Although there are no specific break points in the risk exposure ranking, those risks with an exposure value of less than 20 are generally considered low risks, those risks with an exposure value between 20 and 39 are gen1erally considered moderate risks, and those risks with an exposure value between 40 and 50 are generally considered high risks. The definitions of low, moderate, and high are as follows:

- Low risk: Has little or no potential for increase in cost, disruption of schedule, or degradation of performance. Actions within the scope of the planned project and normal management attention should result in controlling acceptable risk. No response plans will be made for these risks. The project will monitor for them and manage them as they come up.
- Moderate risk: May cause some increase in cost, disruption of schedule, or degradation of performance. Special action and management attention may be required to control acceptable risk. The project will do some response planning for these risks.
- High risk: Likely to cause significant increase in cost, disruption of schedule, or degradation of performance. Significant additional action and high-priority management attention will be required to control acceptable risk. The project will do in-depth response plans for these risks.

Positive risks can use the same table and descriptions, except instead of trying to avoid the risk, we will endeavor to make the risk occur and gain the positive impact.

# **Organization**

This section defines the roles and responsibilities for risk management.

#### Table J.1

#### Risk probability of occurrence

-

\_

-

#### Table J.2

#### **Risk impact**

-

-

#### Impact description

An event that, if it occurred, would have no effect on the project.

\_

a These examples are simply rules of thumb and you should adjust them according to your specific project needs.

#### Table J.3

#### Risk score

-

-

#### Impact

| Probability                               | Negligible (1) | Minor (3) | Moderate (5) |
|---|----------------|-----------|--------------|
| Very likely to occur (5)                  | 5              | 15        | 25           |
| Probably will occur (4)                   | 4              | 12        | 20           |
| Approximately 50% chance of occurring (3) | 3              | 9         | 15           |
| Unlikely (2)                              | 2              | 6         | 10           |
| Very unlikely to occur (1)                | 1              | 3         | 5            |

# Project Management Office/Enterprise Project Management Office (EPMO)

The EPMO has issued a project risk management supplement that this project will use to form the basis of the risk management process.

The Information Technology Department's Project Management Office provides support to the project manager and has some additional processes and templates for software development projects that will be used in this project.

# **Roles and Responsibilities**

See Table J.4.

Table J.4

#### Roles and responsibilities

-

| Project Manager:   | The overall coordinator of the Risk Management Program.                        |
|--------------------|--|
| Project team: Resp | ponsible for identifying, monitoring, and managing risks                       |
| Subject matter exp | perts (SMEs): Responsible for implementing risk management tasks per this plan |
| End users          |  |

# **Risk Management Structure and Procedures**

This section describes the risk management process and provides an overview of the risk management approach.

## **Risk Assessment**

-

| Size:                   | With a budget of \$490,000, this project is a medium-sized project. |
|-------------------------|---|
| Complexity:             | This project involves multiple divisions within the organization    |
| Importance to Business: | This project is determined to be of high priority within the orga   |
| Visibility:             | While not directly public facing, delivers very important public    |
| Agency history:         | Agency seldom does IT projects of this size or complexity.          |
| Skill Levels            |   |
| Vendor:                 | ITD is updating an ITD based app. ITD has already done this w       |
| Project Mgr.:           | Relying on ITD's internal PM. Agency staff has no formal PM         |
| Agency project team     | Approximately 50% of the SMEs have done a similar project           |
|                         |   |

| Summary                          |   |
|----------------------------------|---|
| Risk management effort decision: | It has been determined that the project will spend a moderate a |
|                                  |   |

\_

## **Identification**

-

#### What

Brainstorming/affinity diagram/risk breakdown structure (RBS): The stakeholders will be divided into f

Table Continued

**-**-

#### What

Each group will be brought in, given a brief overview of the project, then, using the brainstorming techn

Delphi technique: We will query each of the key EA architects to identify risks associated with this proj

E-mail: At the end of each of the above activities, everyone will be asked to e-mail the PM with any add

The project will use the following categories of risk in this process: Schedule Schedule creation Timescale Budget personnel Project resources Contractors Project management Change management process Project size and duration **Expectations** End users Customer/sponsor project Vendors commitment Technological objectives Product requirements Environment Internal

Organization and management

Development environment design and implementation

External

**Politics** 

## **Qualitative Analysis**

=

#### What

Review: The PM will ask the core team to review the risks to determine if they understand the risks eno

Scoring: The project team will determine the impact and probability scores for each risk to calculate the  $\,$ 

-

#### What

Threshold 1: Anything with a probability of "very likely" (5) will be considered a fact and managed in t

All risks not excluded by the above thresholds will be passed to quantitative analysis.

Stage gate: Meet with the executive steering committee to review the key risks and get a go/no-go decis

\_

## **Quantitative Analysis**

-

#### What

A moderate risk effort indicates that an EMV analysis will be performed for each of the risked passed on

Analyze: The project team and SMEs from the effected divisions will meet to perform a basic EMV for

\_

## **Risk Response Planning**

-

#### What

The top risks evaluated in the quantitative analysis will be assigned out to the core project team, SMEs,

Stage gate: Meet with the executive steering committee to review the key risks and get a go/no-go decis

-

## **Risk Monitoring and Control**

-

#### What

Monitoring: Risk owners are responsible for monitoring their risks and notifying the PM via e-mail who New risk identification: Any stakeholder can identify additional risks. The stakeholder should notify the Audits: The PM will be responsible for overseeing risk activities and ensuring the risk register is update Review: The project team will review the project's risks biweekly (in every other weekly team meeting).

Reporting: Risks will be reported in two ways. (1) The PM maintains a risk log in the project repository

## Risk Register

The project's risk register is located in the project repository at the company's electronic project database and should cover the following points:

- Date identified: The date the risk was identified.
- Status: Identifies whether the risk is potential, active, or closed.
- Risk description: A description of the risk.
- Risk probability: The likelihood that the risk will occur. See the Evaluating Risk Probability section for possible values. In this category, the descriptive words low, moderate, or high will be used.
- Risk impact: The effect of the project objects if the risk event occurs. See the Evaluating Risk Impact section of the table below for possible values. In this category, the descriptive words low, moderate, or high will be used.
- Risk score: Reflects the severity of the risk's effect on objectives. The risk score is determined by multiplying the risk probability and risk impact values. The intent is to assign a relative value to the impact on project objectives if the risk in question should occur.
- Risk assignment: Person(s) responsible for the risk if it should occur.
- Agreed response: The strategy that is most likely to be effective.
- Avoidance: Risk avoidance entails changing the project plan to eliminate the risk or condition or to protect the project objectives from its impact.
- Transference: Risk transference is seeking to shift the consequence of a risk to

a third party together with ownership of the response. Transferring the risk simply gives another party responsibility for its management; it does not eliminate it.

- Mitigation: Risk mitigation seeks to reduce the probability and/or consequences of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability of a risk's occurring or its impact on the project is more effective than trying to repair the consequences after it occurs.
- Acceptance: This technique indicates that the project team has decided not to change the project plan to deal with a risk or is unable to identify any other suitable response strategy.
- Risk Response Plan: Specific actions to enhance opportunities and reduce threats to the project's objectives.

## Risk Register

## **Technology Risks**

Risks 1–9 are technology risks. They also deal with issues related to the potential for the system to evolve and function for an acceptable life cycle.

Risk ID

12

Risk owner

|   | JG/CF  |
|---|--|
|   | Description: There will almost certainly be general conflicts between project needs and normal b   |
|   | Assessment: The project has not yet identified any conflicts of significance. The implementation   |
|   | Response plan: Business process schedules and issues will be considered as part of the analysis le |
| _ | Lessons learned: This risk has not been active.  |

## Appendix K

## **Measuring the True Value of Maintenance Activities**

\_

# Measuring the True Value of Maintenance Activities







#### Introduction

Gaining full value from capital or physical assets is an important challenge for organizations operating in increasingly competitive environments, where production interruptions due to equipment failures lead to expensive repair costs and lost revenue opportunities.

A key requirement for ensuring that capital assets deliver value is an enterprise asset management (EAM) system that automates maintenance planning and scheduling, tracks supplies of inventory, enables online procurement, and integrates with financial and other information systems.

While implementing a CMMS/EAM solution can be a relatively straightforward initiative, identifying the right solution, determining which organizational processes need adjustment, and ensuring that maintenance best practices are deployed are essential to ensuring that your computerized maintenance management system CMMS/EAM solution delivers promised benefits.

The purpose of this white paper, "Measuring the True Value of Maintenance Activities," is to help you gain maximum value from your CMMS/EAM investment and to support continuous improvement of all related maintenance activities. Key topics include:

- Understanding all of the components of EAM
- Understanding some of the operational and organizational changes needed to

gain advantages from CMMS/EAM solutions

- Measuring your maintenance activities against industry best practices
- Measuring bottom line results from your maintenance investments:
- The Scoreboard for Maintenance Excellence for maximizing overall best practices
- The Benchmarking System for optimizing your IT investment
- The Maintenance Excellence Index for validating bottom line results

The Maintenance Excellence Institute (TMEI) has developed this white paper to help senior executives understand the value of maintenance activities and help maintenance professionals align resources to ensure that they are contributing positively to bottom line results.

The mission of TMEI is to help organizations gain greater value from their assets. We do this by helping clients more effectively manage each stage of the physical asset life cycle process—from acquisition to disposition. However, we believe that people assets are the most important resource and that our Training for Maintenance Excellence builds leadership and technical reliability and maintenance skills at all levels.



# **Understanding the True Value of Maintenance and Physical Asset Management**

There can be a very high cost when we gamble with deferred maintenance costs. This applies to all operations where maintenance activities occur, such as exploration and production facilities in the oil and gas sector, manufacturing plant operations, university facility complexes, equipment fleet operations, health care facilities, chemical plants, or power plants.

With this context, the maxim "maintenance is forever" always holds true. It is also true that if we do not achieve the existing "maintenance requirements" of each physical asset, we are gambling with mission-critical assets. The "high cost of gambling with maintenance" may become a catastrophic failure that causes loss of innocent lives, time, profits, or service. Gambling with maintenance costs is not an option when we fully understand the enormous potential from improving maintenance activities and then invest wisely in maintenance.

Maintenance activities and effective asset management add value to every type of operation. Very often, the true value of maintenance is not understood by everyone in the organization. Leaders within the maintenance organization must communicate to top-level leaders a complete understanding of the importance of maintenance. Maintenance leaders must measure and communicate the true value of maintenance activities to top leaders. Craft leaders in the shop must clearly see that those at or near the "top" truly appreciate the service that maintenance performs. Everyone in maintenance must continuously demonstrate the true value of their own maintenance activities and build understanding across the organization.

Likewise, all senior level positions of an organization must gain an understanding that effective management of physical assets and related maintenance processes is vital to total operations success. The chief financial officer, for example, must see how maintenance contributes to profit and profit optimization. Everyone must understand the following four strategic maintenance challenges that most growing organizations face. Regardless of the operation's current size or scope, plant maintenance and facilities management leaders in the public and private sectors are faced with four unique but very interrelated challenges:

- Challenge 1: Maintain existing production assets and facilities in safe and sound conditions.
- Challenge 2: Improve, enhance, and then maintain existing assets and facilities to achieve environmental/regulatory standards, greater production capacity at better quality, and while using the best energy practices.
- Challenge 3: Enhance, renovate, and modify/overhaul existing assets/facilities using capital funds or funds from tenant/customer and then maintain the additions.
- Challenge 4: Commission new production assets or facilities. Assume increased scope of work to maintain the new assets. Be prepared to assume more work from Challenges 1, 2, and 3 above as production assets and facilities get older and older.

Many organizations experience all four challenges concurrently. Moreover, often some organizations face indiscriminate budget cuts by executives who do not understand the true value of maintenance.

Subsequently, maintenance budget cuts often fall in the one place that they can hurt the worst—which is the reduction of maintenance crafts people, the technicians within all of the necessary trade areas who are out there doing hands-on repairs, the emergency responses, and weekend service calls. The

indiscriminate cutting of these scarce craft resources has been an unfortunate byproduct of the recent trend toward cost cutting.

Unfortunately, if an organization is not doing continuous reliability improvement (CRI) across all its maintenance resources or defining true maintenance requirements and achieving them, cutting craft positions to generate cost savings will have the opposite effect.

The core competency for doing maintenance may not be present, so contracted skills from a service provider may truly be needed. However, regardless of the operation's size or scope, the core requirement for executing required maintenance remains forever. The two core needs for an effective facility management or plant maintenance operation need to be understood by both maintenance leaders and senior executives:

- Maintenance business process improvement: Maintenance leaders must be pursuing business process improvement with a profit and customer-centered strategy and related attitudes toward their maintenance operation and customers. Top leaders should require it, support it, and understand it. There must be Continuous Reliability CRI across all resources: people, materials, assets, capital dollars, and information resources. If continuous improvement is truly present, then the plant maintenance leader or facilities management leader at least has a chance to survive. They must be able to show top leaders that they really are measuring results and maximizing all available maintenance resources. Then there is a true need and a clear case for adding resources to address the new requirements plus the baseline maintenance requirements for the asset.
- Maintenance requirements for the physical asset: The primary mission is executing the required maintenance activities for each asset while improving the equipment or facilities for the customer. This is what maintenance leaders must achieve in addition to many other activities that compete for engineering, craft, and administrative resources. Defining true maintenance requirements to top leaders is extremely important. Because when all resources are strained and

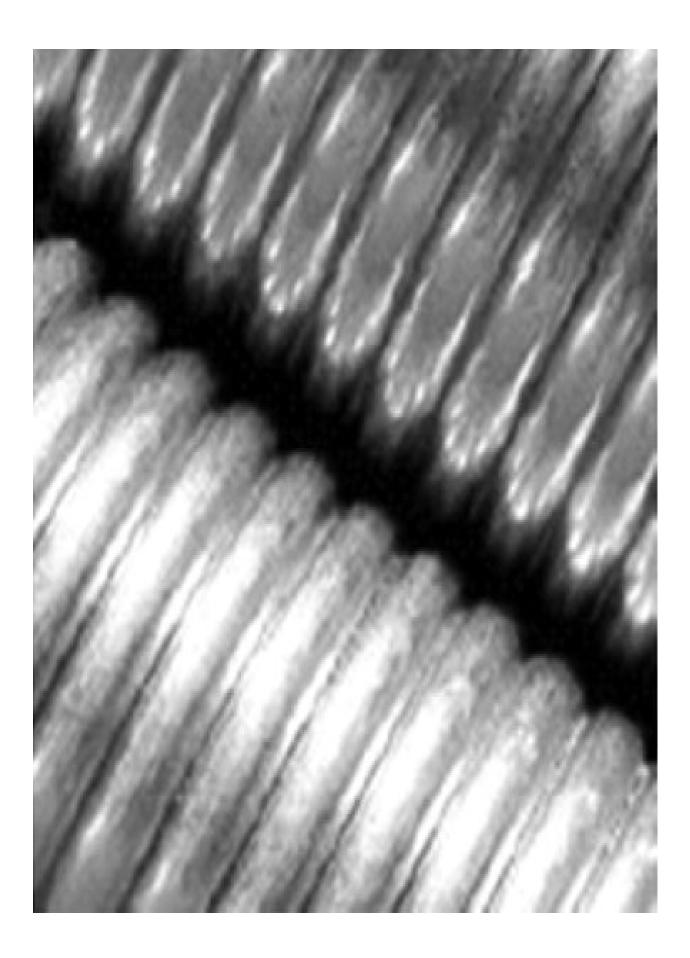
basic preventive maintenance or regulatory compliance is neglected, top leaders must have the right information to make the right choices. Eliminating maintenance resources at a time when basic maintenance requirements are not being met should not be considered even as a short-term option.

Eliminating maintenance resources to match lean manufacturing trends can be fatal. It really will not work if one has truly maximized use of existing resources and your baseline maintenance requirements are not being accomplished. The labor resource needs for the existing maintenance requirements must come from somewhere. Labor resource needs can be offset by either new craft resources and/or greater productivity of existing craft resources.

Therefore, the existing baseline of maintenance requirements and any growing maintenance needs of an organization must continuously be highlighted to top-level leaders. Equally important, the maintenance operation must continuously improve its operation and be provided investments for implementing operational improvements such as an EAM or CMMS system that supports continuous improvement of maintenance activities.









# Determining Where You Are and Where You Need to Go with Maintenance Best Practices

Do you know where you stand with applying today's best practices for maintenance and physical asset management? Do you have a baseline as to what is considered today's best practice and whether or not you have applied them effectively? Are there best practices that you have heard about that need to be considered and implemented? If not, you may very well be gambling with the long-term success of your total operation.

Effective maintenance and physical asset management add value and can be measured, as we will review later. There are many maintenance practices to consider and many software solutions to support profit optimization whether at one site or across multiple sites. There are some very important steps that you should take to gain maximum value from your maintenance operation and your investment in an EAM/CMMS system and help on your journey to maintenance excellence. Now is the time to take action to gain maximum return on all maintenance investments.

Make the commitment: The very first step is to make a commitment to continuous reliability improvement of your total maintenance operation. You should take the time to benchmark your current operation against today's best practices for CRI, preventive/predictive maintenance, planning and scheduling, effective maintenance, repair, and operations (MRO) materials management, storeroom operations, inventory control, work orders, work control, and the effective use of computerized systems for maintenance and respective business systems. Making the initial commitment is often the hardest first step.

# Continuous Reliability Improvement Improves The Total Maintenance Operation

Continuous Reliability Improvement You must know where you are with applying today's Best Practices Conduct a Scoreboard for Maintenance Excellence Assessment

Improve Your Total

Maintenance Operation

Establish Potential Benefits and Validate Results Invest in maintenance and commit to implementation Know where you want to go with a Plan of Action How to determine "where you are": Make a commitment to conduct an objective evaluation of your total maintenance operation. Within plant maintenance operations this is maintenance and repair of all production and facility assets, supporting infrastructure, overhaul and renovation activities, engineering support processes, as well as all material management and procurement of typical repair parts, supplies plus contracted services.

Facilities management operations, fleet operations, and health care all have unique differences to be considered. You should benchmark your current operation against today's best practices for preventive maintenance, planning and scheduling, effective spare parts control, work orders, work management, and the effective use of computerized systems for maintenance business management. A complete review of maintenance operations and the physical asset management process is important because it gives you a baseline as to your starting point for making improvements and for validating results. It will help to ensure that you are taking the right steps for taking care of your mission-essential physical assets. An independent evaluation, in most cases, helps to reinforce the local maintenance leader or facilities manager's desire to take positive action in the first place. Most want to do something to improve the overall maintenance process but never have the resources.

For multiple site operations, an evaluation of several sites provides a great opportunity for developing standard best practices that can be used across the corporation and for new sites. There are a number of very good benchmarking tools to help you get started with this important first step and others along the path forward to maintenance excellence.

The Scoreboard for Maintenance Excellence: Today's most comprehensive benchmarking guide, The Scoreboard for Maintenance Excellence, is available to define "where you are" in terms of today's maintenance best practices. Developed by the Maintenance Excellence Institute, this external benchmarking process has evolved from over 20 years of successful application to many different types of public and private organizations.

Currently there are four versions of the Scoreboard for Excellence:

- The Scoreboard for Maintenance Excellence
- The Scoreboard for Facilities Management Excellence
- The Scoreboard for Fleet Management Excellence
- The Scoreboard Health Care Facilities Management Excellence

This benchmarking process or maintenance audit gets down to the detailed level of "determining where you are" with actually applying today's best practices for maintenance in 27 major evaluation categories with 300 very specific evaluation criteria. The Scoreboard for Maintenance Excellence provides the first of three benchmarking tools introduced here and is the major one that benchmarks where you are with applying external best practices that other successful maintenance operations recognize and use.

The Scoreboard for Excellence concept and the various versions of the scoreboard have been used to perform over 200 maintenance evaluations, and over 5000 organizations have requested and received information for their internal use.

The Scoreboard for Maintenance Excellence, as shown in the summary, includes 27 evaluation categories (plant maintenance best practices areas). It evaluates the total maintenance operation within the scope of coverage for a manufacturing organization. There can also be well-defined focus areas when an evaluation is conducted such as on an EAM/CMMS system, planning/scheduling, MRO materials management, or application of CRI and predictive maintenance

technologies.

# The Scoreboard for Maintenance Excellence: **Benchmarks Your Operation Against Global Best Practices** The CMMS Benchmarking System: Benchmarks Your Current CMMS to Achieve Improved **Utilization of Your IT Investment** The Maintenance Excellence Index: Internal Benchmarks to Measure and Validate Your Maintenance Improvement Results The ACE Team Benchmarking Process: Provides a Method to Establish Reliable Planning Times for Benchmark Repair Jobs

Four Levels of Maintenance Benchmarking

#### **The Scoreboard for Maintenance Excellence**

**Summary of Evaluation Categories** 

| Category | Category Descriptions (Part 1)  | Evaluation<br>Items | Total Points<br>in Category |
|----------|---|---------------------|-----------------------------|
| A.       | The Organizational Culture and P.R.I.D.E. in Maintenance                    | 6                   | 60                          |
| B.       | Maintenance Organization, Administration and Human Resources                | 12                  | 120                         |
| C.       | Craft Skills Development and P.R.I.D.E. in Maintenance                      | 12                  | 120                         |
| D.       | Operator Based Maintenance and PRIDE in Ownership                           | 6                   | 60                          |
| E.       | Maintenance Supervision/Leadership  | 9                   | 90                          |
| F.       | Maintenance Business Operations, Budget and Cost Control                    | 12                  | 120                         |
| G.       | Work Management and Control: Maintenance and Repair (M/R)                   | 12                  | 120                         |
| H.       | Work Management and Control: Shutdowns and Major Overhauls                  | 6                   | 60                          |
| l.       | Shop Level Planning and Scheduling  | 18                  | 180                         |
| J.       | Shutdown and Major Planning/Scheduling and Project Management               | 9                   | 90                          |
| K.       | Manufacturing Facilities Planning and Property Management                   | 9                   | 90                          |
| L        | Production Asset and Facilities Condition Evaluation Program                | 6                   | 60                          |
| М.       | Storeroom Operations and Internal MRO Customer Service                      | 12                  | 120                         |
| N,       | MRO Materials Management and Procurement                                    | 12                  | 120                         |
| 0.       | Preventive Maintenance and Lubrication                                      | 18                  | 180                         |
| P.       | Predictive Maintenance and Condition Monitoring Technology Applications     | 15                  | 150                         |
| Q.       | Process Control, Building Automation and Instrumentation Systems Technology | 9                   | 90                          |
| R.       | Energy Management and Control   | 12                  | 120                         |
| 8.       | Maintenance Engineering Support   | 9                   | 90                          |
| T.       | Safety and Regulatory Compliance  | 12                  | 120                         |
| U.       | Maintenance and Quality Control   | 9                   | 90                          |
| V.       | Maintenance Performance Measurement   | 12                  | 120                         |
| W.       | Computerized Maintenance Management System (CMMS) and Business System       | 18                  | 180                         |
| X.       | Shop Facilities, Equipment, and Tools                                       | 9                   | 90                          |
| Y.       | Continuous Reliability Improvement  | 15                  | 150                         |
| Z        | Asset Facilitation and Overall Equipment Effectiveness (OEE)                | 15                  | 150                         |
| ZZ.      | Overall Craft Effectiveness (OCE)   | 6                   | 60                          |
|          | Total Evaluation Items and Points   | 300                 | 3000                        |

A complete evaluation is recommended: For example, MRO materials management, storeroom operation, and procurement may be areas needing special attention. Shop-level planning and scheduling is often a typical need and can be a primary focus area. Regardless of the different areas creating the obvious concerns and "organizational pain," a short-term, piecemeal approach to an evaluation is not recommended. A complete evaluation of the total maintenance operation is highly recommended. There are 300 specific evaluation items that are evaluated through direct shop floor interviews, close observations, and review of information or procedures. Each one is important; some apply and provide more value more than others. But each of the 300 items on The Scoreboard for Maintenance Excellence summarized following is part of establishing a solid foundation for profit-centered maintenance. Long-term CRI is also a very important connecting link.

#### **Guidelines for conducting a total maintenance operations evaluation:**

While a self-evaluation has benefits, a comprehensive evaluation conducted by an external resource provides a greater sense of the "big picture" in terms of objectivity and completeness. Regardless of your situation, it is important that you do something to "determine where you are." Should you want to conduct an evaluation of maintenance activities, here are some guidelines to consider when using The Scoreboard for Maintenance Excellence.

#### **Key steps for using The Scoreboard for Maintenance Excellence:**

- 1. Obtain leadership buy-in
- 2. Create a maintenance excellence strategy team

- 3. Understand the evaluation categories and evaluation criteria
- 4. Develop an action plan
- 5. Conduct evaluation of total maintenance operation
- 6. Analyze, review, and present results
- 7. Develop path forward for maintenance excellence
- 8. Summary of deliverables to achieve results:
- a. A recommended maintenance excellence strategy team charter and functioning team
- b. The Scoreboard for Maintenance Excellence developed for the organization and revised if required after the pilot evaluation
- c. In-depth evaluation of current maintenance practices at a pilot site
- d. Recommendations in all 27 maintenance evaluation categories
- e. Benchmark evaluation of the current CMMS/EAM systems installation based on the Benchmarking System criteria
- f. Recommendations to improve utilization of the current CMMS/EAM installation
- g. Recommended path forward for a strategic level plan with tactical/operational items
- h. Definition of improvement opportunities
- i. Summary of potential benefits with an estimate of savings and gained value for each
- j. Documented evaluation of results in a written report
- k. Recommended performance measurement process ready for immediate implementation

- l. A maintenance excellence index (MEI) that validates overall performance improvement
- m. Recommended metrics, data sources, and documentation in a standard operating procedure guide for the client-specific MEI
- n. Plan of action for future evaluations at other sites
- o. An organization maintenance champion (CMO) established
- p. Oral presentation of results to top leaders

#### The Scoreboard for Maintenance Excellence Assessment: Key Steps to Continuous Reliability Improvement

- Determine the Need and Gain Commitment to Take Action
- 2. Preplanning for On-Site Time
- Conduct Scoreboard for
   Maintenance Excellence Assessment
- Evaluate Assessment Results and Recognize Successes
- Determine Improvement Opportunities and Prioritize
- Preventive/Predictive Maintenance Improve Parts & inventory Control
- Modernize Storeroom Operations
- Improve Parts Procurement
- Improve Work Management
- Effective Planning & Scheduling
- Reliable Planning Times
- Repair Methods and Quality
- Craft Skills Development
- Performance Measurement
- Implement: or Improve CMMS
- Increase Asset Uptime & Reliability
- Operator-Based Maintenance
- Continuous Reliability Improvement:
- Energy Management
- Improve Regulatory Compliance
- Improve Safety and Security

Determine Savings, Investments and Resources Required

 Develop a Measurable Plan of Action

Oral and Written Presentation of Results

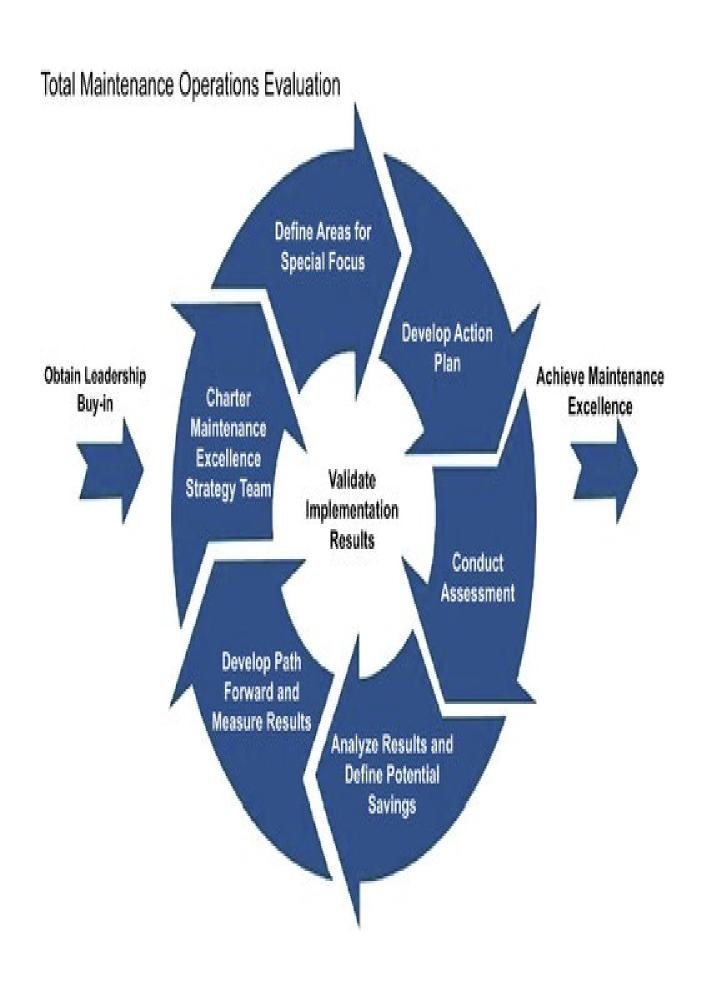
Implement Plan of Action (Short and Long Term Plans)

Implement Maintenance
 Excellence Index to Validate ROI

11. Achieve Maintenance Excellence and Total Operations Success

 Continuous Reliability Improvement Establish a maintenance excellence strategy team: One key element of success is having a commitment from top-level leaders across the organization. Establishing a maintenance excellence strategy team is highly recommended. This high-level, leadership-driven cross-function team made up from maintenance leaders, key operations leaders, shop-level maintenance staff, IT, engineering, procurement, operations/customers, and financial planners. The mission of this team is to lead and facilitate the overall CRI process and to ensure measurement of the results that are achieved. This team would also sponsor other teams within the organization to support implementation of the recommended path forward. One of the very first things that this team should do is to sponsor a comprehensive evaluation of the total physical asset management and maintenance operation and help to determine "where you are." There are a number of very good benchmarking tools to help you get started with this important first step and others along the path forward to maintenance excellence.

Invest in external resources: It is extremely important to know where your organization stands on physical asset management and maintenance issues and challenges so it can quickly identify areas for improvement. Every delay along the way delays receiving the potential benefits and added value. Self-evaluations can be a starting point when nothing else is available for using external support. But a more comprehensive, objective evaluation performed by external consulting resources (or possibly qualified corporate level staff) with maintenance-focused expertise is highly recommended. In the long run, external resources will provide additional justification and measurable results. Use external resources to support this essential first step after your organization makes the initial commitment.



### **Developing Your EAM/CMMS System to Successfully Manage the Business of Maintenance**

Today's information technology for CMMS/EAM offers the maintenance leader or facilities manager an exceptional tool for managing maintenance activities and the overall maintenance operation. Maintenance processes and services can be managed as an internal business. There are many improvement opportunities identified when a Scoreboard for Maintenance Excellence type evaluation is conducted. Maintenance surveys and benchmark evaluations conducted by external sources validate that poor utilization of existing CMMS/EAM systems is a major improvement opportunity. What are some of the typical benefits of an improved CMMS/EAM system that could be missing from your operation?

- Improved work control
- Improved planning and scheduling
- Enhanced preventive and predictive maintenance
- Improved parts and materials availability
- Improved MRO materials management
- Improved reliability analysis
- Increased budget accountability
- Increased capability to measure performance and service
- Increased level of maintenance information

Benchmark your CMMS/EAM system installation: The CMMS/EAM

Benchmarking System is another tool available to evaluate the utilization of an CMMS/EAM system installation. It is designed as a methodology for developing a benchmark rating of your current CMMS/EAM system (Class A, B, C, or D) to determine how well this tool is supporting best practices and the total maintenance process. It is not designed to evaluate the functionality of various CMMS/EAM systems nor is it intended to compare vendors.

The system provides a methodology for developing a benchmark rating of your existing CMMS/EAM installation to determine how well this tool is supporting best practices and the total maintenance process. It can also be used as a method to measure the future success and progress of a new CMMS/EAM system implementation that is now being installed. Maintenance best practices are the key, and the CMMS/EAM is the information technology tool that links it all together. The CMMS/EAM Benchmarking System gives you an easy way to evaluate how well you are using your CMMS/EAM investment.

Maintenance information is a key resource: We illustrate below some key points on maintenance information as one of the key resources for CRI. A summary of The CMMS/EAM Benchmarking System is shown with nine major evaluation categories that include a total of 50 evaluation items for benchmarking your CMMS/EAM installation.

| The CMMS Benchmarking System             |                    |  |  |
|--|--------------------|--|--|
| CMMS BENCHMARK CATEGORIES                | Benchmark<br>Items |  |  |
| 1. CMMS Data Integrity                   | 6                  |  |  |
| 2. CMMS Education and Training           | 4                  |  |  |
| 3. Work Control                          | 5                  |  |  |
| 4. Budget and Cost Control               | 5                  |  |  |
| 5. Planning and Scheduling               | 7                  |  |  |
| 6. MRO Materials Management              | 7                  |  |  |
| 7. Preventive and Predictive Maintenance | 6                  |  |  |
| 8. Maintenance Performance Measurement   | 4                  |  |  |
| 9. Other Uses of CMMS                    | 6                  |  |  |
| TOTAL CMMS BENCHMARK ITEMS               | 50                 |  |  |

### Measuring the Bottom Line Results from Your Maintenance Investments

Maximizing maintenance for profit optimization or increased service to customers is the goal. The goal is successful implementation of prioritized improvement opportunities and to help improve all internal resources do a better job for the tenant/customer. We can measure the "true value" of maintenance activities.

Here we will introduce the third benchmarking tool, the Maintenance Excellence Index. As a result of applying all three benchmarking tools in this proven approach, the journey to maintenance excellence is well underway with these world-class methodologies in place to measure results and long-term contribution to profit:

- The Scoreboard for Maintenance Excellence for maximizing overall best practices
- The CMMS/EAM System Benchmarking System for optimizing your IT investment
- Maintenance Excellence Index (MEI) for validating bottom line results

This section covers the process of defining and gaining consensus on very specific key performance indicators related to the total maintenance operation. It covers a recommended set of internal benchmarks or metrics for today's facilities leader, the purpose for each and where they traditionally can be found in the CMMS/EAM or financial system. Most important this section illustrates how your own uniquely developed Maintenance Excellence Index will validate

results and ROI for maintenance operations.

Measure and validate results: The topic of measurement must be foremost in our minds as we begin to determine "where we are" with the evaluation of physical asset management and the maintenance activities. Each of the 300 evaluation items on The Scoreboard for Maintenance Excellence must be viewed in terms of whether or not there are tangible or intangible benefits possible. Are we able to make improvements that generate benefits and can we measure them? Often performance measurement is something new to the in-house maintenance operation, but we highly recommend that a performance measurement system be put in place.

Contract maintenance providers understand the value of measurement so that their customers clearly see value-added services received. Justification for investments in maintenance best practices for in-house maintenance operations must be validated. If your maintenance operation were a third-party contract maintenance provider that you owned and operated, you would expect a profit. We too must measure and validate results from internal maintenance improvement.

Initiate a maintenance excellence index: A proven approach has been to help clients create an MEI that includes 10 to 15 key performance indicators with agreed upon weighted values. These metrics are then used to provide a spreadsheet that brings them all together into a composite total MEI performance value, an index of how all resources are contributing to your part of profit optimization. The metrics selected should be applicable to the specific organization. For example, a pure facilities maintenance operation without critical production or operations equipment to maintain would not use OEE as part its MEI to measure overall equipment effectiveness, a world-class metric best suited to a small number of mission essential critical assets within a production operations. The metrics encompass the measurement of all key resources necessary for effective physical asset management:

- People resources and craft labor
- Dollar resources and overall budget dollars from both maintenance and the customer
- MRO material resources
- Planning resources and customer service
- The physical asset as a key resource, its uptime, availability and reliability to perform its function
- Information resources and how data become true information via effective CMMS/EAM

Potential performance metrics for using on an MEI: The following section provides a review of 21 key metrics that should be considered. There are numerous other metrics and key performance indicators available, but these 21 metrics encompass the measurement of all key resources necessary for effective physical asset management.

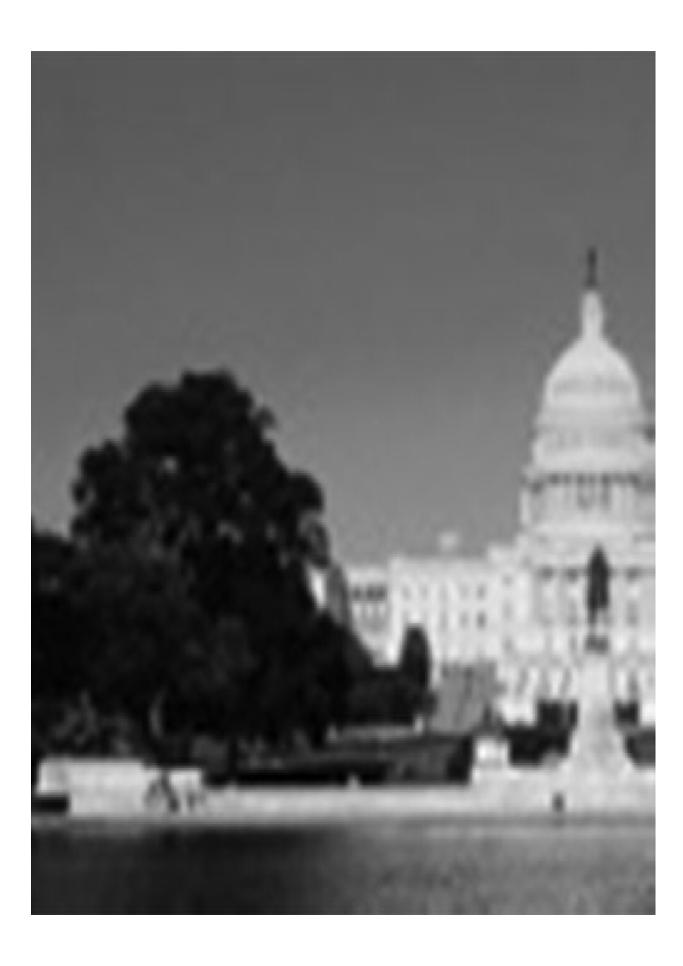
| Number | Performance Metric, Purpose and Data Source  |  |  |  |  |
|--------|--|--|--|--|--|
| 1.     | % Overall Maintenance Budget Compliance: To evaluate management of \$ assets; Obtained from monthly financials   |  |  |  |  |
| 2.     | Actual Maintenance Cost per Unit of Production: To evaluate/benchmark actual costs against stated goals/baselines or against industry standards; Obtained from asset records and monthly EAM WO file of completed WOs for the month. Obtained from production results and financial report. Provides ideal support to ABC Costing practices                                |  |  |  |  |
| 3.     | % Customer or Capital Funded Jobs Completed as Scheduled and within +/- 5% of Cost Estimate: To measure customer service & \$ assets plus planning effectiveness; Obtained from funded WO types from the EAM WO files, comparing date promised to date completed and estimated cost to actual cost   |  |  |  |  |
| 4.     | % Other Planned Work Orders Completed as Scheduled: To measure customer service and planning effectiveness; Obtained from a query of all planned WO types in EAM WO files and comparing date promised to date completed. Could be expressed in % based on craft hours  |  |  |  |  |
| 5.     | Schedule Compliance: To evaluate how effectiveness scheduling was in regards to executing to meet scheduled dates/time; Obtained from query of EAM completed WO file where all scheduled jobs coded and their actual completion compared to actual planned completion date/time  |  |  |  |  |
| 6.     | % Planned Work Orders versus % True Emergency Work Orders: To evaluate positive impact of PM, planning processes and other proactive improvement initiatives (CRI, /RCM/etc); Obtained from a query of all true emergency WO types in EAM WO files and comparing to total WOs completed. Could be expressed in % based on craft hours                                      |  |  |  |  |
| 7.     | % Craft Time to Work Order for Customer Charge Back: To monitor craft resource Accountability for<br>Internal Revenue Generation (or External); Obtained from a query of all WO types in EAM WO files that are<br>charged back comparing these craft hours to total craft hours paid   |  |  |  |  |
| 8.     | % Craft Time to Work Orders: To monitor overall craft resource accountability and to support internal revenue generation; Obtained from a query of all WO types in EAM WO files and summation of actual craft hours  |  |  |  |  |
| 9.     | % Craft Utilization (Actual Wrench Time): To maximize craft resources for productive, value-adding work<br>and to evaluate effectiveness of planning process; Obtained from a query of all craft hours reported to non<br>craft work from EAM time keeping WO files and summation of actual craft hours  |  |  |  |  |
| 10.    | % Craft Performance (Against reliable estimates for PM and planned work): To maximize craft resources, to evaluate planning effectiveness and also to determine training ROI; Obtained from completed WO file in EAM System  |  |  |  |  |
| 11.    | Craft Quality and Service Level: To evaluate quality and service level of repair work as defined by customer;<br>Obtained from WO file in CMMS where all call backs are tracked and monitored via work control and planning<br>processes   |  |  |  |  |
| 12.    | Overall Craft Effectiveness (OCE): To evaluate cumulative positive impact of overall improvements to Craft Utilization (CU), Craft Performance (CP) and Craft Quality and Service Excellence (CQSE) in combination; Obtained from using results of measuring all three OCE Factors: a) Craft Utilization, b) Craft Performance and c) Craft Quality and Service Excellence |  |  |  |  |
| 13.    | % Work Orders with Reliable Planned Times: To measure planner's effectiveness at developing reliable planning times; Obtained from completed WO file in EAM where panning times are being established for as many jobs as possible by planner/supervisor   |  |  |  |  |
| 14.    | % Overall Preventive Maintenance Compliance (Could be by type asset, production department/location or by supervisory area): To evaluate compliance to actual PM requirements as established for assets under scope of responsibilities; Obtained from completed WO file in EAM System   |  |  |  |  |

| 15. | Gained SValue from Craft Utilization/Performance: To determine actual gained \$ value of craft productivity gains as compared to original estimate and/or the initial baseline; Obtained only from using results of measuring two of the OCE Factors: a) Craft Utilization, b) Craft Performance   |
|-----|--|
| 16. | % Inventory Accuracy: To evaluate one element of MRO material management and inventory control policies; Obtained from cycle count results and could be based on item count variances or on cost variance  |
| 17. | % or \$ Value of Actual MRO Inventory Reduction: To evaluate another element of MRO material management against original estimates and the initial baseline MRO inventory value; Obtained from inventory valuation summation at end of each reporting period   |
| 18. | Number of Stock Outs of Inventoried Stock Items: To monitor actual stock item availability per demand plus to monitor any negative impact of MRO inventory reduction goals; Obtained from tracking stock item demand and recording stock outs manually or by coding requisition/purchase orders for the items not available per demand.  |
| 19. | S Value of Direct Purchasing Cost Savings: To track direct cost savings from progressive procurement practices as another element of MRO materials management. Could apply to contracted services, valid benefits received from performance contracting, contracted storerooms, vendor managed inventory; Obtained via best method per a standard procedure that defines how direct purchasing savings are to be accounted for |
| 20. | Overall Equipment Effectiveness (OEE): World-class metric to evaluate cumulative positive impact of overall reliability improvements to Asset Availability (A), Asset Performance (P) and Quality (Q) of output all in combination. (Similar to OCE above but for the most critical production assets); Obtained via downtime reporting process, operations performance on critical assets and the resulting quality of output |
| 21. | % Asset Availability/Uptime: To evaluate trends in downtime due to maintenance and the positive impact of actions to increase uptime; Obtained via downtime reporting process  |









### Using CMMS/EAM to Develop Your Maintenance as a Profit Center

This section summarizes 12 direct and indirect savings opportunities and illustrates how one of those opportunities increased craft productivity. It also shows how just one of many best practice areas from The Scoreboard for Maintenance Excellence, effective shop-level planning and scheduling, provides more than a five-to-one return on the investment for just one planner position for a 20-person craft workforce.

Understand the power of CMMS/EAM to support potential savings: The evaluation of your CMMS/EAM using The CMMS/EAM Benchmarking System will identify improvement opportunities that translate into direct savings. It is important that these areas be highlighted and that the future process for performance measurement is focused upon these specific areas that may have been used initially for CMMS/EAM capital project justification. The opportunities to realize both quantifiable and qualitative benefits are numerous.

Maintenance must be given the best practice tools, the people resources, and capital investments to address the improvement opportunities and in turn be held accountable for results. Direct savings, cost avoidances, and gained value can be established and documented with an effective CMMS/EAM system.

Applied best practices plus the right EAM/CMMS system will help to increase the:

- 1. Value of asset/equipment uptime providing increased capacity and throughput
- 2. Value of increased quality and service levels due to maintenance
- 3. Value of facility availability or cost avoidance from nonavailability
- 4. Value of increased direct labor utilization (production operations)
- 5. Gained value from increased craft labor utilization/effectiveness via gains in wrench time
- 6. Gained value from increased craft labor performance/efficiency
- 7. Gained value of clerical time for supervisors, planners, engineering, and administrative staff
- 8. Value of MRO materials and parts inventory reduction
- 9. Value of overall MRO materials management improvement
- 10. Value of overall maintenance costs reductions with equal or greater service levels
- 11. Value of increased facility and equipment life and net life cycle cost reduction
- 12. Other manufacturing and maintenance operational benefits, improved reliability, and other reduced costs

What is your craft utilization? Surveys consistently show that wrench time (craft utilization) within a reactive maintenance environment is within the range of 30–40%. This means that for a 10-h day there are only 4 h of actual hands-on wrench time. Typically, low craft utilization is due to no fault of the craft workforce. Most of the lost craft labor productivity can be attributed to the following reasons:

- 1. Running from emergency to emergency (a reactive operation)
- 2. Waiting on parts and finding parts or part information

- 3. Waiting on other information, drawings, instructions
- 4. Waiting for the equipment to be shut down
- 5. Waiting on rental equipment to arrive
- 6. Waiting on other crafts to finish their part of the job
- 7. Travel to/from job site
- 8. Lack of effective planning and scheduling
- 9. Make ready, put away, clean up, meetings, troubleshooting

The most valuable resource: Maintenance operations that continue to operate in a reactive, run-to-failure, firefighting mode and disregard implementation of today's best practices will continue to waste their most valuable asset and very costly technical resource: craft time. Best practices such as effective maintenance planning/scheduling, preventive/predictive maintenance, more effective storerooms and parts support all contribute to proactive, planned maintenance and more productive hands-on "wrench time."

An improvement in actual wrench time from 40% to 50% represents a 25% net gain in craft time available and a significant gained value. When we are able to combine gains in wrench time with increased craft performance when doing the job, we increase our total gain in craft productivity. Measuring and improving overall craft productivity can be a key component to justify an effective CMMS/EAM system and other investments for maintenance improvement.

Example: Gained value from 10% increase in wrench time. What if through better planning and scheduling, good parts availability, and having equipment available to fix it on a scheduled basis, we are able to increase actual wrench time by 10%? What is the value to us if we get that 10% increase across the board for a 20-person crew operating now at 40% wrench time and being paid an average hourly rate of \$18 per hour?

| Total Craft Hours Available and Annual Craft Labor Costs |                         |                 |                                 |  |
|--|-------------------------|-----------------|---------------------------------|--|
| 20 Crafts x  | 40 hours/week x         | 52 weeks/year = | 41,600 Craft Hours Available    |  |
|  | 41,600 Craft Hours @ \$ | 18 /hour =      | \$748,800 Craft labor Cost/Year |  |

# Summary for Crew of 20 Craft at \$18.00/Hr Average Rate: Wrench Time with Actual Costs Per Hour at Various Levels of Craft Utilization

| Level of Craft Utilization | Total Wrench Time (Hours) | Actual Hands On<br>Cost Per Hour | Average Wrench Time<br>Hours Per Craft Position |
|----------------------------|---------------------------|----------------------------------|---|
| 30%                        | 12,480                    | \$60.00                          | 624   |
| 40%                        | 16,640                    | \$45.00                          | 832   |
| 50%                        | 20,800                    | \$36.00                          | 1040  |
| 60%                        | 24,960                    | \$30.00                          | 1248  |
| 70%                        | 29,120                    | \$25.71                          | 1456  |
| 80%                        | 49,920                    | \$22.50                          | 1664  |
| *85%                       | 35,360                    | \$21.18                          | 1768  |
| 90%                        | 37,440                    | \$20.00                          | 1872  |
| 100%                       | 41,600                    | \$18.00                          | 2080  |

**Note:** Maximum possible craft utilization is = 85 percent considering paid holidays, vacation time, breaks, cleanup, employees meetings, craft training, etc.

### **CRAFT LABOR RESOURCES** People Resources: Our Most What if We Important We Must Gain Train Them & Resource **Maximum Value** They Leave? From This Valuable What if They Resource Stay? Craft Labor Resources Typically, We Get Craft Labor: Only 30% to 40% Often a Scarce **Wrench Time** Resource To Find Also Storeroom Labor Resources!

Example: Gained value of 10% increase in wrench time. With effective planning and scheduling, we can achieve at a minimum a 10-point improvement in craft utilization. From a baseline of 40% up to a level of 50%, we in effect get a 25% increase in craft capacity for actual work. The 40% baseline for our example is very conservative since wrench time typically is normally 30–40% and/or below.

Total Hours Gained in Wrench Time: 4160 h

20,800 h @ 50% - 16,640 h @ 40% = 4160 h gained

Total Gain in Equivalent Number of Crafts Positions: 5

4160 h gained

832 Average Wrench Time Hours @ 40% = 5 Equivalent Craft Positions

Total Gained Value of 5 Equivalent Positions: \$187,200

5 Equivalents  $\times$  40 h/week  $\times$  52 weeks/year  $\times$  \$18.00/hour = \$187,200 Gained Value

Valuable craft time can slip away: With only a 10% improvement, 40% up to 50% wrench time, the 20-person craft workforce gains 4160 h of wrench time, which represents a 25% increase in craft labor capacity. The maintenance best practice for planning and scheduling requires a dedicated planner(s). An effective maintenance planner in turn can support and plan for 20 to 30 craft positions. With only a 10% increase in craft utilization for a 20-person craft workforce, this can be much more than a five-to-one return to offset a maintenance planner position.

If the wrench time in our example is really at the 30% level, then the gain up to 50% craft utilization is 8320 h of wrench time; this increase in craft labor capacity is extraordinary as shown below:

#### **Total Gain in Equivalent Craft Positions: 13.3 Equivalent Positions**

8320 h gained

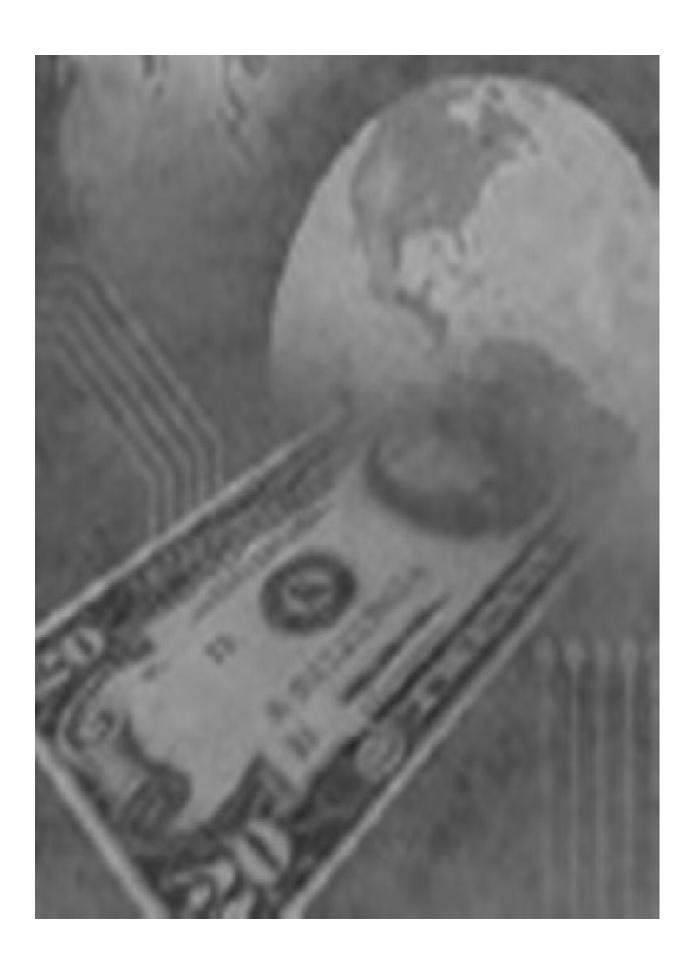
624 Average Wrench Time Hours @ 30% = 13.3 Equivalent Craft Positions

Total Gained Value of 13.3 Equivalent Positions: \$497,952

13.3 Equivalents  $\times$  40 h/week  $\times$  52 weeks/year  $\times$  \$18.00/h = \$497,952 Gained Value

Your maintenance operation as a profit center: A fully utilized CMMS/EAM system is your business management system to support the business of maintenance and a philosophy of profit-centered maintenance. Your CMMS/EAM system is a mission-essential information technology tool that can support planning and scheduling, better MRO materials management, and effective preventive maintenance, three key elements for improving craft wrench time. Bottom line results that give us 5–13 more equivalent craft positions and up to \$500,000 in gained value of more wrench time with existing staff can be dramatic proof that internal maintenance operations can be profit centered.









#### **Summary**

We can measure the true value of maintenance activities and document savings that go directly to the bottom line. We can change the status quo and view all maintenance operations as potential profit centers. Maintenance and physical asset management operations within your organization can be true contributors to profit generation or increased service levels. We know that the value of effective CMMS/EAM can have tremendous ROI potential. The cost of external resources and support services for getting started with a Scoreboard for Maintenance Excellence evaluation is also a very good investment. The value of our investments in information technology and best practices is now something that can be validated by the three tools we have discussed previously:

- The Scoreboard for Maintenance Excellence for maximizing overall best practices
- The CMMS/EAM System Benchmarking System for optimizing your IT investment
- Maintenance Excellence Index for validating bottom line results

### **Go Beyond RCM and TPM**

We understand the need for the reliability-centered maintenance (RCM) and total productive maintenance (TPM) types of improvement processes. On the shop floor, we often see a trend toward forgetting about the basics of "blocking and tackling" while going for the long touchdown pass with some new analysis paralysis scheme. We strongly believe in basic maintenance best practices as the

foundation for maintenance excellence. Build your approach upon the basics but then go well beyond the traditional RCM/TPM approaches with CRI; an improvement process includes all maintenance resources, equipment, and facility assets as well as the crafts people and equipment operators. It also includes MRO materials management assets, maintenance informational assets, and the added value resource of synergistic team-based processes. CRI improves the total maintenance operation.

A profit-centered approach is needed: Both large and small maintenance operations can operate as a true profit-centered maintenance organization. This must encompass all aspects of their extensive business enterprise: administration, financial, design, maintenance, construction, planning/scheduling, procurement, and overall MRO materials management. Constraints may continue from within the public sector organizations.

Attitudes that in-house maintenance is a "necessary evil" will die hard. But to survive in the twenty-first century, both private and public sectors must put in place effective performance measurement processes that truly validate profitcentered results.

By

Ralph W. "Pete" Peters

Founder, President, The Maintenance Excellence Institute

-6809 Foxfire Place, Suite 100, Raleigh, North Carolina 27615

-2625 East Beach Drive, Oak Island, North Carolina 28465

Office: 919-270-1173 Web: www.PRIDE-in-Maintenance.com

E-Mail: Pete@PRIDE-in-Maintenance.com & RalphPetePeters@aol.com







## **About The Maintenance Excellence Institute International**

The Maintenance Excellence Institute is an alliance of highly qualified individuals and organizations with the technical knowledge and practical experience to help you manage and lead your maintenance operation as an internal business. Our cornerstone value is to implement profit-centered practices and attitudes in large and small maintenance operations. Our profit-centered approach for maintenance excellence services and continuous reliability improvement are focused on four main areas of physical asset management and maintenance: plant maintenance operations, health care facilities management, facilities management operations, and fleet maintenance operations.



### **Further reading**

Dunn Richard L. Plant/Facilities engineering-definitions and descriptions of functions and responsibilities. AFE Facil. Eng. J. December 1997.

Higgins L.R. Maintenance Engineering Handbook. fifth ed. McGraw-Hill; 1995.

Peters R.W. Achieving Real Maintenance Return on Investment. Raleigh, NC: Tompkins Associates; 1994.

Peters R.W. The Scoreboard for Excellence. Raleigh, NC: Ralph W. Peters and PEOPLE; 1987.

Peters R.W. The Scoreboard for Maintenance Excellence. Raleigh, NC: Tompkins Associates; 1994.

Peters R.W. Planning for Maintenance Excellence. Raleigh, NC: Tompkins Associates; 1996.

Peters R.W. The ACE Team Benchmarking System. Raleigh, NC: NC Department of Transportation; 1978.

Peters R.W. "Benchmarking Your CMMS System. Industrial Maintenance and Plant Operations; May 1998.

Peters R.W. The Guide to Computerized Maintenance Management Systems. New York: Alexander Communications/Scientific American; 1999.

Peters R.W. Chapter 12- Maintenance in Book by: Tompkins, Jim. Future Capable Company. Raleigh: Tompkins Press; 2001 2001.

Peters R.W. Maximizing Maintenance Operations for Profit Optimization. Tulsa, OK: Schneiderman and Associates, LLC; 2002.

Salvendy Garviel. Industrial engineering handbook Chapter 59. In: Peters R.W, ed. Maintenance Management and Control. third ed. John Wiley and Sons; 2001.

### Appendix M

# Planner Viewpoints on the Question; "Is it Required to Have a Trades Background to be a Planner?"

-

Introduction: The following discussion is a very interesting look at the question, "Is it required to have a trades background to be a planner?" My personal answer to this question is that you make a good selection and promote someone from your crafts workforce. In the book, I also recommend training a back up planner as well. I think you will enjoy these comments shared on a blog site. Answers come from a wide range of individuals, and when you look at all in total you will see what type of person is needed for this important position.

Maintenance Planner: Having a trade helps you understand the concepts and understand exactly what you need to do, especially when it comes to parts planning so that you plan the correct parts and know exactly what it is in relation to the problem. You can do it without the trade as an on-the-job training and you get to understand the job well.

Project Manager: Trade background is a good start but not essential—neither is an engineering degree or university degree—essential experience in that industry is helpful but you can be trained as a planner, whether it is industrial planning town planning or any other planning.

I don't believe so. I think understanding the trade and its expectations are important, especially if you are coming into a union environment. You always want to have a "basic" understanding of what you are asking your people to jump into. Understanding the industry you wish to work in is key. Understanding the working environment is second to that. Having a trade is good. Having a

trade with a degree is better. Having a degree and proven frontline management experience, successfully working with tradesmen, is best. To be clear, your team is going to be on board with you, until they aren't. That said, the more you know about what they do and how to work with that, the better you'll be. Know your team, lean on your team.

Contract Manager: It is a must because you have to know the language/terminology of the trade and the usual function of that particular part, e.g., if it is a gearbox, you have to know the power train/drive train, which is how the power or drive is transmitted to the axles or whatever is being driven. If you are an electrician you can do well if you plan for electrical department, the field that you know.

Sr. Consultant: Planners do not necessarily need to be a tradesperson. It does help, but to me planners need to be very organized, have good communicating skills, plus many other skills. Planning work orders need attention to quality not quantity, and do planners know everything, no, so they use their resources to help them plan. Fox example, mechanical planners will need electrical planning help some time in the future. And vice versa, so they use their resources to help the plan. One thing that I have done, when developing a new planning department, and I have developed several of them, is to centralize all the planners. That way they can use each other when needed.

Equipment Superintendent: It helps to be a trades person with computer skills, because you have a clear picture of the components, how they work, and what it takes to get the job done, PMs, repairs etc. However I'm training somebody that never was involved with machinery and they are learning the basic skills very fast and strategies to set weekly and monthly plans and become a planner. The most important thing is the attitude to learn adaptation and be an organized person. On the other hand, the planner has to be sharpest man on your payroll so a good tradesman that becomes a planner is the best choice in my opinion because of the experience...on the field.

Assistant Maintenance Planner: You will be working in a dreamland if you do not have any skill. Whatever you do will be imagination because you do not have a clear picture of the equipment and their components.

Maintenance Planner: No, but you need to replace the experience factor with education in an engineering or maintenance organization experience. Knowledge or experience or both makes the planner.

Lead Maintenance and Management Consultant: Just an opinion mind you however expecting someone to plan anything without having the skill set/experience is a setup for disappointment, if not complete failure. I personally would not entertain the thought of hiring a planner who has never had the pleasure and opportunity to "do" the tasks. Over the years I have encountered (quote) degreed engineers (unquote) without hands-on experience who could not find their hands if they were sitting on them.

Equipment Superintendent: I agree with the above comment, especially for a planner position where it is critical to have somebody that knows the business of maintenance.

Lead Maintenance and Management Consultant: Thank you! Although quite time consuming, I would pair the potential planner with a lead or tech so that she/he will at least get an overview of what might be involved in performing the tasks.

Area Manager: I would say it all depends on the maturity and culture of the team you are planning for. Having a trades background gives you instant buy-in with the maintainers and supervisors executing the plan. If they are accepting and

mature, you will have help building the plan based on their input. Gain trust by saying things like: You guys are the best preplanners on site and such will help the initial period. Having a trade though helps with things like the imperatives of what is needed on the identification of work through notifications and possible feedback to initiators. If you take an interest in the equipment and the team, that will help break down barriers as well.

Senior Turnaround Planner: Many employers make it a specific qualification to have a trade. In some cases, a technologist is equally accepted. Humans are adaptive creatures so anything is possible. Also depends on what one's other qualifications are. In a previous role, I saw initially that very few planners had a trade. Then as planners with trades were hired and began to significantly outperform those without trades, there was a paradigm shift in hiring strategy and movement of planners without trade tickets (except for a select few who were able to produce good results, of which most were technologists or engineers). One interesting observation was that non-trades often expected promotions or wanted transfers to engineering or other roles, whereas the tradespersons seemingly were more likely to want to hone and expand their skills (subsequently leading to increased compensation) but stay within the field of planning and scheduling. This pattern or tendency further bolstered the employer's desire to hire trades. Someone said previously that "it is quite time-consuming if people do not have a trade."

Experienced Maintenance Reliability, Turnaround Professional: Planner must have a trade skill, or your team will call you a data encoder or a data reporter. Planning always goes with scheduling; if you don't know what you're planning, how can you schedule? You may learn the language and be familiar with all the equipment, but if you never had an experience to work on it "hands on" or just even visually seeing what you plan on site, you can never progress as a true planner.

Take note: being a successful planner is the best/good career path to maintenance management. So, learn from the ground, move up slowly, and

surely you will avoid getting embarrassed once you get on TOP. All the best, Get greasy, and Life will be Easy!!!

Maintenance Mechanical Planner: Trade background is a good start but not essential, neither is an engineering degree or university degree essential experience in that industry. It is helpful but you can be trained as a planner and transform yourself to become the professional planner, whether it is industrial planning, town planning, or any other planning. But it all depends on the maturity and culture of the team you are planning on and what might be involved in performing the tasks.

SAP-PM-Maintenance Planning Consultant: A good planner will understand how work gets done and the issues a tradesperson faces. The best way to learn is by doing; if you haven't worked in maintenance you will not be able plan effectively. The best planners know how to plan because of experience on the floor, so either tradespeople or engineers/technologists who have spent a few years on the shop floor have the right skill set. Planners without a trade/tech ticket don't have the needed experience.

Project and Shutdown Superintendent: Definitely having a relevant trade to what you are planning for is a good foundation, but I have also come across individuals in my career that have the natural aptitude to be able to look at a task and understand the requirements for completion. The difference is having the experience of what influences can prevent a task being completed and being able to plan contingencies, which comes with having the experience.

Mechanical Planner: A planner without a trade can succeed. If the company has a decent computerized maintenance management system set up with routine job plans that can be pulled across. If they are willing to improve, the skill will come.

Planner: It has been my experience that in the position of planner it is far more important to be able to understand how the process works (maintenance and production) so that you can better understand how the work should "flow." Understanding what unmet time frames can do to the overall scope of work and the "domino" effect it can have on other jobs is critical. Also, be involved in understanding what goals are set for the work that is being done (especially new installations and/or upgrades). A degree is nice, a title is impressive, but a good maintenance understanding can go a long way in becoming a successful planner.

Senior Turnaround Planner: I recently witnessed at a facility where third-party consultants were brought in that worked with a team of internal experts from multiple aspects of the business. The mandate of this group was to draw conclusions on how and where to focus improvement efforts for the company. It was determined early on that improvements in planning would make for huge gains. That is no surprise! However, a particular recommendation coming out of this was to only hire planners with a trade ticket and to laterally move or offer buyouts to those preexisting that did not have a ticket. Planners should have a trade, especially to perform maintenance.

National Contracts Manager: Four of the best planners I had were not tradespeople. Two women and two men, they started out at the lowest level of their occupation and worked themselves up in the Planners office to become the best. Unfortunately, they will have to do some engineering studies if they want to go beyond being planners. One was a fixed plant and the other three were mobile heavy earth-moving planners. In saying all of this, there is always an advantage for those who have a trade as they will have a better understanding of the physical attributes of a job.

Maintenance/Production Planner Trainee: I am a maintenance planner of a small airline company, who began operating Fokker 50s right out of university. I have no trade in aviation at all; I must say I am not a really expert maintenance planner, but my first/last two performance reviews were very satisfactory. My point is, I agree with most of the discussion above, which generally says, "you

don't really need to have the trade, just good organizing skills." Though an initial familiarization of principles of operations/organization is musts to know before you even begin.

Maintenance Planner: Coming from a 19-year-certified millwright/certified welder who has been a mechanical planner for the past decade, the experience that came about by way of my trades was and is invaluable, maybe not a must, but it sure helps to be able to talk the talk after you have walked the talk. Did I say that right?

Top Contributor: It helps when you have a trade, and also it depends on which field you are. As Max said, you need to have a clear picture of what type of a job you are planning, as you are supposed to understand the drawings in case you are in the mining industry, are supposed to know the working principles of most machinery in your area. Throughout my working career, mostly in the mining industry, all the planners I have worked with had an engineering trade, and this helps, as you will not rely on the foremen to have most of the information on components or spares to be arranged for a particular job, so my choice is a planner with a trade.