DEVELOPING PERFORMANCE INDICATORS FOR MANAGING MAINTENANCE

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This book is dedicated to my wife, Kay
and my sons, Justin and Chad.
They earned it.

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About the Author

TERRY WIREMAN is currently the Director of Advanced Consulting where he is responsible for assisting clients in developing "Best Practices" methodologies in asset care and maintenance management and in determining the maximum return on investment for their improvement programs. He also serves as the Maintenance Editor for "Engineer's Digest."

For over a decade, the author has operated an independent consulting firm specializing in maintenance management improvement using techniques and tools such as CMMS and Total Productive Maintenance. An international expert in maintenance management, Wireman has assisted hundreds of clients in North America, Europe and Pacific Rim countries in improving their maintenance effectiveness. In addition to published articles, he has authored nine books dealing with maintenance-related topics as well as conducted numerous technical seminars for major colleges, universities, and technical societies. Cited as a "nationally recognized expert" (Plant Engineering Magazine, January 1990), the author frequently speaks at the National Plant Engineering and Maintenance Conference and belongs to the Institute of Industrial Engineers, Society of Manufacturing Engineers, and International Maintenance Institute.

Preface

When companies evolve from a worst to a best performer they find that the process is a selective learning model. Biologically speaking, the model is a Darwinistic one, where managers select the best practices and change or eliminate inferior practices or policies. Performance indicators are used by leaders to lead. The leaders must set a clear direction, focusing on the company vision. They then require good navigational tools, typically called performance indicators to help them steer the organization.

Leaders need to develop a *change* organization, one that is open to continuous and rapid improvements. These improvements should either strengthen best practices or eliminate poor practices.

The strategic approach to management focuses on effectiveness and results. Unfortunately, most of the traditional measures used to evaluate performance were financial based. Measures such as balance sheets, as well as monthly or quarterly profit and loss statements, are, in effect, damage reports. These measures tell us that we performed poorly, after the fact. They give us little information about our status today or what we need to do to improve tomorrow.

In the current business climate, competitiveness requires measures that accurately reflect our future business performance. These measures allow the organization to focus on priority items and not waste resources on non-value added initiatives or programs.

This book is designed to provide details on how to measure and improve one of the most important functions in an organization today: *Equipment or Asset Maintenance Management.*

Many companies view maintenance as a necessary evil, an expense to the organization, or a non-value added function. These companies will not survive in business for another decade. Instead they will be put out of business by companies that see the equipment or asset maintenance management function as a competitive weapon. These competitors view maintenance as a way to reduce costs of producing their product or providing their services. They are using this cost advantage to lower prices, improve profit margins, and improve shareholder value.

What is the difference between the two types of companies? The ones seeing no value in maintenance have never learned to measure it.

Since they can't measure it, they can't manage it. They can't even understand what maintenance is and how their competitiveness in the future hinges on it.

This book provides organizations with a fresh look at the value of the technical disciplines in their organizations. If it accomplishes this one task, the time investing in reading it should provides individuals and their companies with dramatic returns on their investment of time.

I would like to give special thanks at this point to one person who has done much to increase the awareness of the maintenance function in organizations today: Robert Williamson of Strategic Work Systems. The NASCAR illustrations used in this text are based on his contributions to the industry in this area.

Introduction

In today's business environment, every conceivable advantage is being pursued by companies. They have implemented improvement initiatives such as Total Quality Management (Control) TQM - TQC, Just-in-Time Manufacturing (JIT), and Total Employee Involvement (TEI). In the latter part of the 1990s, many companies are shifting their focus to the optimization of their assets. This change in focus involves virtually all parts of the organization that impact the effectiveness of the assets. One of the parts of the company that affects the assets the most is the maintenance department or those responsible for the maintainance function in a company. Since the maintenance department has the greatest impact on the condition and ultimately the capacity of the assets, companies are focusing on finding the best method of managing maintenance.

Companies have tried different organizational structures, changing reporting structures, upsizing, downsizing, contracting out, and empowered teams in an attempt to *control* maintenance. Yet, the majority of companies have not been able to *manage* maintenance. The two largest factors contributing to this have been the lack of proper measurement and the lack of control systems for maintenance.

This books presents an overview of what maintenance is, how it has developed or evolved, and, finally, the performance measures that can be used to effectively manage maintenance.

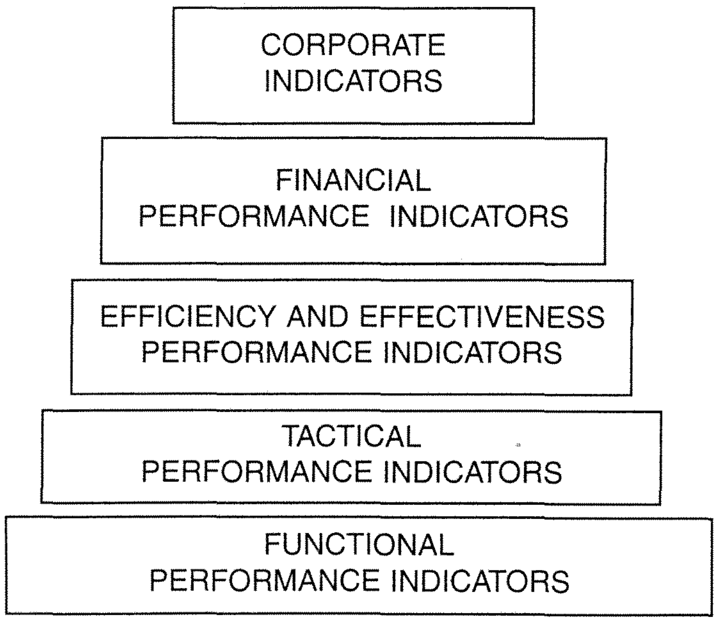
Performance Measures

Performance measures have been misunderstood and misused in most companies today. Performance indicators are just that, an indicator of performance. They are not to be used to show that individuals are not doing their jobs in the company and how, now that they are exposed, they can be dismissed. Performance indicators are not to be used for ego gratification, that is, for comparison with another company to show how much better one company is than another. Nor are performance measures to be used to show "we are just as good as everyone one else in our market, so we don't need to change."

Properly utilized, performance indicators should highlight opportunities for improvement within companies today. Performance measures should be used to highlight a soft spot in a company and then be further analyzed to find the problem that is causing the indicator to be low. Ultimately the indicator can then point to a solution to the problem.

Thus there should be multi-level indicators. One layer of indicators might be at a *corporate strategic level*. A supporting level would be the *financial performance indicator* for a particular department or process. A third level would be an *efficiency and effectiveness indicator* that highlights what impacts the financial indicator. A fourth level would be a *tactical level indicator* that highlights the departmental functions that contribute to the efficiency and effectiveness of the department. The fifth level of indicator is the measurement of the actual *function* itself. To better see this tiered approach to performance indicators, consider the pyramid in figure 1.

The pyramid shows the hierarchical relationship of the performance indicators. Note that the indicators are determined not from the bottom up, but rather from the top down. The corporate indicators are measuring what is important to top management in order for the needs of the stakeholders or shareholders to be satisfied. Therefore these indicators will help the organization focus its efforts on supporting the company direction.



The corporate indicators will vary from company to company depending on current market conditions, business life cycle, and the corporation's financial standing. Even different parts of a corporation may be measured with different indicators. For example, in energy exploration and production, a particular or and gas field will be measured based on where it is in its life cycle. A new field will tend to have higher spending levels for operations and maintenance; a field that is nearing the end of its life cycle tends to operate with lower expenses.

The corporate indicators set the direction. In turn, the subsequent indicators must focus the organizational levels on supporting the corporate direction. If the indicators are not connected, the overall organizational effort is suboptimized, endangering the corporation's survival when faced with competitors who have greater focus.

Rule Number 1: All Performance Indicators Must be Tied to the Long-Range Corporate Business Objectives.

If a corporate indicator highlights a weakness, then the next lower level of indicators should further define and clarify the cause of the weakness. When the functional performance indicator level is reached, the particular problem function should be highlighted. It will then be up to the responsible manager to take action to correct the problem condition. When the problem is corrected, the indicators should be monitored for improvement at the next higher level to insure the action taken was appropriate. If the appropriate action was taken, the improvement should be noticed as it impacts the hierarchical indicators up to the original corporate indicator.

Organizations that use performance indicators effectively react quickly to problems. They use the hierarchy of indicators to help small problems from becoming large ones. For instance, if changes made at the functional level do not result in a timely change in the tactical performance indicator, then it is obvious the changes made were incorrect. The impact should be apparent quickly. The organization should not have to wait to the end of the month or quarter to evaluate the effect on the corporate indicator.

Developing Comprehensive Performance Indicators

Companies today face tremendous competition in a global market. They have made rapid changes in organizational structures, reporting systems, and, in some cases, operational and production processes. Often they have struggled with the performance measurement systems. How can rapidly changing companies focus on improvements when there is no system to tell them if they are making progress? This highlights the need for measurable and consistent performance indicators.

Objectives of Performance Indicators

Performance indicators should be integrated and interdependent to provide an overall perspective on the company's goals, business strategies, and specific objectives.

During the process of developing performance indicators, the following steps should be considered:

1. Make strategic objectives clear, in order to focus and bring together the total organization.
2. Tie the core business processes to the objectives.
3. Focus on critical success factors for each of the processes, recognizing there will be variables.
4. Track performance trends and highlight progress and potential problems.
5. Identify possible solutions to the problems.

Many companies need a performance indicator system that truly pulls together all parts of the organization in a strategic model that allows for optimum return on investment, thus constantly attracting investors.

Categories of Performance Indicators

Performance indicators will vary according to the firm's needs, but will likely include corporate, financial, efficiency and effectiveness, tactical, and functional indicators.

Implementing Performance Indicators

The process of implementing new performance indicators so that they become ingrained in the culture of the business presents both opportunity and challenge. The opportunity is for each department to connect its operation to the overall business of the company. The challenge is to find indicators that allow this connection to be clearly communicated. Effective implementation requires the following steps:

1. Recognize the need for performance indicators by identifying new challenges (e.g., loss of market share to competitors, excessive cost to produce, low return on investment for the shareholders).
2. Ensure top management support and commitment by actively involving them in the development of the new indicators. Communication should involve the need for the performance indicators. Management should be directly involved with the implementation team.
3. Create an implementation team that can develop and communicate a common understanding of the company's strategic direction. It should actively solicit input from all levels of the company and be able to refine the input into a cohesive plan. The implementation team should develop the complete set of key corporate performance indicators. The indicators should then be incorporated throughout the various levels of the corporation.
4. Develop a departmental performance model that can put the departmental goals, strategies, objectives, critical success factors, and performance indicators into context first by viewing the corporate strategic direction and then by typing the departmental performance indicators to this direction.
5. Understand the departmental goals and strategies by categorizing them into functional, tactical, efficiency and effectiveness, and financial indicators.
6. Define the departmental activities that will have the largest impact on the department's performance.
7. Develop the performance indicators. Consult with different levels of management to determine who will be tracking the indicators, how the information should be tracked, tracking frequency, and the performance targets.
8. Establish the underlying technology (typically a CMMS) necessary for the performance indicators. Consider what data is required, the level of detail, reporting frequency, amount required and source.
9. Reevaluate the reward and recognition system to insure that it is consistent with the new performance indicator system.
10. Ensure continuous improvement by updating the system. Keep in mind that the business needs of the company and what is critical to competitiveness may change.

Challenges

The challenge for management is to put into place new performance indicators that will contribute, the success of their companies in the ever-changing business environment. The challenges faced by management include:

1. Developing awareness of the need to modify existing performance measurement styles;
2. Procuring top management support and commitment;
3. Gaining cross-functional support;
4. Obtaining resources necessary to the design and development of the performance indicator system;
5. Assuring accurate, timely, and useful data;
6. Linking new indicators to long-term economic value; and
7. Assessing the new system's effects.

Most departments cannot be evaluated with one indicator. Most effective efforts rely on multiple measures and multiple forms of measurement. The simple application of a measure proven in one department to another may also be a poor strategy, given the variances in departments and services rendered. Considerable effort may be required to develop an elegant solution: a relatively small number of indicators, easily managed, that capture the intended departmental performance.

An ideal performance measurement system requires:

1. Long-term cooperation on defining and implementing goals and measures. The entire organization must be involved.
2. Connections between the measures and resource allocation decisions. You must be able to support the indicators you implement.
3. Measures that are easily developed, understood, and valid. The information systems (particularly the CMMS) should allow for the accurate assessment of costs and other measures.

Organization of the Book

Since the theme of this book is maintenance performance, it is only fitting to adapt the previous concepts to the maintenance process for a corporation. The book is organized in the following manner: First, an overview of maintenance management is presented. Second,the steps to implement a maintenance management program are discussed. Third, performance indicators are highlighted for each of the functions of the

maintenance management program. Fourth, the hierarchical indicators typically used will be examined, with each one's strengths and weaknesses dicussed. The material is designed to help each company choose the correct indicator for its business needs.

Chapter 1
The Maintenance Function

WHAT IS MAINTENANCE MANAGEMENT?

In today's business environment, terms like "best practices," "benchmarking," "world class," and others continuously bombard us. Another term to emerge recently is *"Performance Measurement or Performance Indicators"*. The measures or indicators can be applied to any function within an industrial plant or facility, public or private organizations, or even non-profit organizations.

There are performance measures for quality, production, processes, and even financial departments. However, one function within organizations that is beginning to emerge as a key to future competitiveness is the maintenance function. The focus of the maintenance function is to insure that all company assets meet and continue to meet the design function of the asset. What is Maintenance Management (sometimes referred to as Asset Management) and what importance does it have for managers in corporations today?

Maintenance management is *the management of all assets owned by a company, based on maximizing the return on investment in the asset.* This definition encompasses the philosophies contained in many of the more popular techniques currently being utilized by companies today.

What techniques would fall under the definition of maintenance management? The list would include, but not be limited to, the following:

Preventive Maintenance
Inventory and Procurement
Work Order Systems
Computerized Maintenance Management Systems (CMMS)
Technical and Interpersonal Training
Operational Involvement

Predictive Maintenance
Reliability-Centered Maintenance
Total Productive Maintenance
Statistical Financial Optimization
Continuous Improvement

Each of these initiatives is a building block for the maintenance management process. A brief examination of each will show its importance.

1. Preventive Maintenance

The preventive maintenance (PM) program is the key to any successful asset management process. The preventive maintenance program reduces the amount of reactive maintenance to a level low enough that the other initiatives in the asset management process can be effective. However, most companies in the United States have problems keeping their PM programs focused. In fact, surveys have shown that only 20% of the companies in the United States feel their PM programs are effective.

This finding indicates that most companies need to focus on the basics of maintenance if they are to achieve any type of asset management process. Effective preventive maintenance activities would enable a company to achieve a ratio of 80% (or more) proactive maintenance to 20% (or less) reactive maintenance. Once the ratios are at least at this level, the other initiatives in the asset management process become more effective.

corrective

From the financial perspective, reactive maintenance typically costs two to four times what proactive maintenance costs, due to its inherent inefficiencies. This increased cost impacts the ROI (Return on Investment). The ROI examines maintenance expenditures in light of potential savings or cost avoidance. Savings typically come from the improvement in maintenance efficiencies that will occur. Cost avoidance includes avoiding lost production, added energy costs, increased contractor costs, or lack of availablity of the facility. Since the asset management process focuses on ROI, it is critical for all companies to have a successful PM program as a foundation.

2. Inventory and Procurement

Inventory and procurement programs must focus on providing the right parts at the right time for the asset repairs and maintenance. The goal is to have enough spare parts, without having too many spare parts. However, the interdependency between the asset management initiatives becomes apparent: No inventory and procurement process can cost effectively service a reactive maintenance process. However, if the majority of maintenance work is planned several weeks in advance, then the practices within the inventory and procurement process can be optimized.

What level of performance is typical in companies today? Many companies see service levels below 90%, which means stockouts run greater than 10% of requests made. This level of service leaves the customers (maintenance) fending for themselves, stockpiling personal stores, and circumventing the standard procurement channels to obtain their materials. These actions are not done for personal reasons, but rather because maintenance want to provide service to its customer (operations or facilities). It is really a self-defense mechanism.

In order to prevent this situation, it is necessary to institute the type of inventory (stores) controls that will allow the service levels to reach 95% to 97% with complete accuracy of the data. When this level of inventory and procurement performance is achieved, the next step in asset management is ready to be taken.

3. Work Order Systems

The work order initiative in asset management involves documenting and tracking the maintenance work that is performed. A work order system is used to initiate, track, and record all maintenance and engineering activities. The work may start as a request that needs approval. Once approved, the work is planned, then scheduled, performed, and finally recorded. Unless the discipline is in place and enforced to follow this process, data is lost and true analysis can never be performed.

Unfortunately, many organizations record only a small part of their maintenance and engineering actions. Much data is lost. When it comes time to perform an analysis of the data, the analysis is incomplete and inaccurate. Therefore management doesn't support the decisions made, based on the data, and further degradation of its confidence in the maintenance department occurs.

The solution requires complete use of the work order system to record all maintenance and engineering activities. Unless the data is tracked from work request through completion, the data is fragmented and useless. If 100% of all maintenance and engineering activities are tracked through the work order system, then planning and scheduling can be effective.

Planning and scheduling requires someone to perform the following activities:

- Review the work submitted
- Approve the work
- Plan the work activities
- Schedule the work activities
- Record the completed work activities

Unless a disciplined process is followed for the above activities, the company will never see productivity increases and reduced equipment downtime. This leaves the perception that maintenance planning is a clerical function. In turn, the planning function becomes vulnerable to the first cuts when any type of reduction in overhead costs is examined. At least 80% of all maintenance work should be planned on a weekly basis. In addition, the schedule compliance should be at least 90% on a weekly basis.

4. Computerized Maintenance Management Systems (CMMS)

In most companies, sufficient data is accumulated by the maintenance and engineering functions to require the computerization of the data flow. Computerization facilitates the collection, processing, and analysis of the data. The usage of the Computerized Maintenance Management System (CMMS) has become popular in most countries around the world. This software manages the functions discussed previously, and provides support for asset management.

CMMS has been used for almost a decade in some countries with very mixed results. A recent survey in the United States showed that the majority of companies used less than 50% of their CMMS' capabilities (ED 5/92). What this means for these companies is that the data they collect is highly suspect and probably highly inaccurate. Unless this is corrected, they will never be able to achieve true asset management since there will be no methods of tracking asset costs and calculating ROI.

5. Technical and Interpersonal Training

The training function of maintenance insures that the technicians working on the equipment have the technical skills that are required to understand and maintain the equipment. Additionally, those involved in the maintenance functions must have the interpersonal skills to be able to communicate with other departments in the company. They must also be able to work in a team or natural work group environment. Without these skills, there is little possibility of maintaining the current status of the equipment. Furthermore, the probability of ever making any improvement in the equipment is inconceivable.

While some exceptions exist, the majority of companies today lack the technical skills within their organizations to maintain their equipment. In fact, studies have shown that almost one third of the adult population in the United States is functionally illiterate or just marginally better. When these figures are coupled with the lack of apprenticeship programs available to technicians, the specter of a workforce where the technology of the equipment exceeds the skills of the technicians that operate or maintain it becomes a reality.

6. Operational Involvement

Operational involvement requires the operations, production, or facilities departments to take ownership of their equipment to the extent that they are willing to support the maintenance and engineering department's efforts. The aspects of involvement vary from company to company. The involvement activities may include some of the following:

- Inspecting equipment prior to start up
- Making out work requests for maintenance *(includes building occupants requesting work)*
- Recording breakdown or malfunction data for equipment
- Performing some basic equipment service *(e.g. lubrication)*
- Performing routine adjustments on equipment
- Performing maintenance activities *(supported by central maintenance)*

The extent to which operations, production, or facilities is involved in maintenance activities may depend on the complexity of the equipment, the skills of the individuals, or even union agreements. The goal should always be to free some of the maintenance and engineering resources to concentrate on more advanced management techniques.

7. Predictive Maintenance (PDM)

Once the maintenance and engineering resources have been freed by the operational involvement, they should be refocused on the predictive technologies that apply to the assets. For example, rotating equipment is a natural fit for vibration analysis, electrical equipment for thermography, and so forth. In some cases, the devices monitoring the asset may be connected to a building automation system, a distributed control system, or a PLC (Programmable Logic Controllers) system and all parameters are monitored in a real time environment.

The focus is not to purchase all the technology available, but to investigate and purchase technology that solves or mitigates chronic equipment problems that exist. The predictive inspections should be planned and scheduled utilizing the same techniques that are used to schedule the preventive tasks. All data should be recorded in or interfaced to the CMMS.

8. Reliability-Centered Maintenance

Once the data is recorded, Reliability-Centered Maintenance (RCM) techniques are applied to the preventive and predictive efforts to optimize the programs. If a particular asset is environmentally sensitive, safety related, or extremely critical to the operation, then the appropriate PM/PDM techniques are decided upon and utilized.

If an asset is going to restrict or impact the production or operational capacity of the company, then another level of PM/PDM activities are applied with a cost ceiling in mind. If the asset was allowed to fail and the cost would be expensive to replace or rebuild the asset, then yet another level of PM/PDM activities would be specified. There is always the possibility that it is more economical to allow some assets to run to failure. This option is considered in RCM.

The RCM tools require data to be effective. For this reason the RCM process is utilized after the organization has attained a level of maturity that insures accurate and complete asset data.

9. Total Productive Maintenance

Total Productive Maintenance (TPM) is an operational philosophy where everyone in the company understands that, in some way, their job

performance impacts the performance of the asset. For instance, operations must understand the true capacity of the equipment and not run it beyond design specifications, creating unnecessary breakdowns. The purchasing department must always buy the spare parts to the correct specifications and not try to save a small amount, creating breakdowns because the parts didn't last as long as they should.

The TPM philosophy focuses all parts of the company on their roles and responsibilities in optimizing the company's investment in the assets. TPM can include, but is not limited to operations, maintenance, inventory, purchasing, engineering, and management.

TPM is like Total Quality Management. The only change is that instead of companies focusing on their product, their focus shifts to their assets. All of the tools and techniques used to implement, sustain, and improve the total quality effort can be used in TPM.

10. Statistical Financial Optimization

Statistical Financial Optimization is a statistical technique that combines all of the relevant data about an asset, such as downtime cost, maintenance cost, lost efficiency cost, and quality cost. The technique then financially balances decisions based on the lowest total cost, not what is necessary, the lowest cost for an individual department or area. These decisions include:

When to take the asset offline for maintenance
Whether to repair or replace an asset
How many critical spare parts to carry
The maximum-minimum (max-min) levels for routine spare parts

Financial optimization requires accurate data, since making these types of decisions incorrectly could have a devastating effect on a company's competitive position. By the time a company reaches a level of sophistication where this technique can be used, it is approaching the pinnacle of the asset management pyramid.

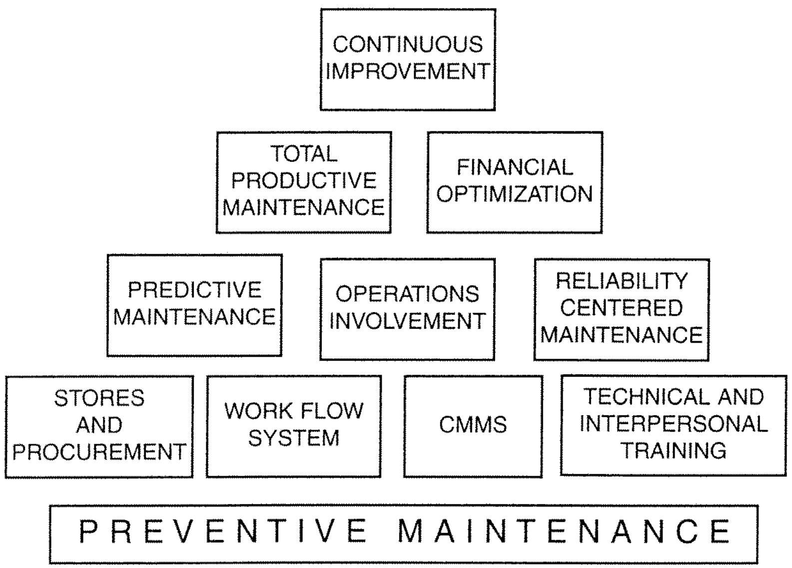
11. Continuous Improvement

Continuous improvement is best epitomized by the expression, "Best is the Enemy of Better." Continuous improvement in asset care is an ongoing program of evaluation, constantly looking for the little things that can make a company more competitive.

One of the key tools for continuous improvement is benchmarking. Process benchmarking is one of the most successful types. It examines specific processes in maintenance, compares the processes to companies that have mastered those processes, and maps changes to improve the specific process. The key to benchmarking is self-evaluation. A company must know its current status before it tries to benchmark with other companies. Without this knowledge, getting an accurate comparison of the benchmarked process is impossible.

MAINTENANCE (ASSET) MANAGEMENT STRUCTURE

The structure of the maintenance (asset) management function best can be compared to a pyramid (see below). In this figure, it is apparent that a foundation must be in place to build the maintenance management process. The basics of preventive maintenance form that foundation. Once the PM foundation is in place, inventory, work orders, CMMS, and training form the next level. The operational involvement, along with predictive and RCM techniques, build on this foundation. With sufficient data, the organization can focus on its asset strategy in TPM and optimize its financials. Once that level is achieved, all that is left is the continuous improvement loop of self-evaluation and benchmarking.



Chapter 2
Developing Maintenance Functions

MAINTENANCE MANAGEMENT DECISION TREE

Good, sound maintenance practices are essential for effective maintenance management. But what exactly are "good, sound maintenance practices?" This chapter explains the *maintenance management implementation decision tree* designed to assist in the development of a *best practice* maintenance management process. The practices described in this decision tree (see page 19) are intended to serve as a general model to guide the maintenance management development process. The pyramid (see Chapter 1) and the decision tree will be used to develop the performance indicators required to be effective in managing the maintenance process.

PM Program Development

Preventive maintenance is the core of any strategy to improve the equipment maintenance process. All plant equipment, including special backup or redundant equipment, must be covered by a complete, cost - effective preventive maintenance program. Such programs are designed to eliminate all unplanned equipment failures.

Evaluation of the PM Program

The preventive maintenance program should be evaluated to insure proper coverage of the critical equipment of the plant or facility. The program should include a good cross section of inspections, adjustments, lubrication, and proactive replacements of worn components. The goal of the program is to insure there will be no unplanned equipment downtime.

Is PM Effective? (<20% Reactive Work?)

The effectiveness of the preventive maintenance program is determined by the level of unplanned equipment maintenance that is performed. Unplanned equipment maintenance, which is defined as any maintenance activity that is performed with less than one week of advanced planning, is commonly referred to as reactive maintenance.

An effective PM program will reduce the amount of unplanned work to less than 20% of the total manpower expended for all equipment maintenance activities. If more time is being spent on unplanned activities, then a reevaluation of the preventive maintenance program is required. It will be difficult to make progress in any of the other areas unless the PM program is effective enough for the equipment maintenance to meet the 80%/20% rule.

Review of the Maintenance Inventories

After the preventive maintenance program is effective, the equipment spares, stores, and purchasing systems must be analyzed. The spares and stores should be organized, with all of the spare parts identified tagged, and stored in an identified location, with accurate on-hand and usage data. The purchasing system must allow for procurement of all necessary spare parts to meet the maintenance schedules. All data necessary to track the cost and usage of all spare parts must be complete and accurate.

Are the Stores Effective? (> 95% Service Level)

The service level measures what percent of the time a part is in stock when it is requested. Spare parts must be on hand at least 95% of the time for the stores and purchasing systems to support equipment maintenance activities. On the other hand, unless maintenance activities are proactive (less than 20% unplanned weekly) it will be impossible for the inventory and procurement departments to be cost effective in meeting equipment maintenance spare parts demands.

Review the Work Order System

The work order system is designed to track all equipment maintenance activities. The activities can be anything from inspections and adjustments to major overhauls. Any maintenance that is performed without being recorded in the work order system is lost. Lost or

unrecorded data makes it impossible to perform any analysis of equipment problems. All activities performed on equipment must be recorded to a work order by the responsible individual. Thus, maintenance, operations, and engineering will be extremely involved in utilizing work orders.

Are Work Orders Fully Utilized? (100% Coverage)

This question should be answered by performing an evaluation of the equipment maintenance data. The evaluation may be as simple as answering the following questions:

How complete is the data?
How accurate is the data?
How timely is the data?
How usable is the data?

Complete data is necessary for performing any meaningful analysis of the equipment's historical and current condition. Accurate data is needed to correctly identify the root cause of any equipment problems. Timely data is needed to correct equipment problems before they cause equipment failures. Data that is not usable cannot be formatted in a manner that allows for any meaningful analysis. Unless the work order system provides data that passes this evaluation, further progress is impossible.

Review Planning and Scheduling

The goal of planning and scheduling is to optimize any resources expended on equipment maintenance activities, while minimizing any interruption the activities have on the production schedule. Equipment maintenance activities should run like a pit stop in a NASCAR race, insuring optimum use of equipment with quality equipment maintenance activities being performed. Planning and scheduling pull together all of these activities (maintenance, operations, and engineering) and focus them on obtaining maximum (quality) results in minimum time.

Are Planning and Scheduling Effective? (>80% Weekly)

An effective planning and scheduling program will insure maximum productivity of the employees performing any equipment maintenance activities. Delays, such as waiting or looking for parts, rental equipment, equipment to be shut down, drawings, or tools, will all be eliminated. If these delays are not eliminated through planning and scheduling, then it will be impossible to optimize equipment utilization. These inefficiencies will be the same as a NASCAR pit crew taking too long for a pit stop; the race is lost by not keeping the car on the track. Similarly, equipment utilization is lost by not properly keeping the equipment in service.

Investigate the Computerization of the Work Order System

A considerable volume of data must be generated and tracked to properly utilize the work order system and to effectively plan and schedule. If the data becomes difficult to manage using manual methods, or if the workforce is burdened with excessive paper work and is accumulating file cabinets of equipment data that no one has time to look at, then it is best to computerize the work order system. If, however the number of pieces of equipment is relatively small and data tracking and analysis are not a burden, then it may be best to keep the manual work order system.

Establish a Manual Equipment Maintenance System

A manual system can be a simple as a card file with cards for each equipment item showing notations of all repairs and services on the cards. Other methods include a visual white board with markers and spaces for notations, a magnetic board with tags that can be moved as each service is completed, and a log book, which may be a three-ring notebook with pages for notations. The method doesn't matter as long as the equipment data is complete and in a format which can be analyzed.

Is the Manual System Effective?

The manual system should meet the equipment management information requirements of the organization. Some of the system's requirements include complete tracking of all repairs and service and the ability to develop reports, such as top ten equipment problems, most costly equipment to maintain, percent reactive vs. proactive maintenance, and cost tracking of all parts and costs. If the manual system does not produce this level of data, then it needs to be reevaluated. (If the system is effective, then go to Operational Involvement.)

Evaluate the Manual Work Order Process

The reevaluation of the manual work order system tries to determine where the weaknesses are in the system so that they can be corrected and good equipment data can be collected. Several questions for consideration include:

Is the data we are collecting complete and accurate?
Is the data collection effort burdening the work force?
Should we change the methods used to manage the data?
Do we need to reevaluate the computerization decision?

Once problems are corrected and the equipment management information system is working, then constant monitoring for problems and solutions must be put into effect. (go to Operational Involvement.)

Purchase and Install a CMMS

The computerized maintenance management system (CMMS) is a computerized version of a manual system. Currently over 200 commercially-produced CMMSs are available in the North American market. Finding the correct one may take some time, but through the use of lists, surveys, and word of mouth, not more than three to six months. When the right CMMS is selected, it must then be implemented. CMMS implementation may take from three months for smaller organizations to as long as 18 months for large organizations.

Companies can spend much time and energy selecting and implementing the CMSS. Remember that CMMS is only a tool to be used in the improvement process; it is not the goal of the process. Losing sight of this fact can curtail the effectiveness of any organization's path to continuous improvement.

Is the CMMS Usage Effective?

The correct CMMS should make the equipment data collection faster and easier. It should also make the analysis of the data faster and easier. The CMMS should assist in enforcing world class maintenance disciplines such as planning, scheduling, and effective stores controls. The CMMS should provide the employees with usable data with which to make equipment management decisions. If the CMMS is not improving these efforts, then its usage of the CMM needs to be evaluated.

Some of the problems encountered with CMMS include:
- Failure to fully implement the CMMS
- Incomplete utilization of the CMMS
- Inaccurate data input into the CMMS
- Failure to use the data once it is in the CMMS

Investigate Operator Involvement

As the equipment management system becomes effective, the next step is to investigate whether operator involvement is possible in some of the equipment maintenance activities. Many issues need to be explored, from the types of equipment being operated, the operators-to-equipment ratios, and the skill levels of the operators, to contractual issues with the employees' union. In most cases, there will be some level of activity that the operators can be involved within their areas. If there are no obvious activities for operator involvement, then a reevaluation of the activities will be necessary.

Identify the Activities

The operators may be involved in basic or complex activities. It is determined partially by their current operational job requirements. Some of the more common tasks for operators include:

Equipment Cleaning. This task may involve simply wiping off equip ment when starting it up or shutting it down.

Equipment Inspecting. This task may range from a visual inspection while wiping down equipment to a maintenance inspections checklist while making operational checks.

Initiating Work Requests. Operators may make out work requests for any problems (either current or developing) on their equipment. They would then pass these requests to maintenance for entry into the work order system. Some operators will directly input work requests into a CMMS.

Visual Systems. Operators may use visual control techniques to inspect and determine the condition of their equipment.

Whatever the level of operator involvement, it should contribute to the improvement of the equipment effectiveness.

Are the Operations Personnel Certified to Perform the Activities?

Once the operator activities been determined, the ability to perform these activities must be examined. The operators should be properly trained to perform any assigned tasks. The training should be developed in a written and visual format. Copies of the training materials should be given to the operators for their future reference. This will contribute to the standardization required for operators to be effective while performing these tasks. Note that certain regulatory organizations (e.g., OSHA and EPA) require documented and certified training for all employees.

Begin Operator Involvement

Once the operators are trained and certified, they can begin performing their newly assigned tasks. It is important for the operators to be coached for a short time to insure they have the full understanding of the hows and whys of the new tasks. Some companies have made this coaching more effective by having the maintenance personnel assist with it. This way background knowledge can be transferred to the operators that they may not have gotten during the training.

Is Predictive Maintenance Being Performed?

Once the operators have begun performing some of their new tasks, some maintenance resources may be available for other activities. One area that should be explored is predictive maintenance. Some fundamental predictive maintenance techniques include vibration analysis, oil analysis, thermography, and sonics.

Plant equipment should be examined to see if these techniques will help reduce downtime and improve service. Predictive technologies should not be utilized because they are technically advanced, but only when they contribute to improving the equipment effectiveness. The correct technology should be used to monitor and solve the equipment problems encountered.

Investigate Reliability Engineering

Reliability engineering is a broad term that includes many engineering tools and techniques. Some common tools are:

Life Cycle Costing. This technique allows companies to know the cost of their equipment from the time it was designed to the time of its disposal.

RCM. Reliability-Centered Maintenance is used to track the types of maintenance activities performed on equipment to insure they are the correct activities.

FEMA. Failure and Effects Mode Analysis examines the way equipment is operated and any failures incurred during its operation in order to find methods of eliminating or reducing subsequent failures.

Early Equipment Management and Design. This technique takes information equipment and feeds it back into the design process to insure that any new equipment is designed for maintainability and operability.

These and other reliability engineering techniques improve equipment performance and reliability help to insure competitiveness.

Investigate Financial Optimization

Once the equipment is correctly engineered, the next step is to understand how the equipment or process impacts the financial aspects of the company's business. Financial optimization considers all costs impacted when equipment decisions are made. For example, when calculating the timing to perform a preventive maintenance task, is the cost of lost production or downtime considered? Are wasted energy costs considered when cleaning heat exchangers or coolers? In this step, the equipment data collected by the company is examined in the context of its financial impact on profitability.

Are the Tools and the Data Available for Financial Optimization?

While financial optimization is not a new technique, most companies do not properly utilize it because they do not have the data necessary to make it effective. Some of the data required includes:

MTBF (mean time between failure) for the equipment
MTTR (mean time to repair) for the equipment
Downtime or lost production costs per hour
A pareto analysis of the failure causes for the equipment
Initial cost of the equipment
Replacement costs for the equipment
A complete and accurate work order history for the equipment

Without this data, financial optimization can not be properly conducted on equipment. Without the information systems in place to collect this data, a company will never have the accurate data necessary to perform financial optimization.

Use Financial Optimization

If the data exists and the information systems are in place to continue to collect the data, then financial optimization should be utilized. With this tool, equipment teams will be able to financially manage their equipment and processes.

Evaluate the Success of the Maintenance Management Program

Are the results achieved by maintenance reaching the goals that were set for the improvement program when it was started? If they are not, then the maintenance improvement program needs to be examined for gaps in performance or deficiencies in existing parts of the process. Once weaknesses are found, then steps should be taken to correct or improve these areas.

Strive for Continuous Improvement

Continuous improvement means never getting complacent. It is the constant self-examination with the focus on how to become the best in the world at the company's business. Remember:

Yesterday's Excellence
is
Today's Standard
and
Tomorrow's Mediocrity

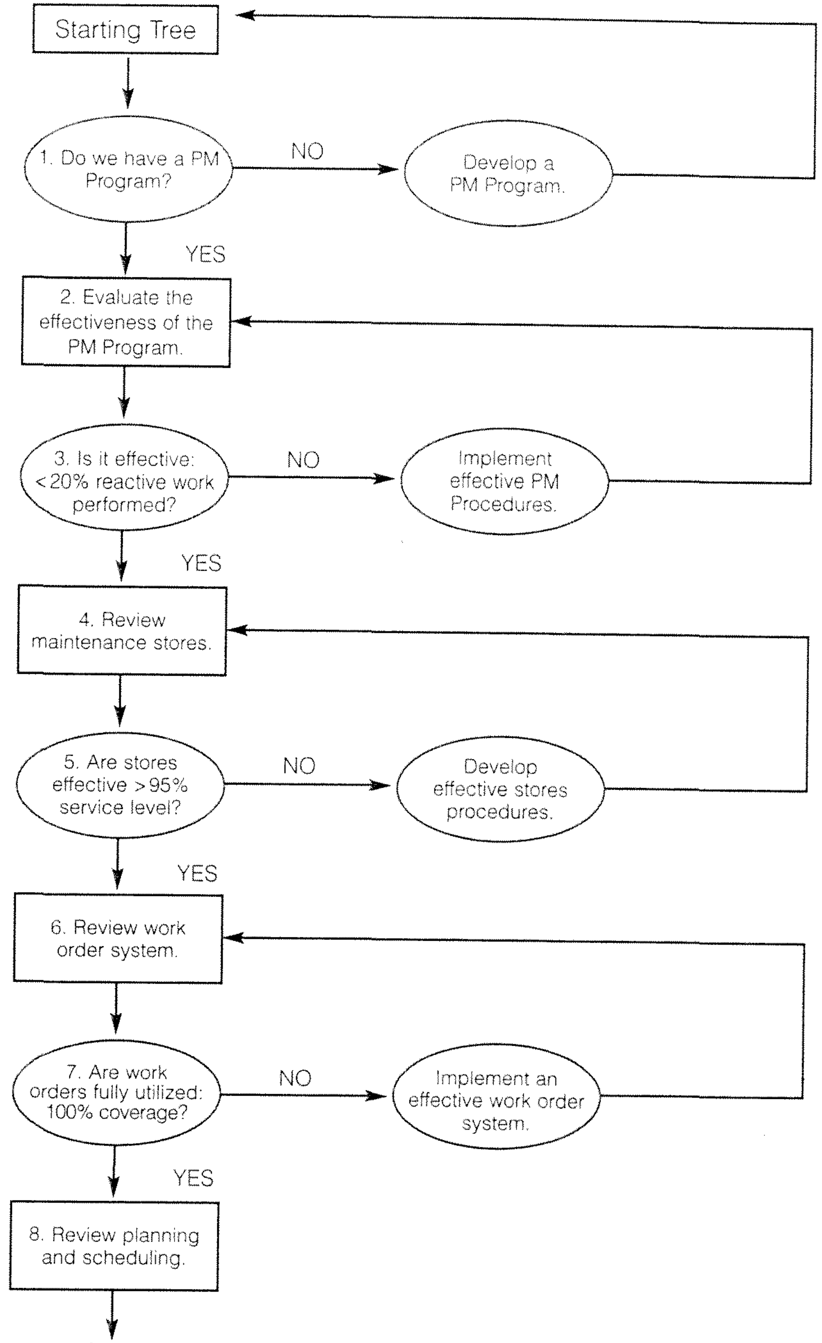
Introduction to Functional Performance Indicators

Functional indicators derive their name from the word function. These indicators show how the function is performing. Chapters 1 and 2 discussed the functions of the traditional maintenance organization. To review, the following is a list of functions required by most maintenance departments:

- Preventive Maintenance
- Inventory and Procurement
- Work Order Systems
- CMMS
- Technical and Interpersonal Training
- Operational Involvement
- Predictive Maintenance
- Reliability-Centered Maintenance
- Total Productive Maintenance
- Statistical Financial Optimization
- Continuous Improvement

Chapters 3 through 13 highlight main functions of maintenance management. Each chapter begins with a brief overview of the function, followed by common performance indicators used for each function. The strengths and weaknesses of each indicator will be presented. The last section in each chapter covers the eight most common problems leading to low indicators in the function with suggested solutions to each problem.

Maintenance Management Implementation Tree



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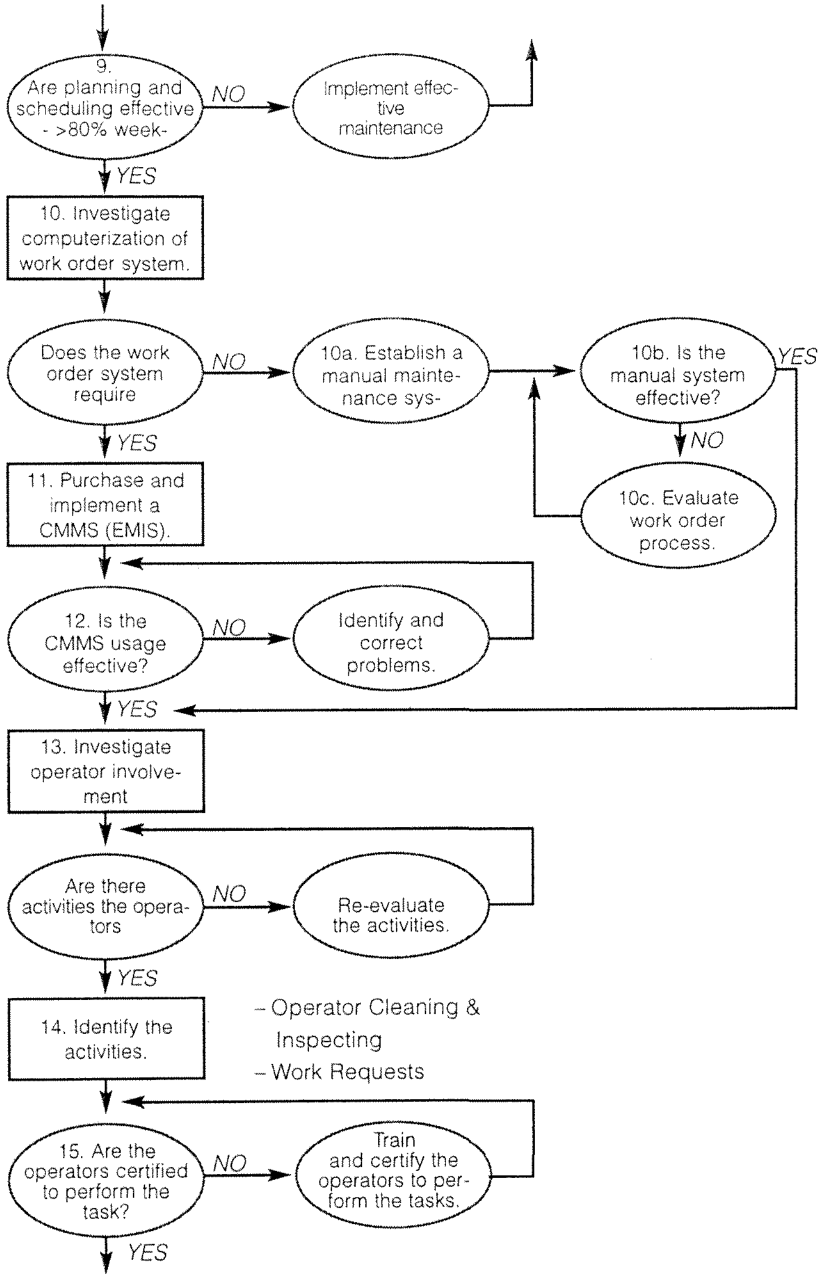
Maintenance Management Implementation Tree



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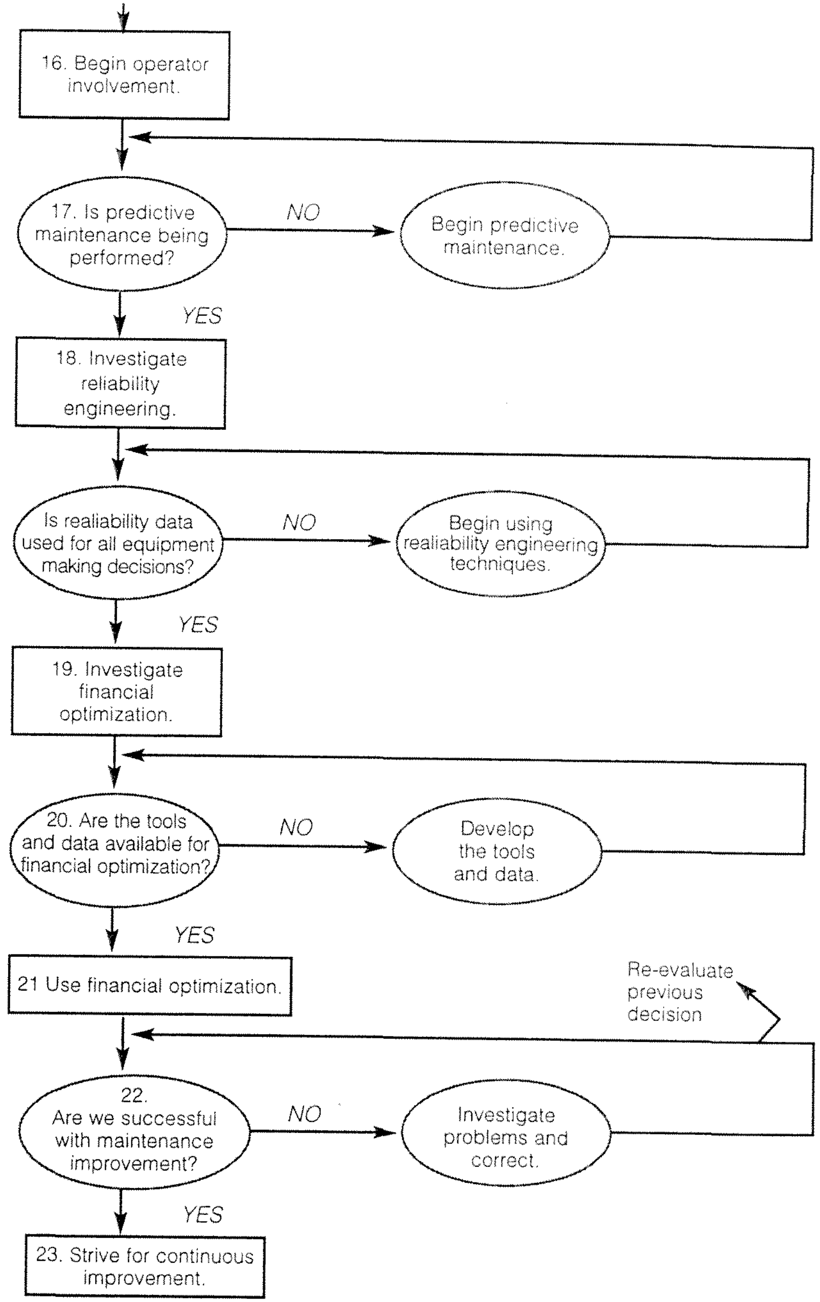
Maintenance Management Implementation Tree



Chapter 3
Preventive Maintenance

Preventive maintenance is the foundation of all maintenance philosophy. Unless the PM program is effective, all subsequent maintenance activities will be suboptimized. In short:

UNLESS THE PM PROGRAM IS SUCCESSFUL,

NOTHING ELSE WILL BE.

How can the success of the PM program be determined? The following indicators can be applied to the PM program. Each indicator has its strengths and weaknesses.

1. Equipment Downtime Caused by Breakdowns

This first indicator highlights the impact the preventive maintenance program has on the plant or facility. It focuses on what the PM program is designed to eliminate: equipment breakdowns.

$$\frac{\text{Downtime Caused by Breakdowns}}{\text{Total Downtime}}$$

This indicator takes the total amount of downtime caused by the breakdown of a piece of equipment, a department, an area, or even an entire plant or facility, and examines it in the context of all downtime. It may be common at some plants or facilities to refer to breakdowns as unplanned downtime. Total downtime represents all lost time, whether due to maintenance, operations, purchasing, transportation, or even an external supplier.

Strengths

This indicator identifies whether the breakdown or unplanned downtime is actually a problem at the plant or facility. It may be that downtime is caused by another problem, rather than the preventive maintenance program.

Weaknesses

The largest weaknesses of this indicator are the proper classification of downtime and the accurate record keeping required. Downtime must be closely tracked and categorized. If an equipment-related breakdown is not closely tracked, then the time the operator is taking a break, procuring raw materials, or even eating lunch may be included in the breakdown time. Such tracking would inflate the downtime and obscure other problems. Unless accurate records are kept, the breakdown downtime becomes a "catch-all" and is not useful as a management tool.

2. Emergency Manhours

This indicator highlights the resources being allocated to plant or facility breakdowns. When the level of resource consumption for emergency or breakdown activities is high, then the productivity rates for the labor resources, whether in-house or contract, is low. This indicator may be used at a department, area, or even plant level. It may be used to examine resources by trade or craft line.

This indicator is also useful for examining work distribution. A typical distribution would examine the resources used in at least 4 categories:

Preventive maintenance
Emergency or breakdown maintenance
Repair or corrective maintenance
Routine (or standing) maintenance

$$\frac{\text{Manhours Spent on Emergency Jobs*}}{\text{Total Manhours Worked}}$$

Specifically this indicator takes the time spent on emergency or breakdown work and divides it by the total manhours expended. The indicator, which is expressed as a percentage, should examine total resources, not just maintenance. If there are operators involved, or contractors, their time should be included as well.

Strengths

This indicator is useful for examining if maintenance labor is being consumed by emergency or breakdown work. Typically, if the amount of emergency or breakdown work consumes more than 20% of the maintenance labor resource, then the preventive maintenance program is viewed as ineffective. This indicator, then, becomes a key to PM program evaluation.

Weaknesses

This indicator, like almost all others, depends on accurate data collection. Without accuracy, then a problem with the preventive maintenance may go undetected. Additionally, what is classified as an emergency or breakdown may need clarification.

3. Cost of Breakdown Repairs

This indicator examines breakdowns in yet another way: the direct cost of breakdowns and emergency repairs. This figure includes the cost of labor, materials, rental equipment, contractors, and any other direct maintenance cost. However, the cost of lost production (or throughput) should not be included in this calculation. This total is then divided by the total direct maintenance cost and a percentage is derived. This indicator can be calculated at different levels: the maintenance department level, the trade or craft level, the production department or area level, or even the equipment level.

$$\frac{\text{Direct Cost of Breakdown Repairs*}}{\text{Total Direct Cost of Maintenance}}$$

Since the cost to perform maintenance in a reactive mode is considerably higher than the cost to perform maintenance in a planned mode (by as much as two to four times), this indicator will not match the percentage in the previous indicator.

Strengths

This indicator will highlight the impact the breakdown or emergency work is having on the maintenance budget. It can be used to cost justify improvements in the preventive maintenance program, when the percentage of maintenance dollars spent on breakdown or emergency activities is clearly shown.

** Indicators marked with an (*) are expressed as a percentage*

Weaknesses

This indicator requires that all breakdown or emergency repairs be clearly identified. When the small activities are not included, problems with preventive maintenance are hidden, making them difficult to detect. Since the root cause of the problem is not defined, any cost effective corrections or improvements are difficult to make.

4. Preventive Maintenance Compliance

This indicator compare the number of preventive maintenance tasks that are completed to the number of preventive maintenance tasks that are scheduled. This indicator is typically compiled on a weekly basis. It is useful for highlighting a preventive maintenance program that may be developed, but is not effective. The effectiveness is hampered by failure to complete the tasks that are scheduled. The reason for this failure may be that production is overcommitted and won't release the equipment for maintenance, or the maintenance resources are overcommitted due to breakdowns and emergency work and, therefore, don't have the capacity to complete the scheduled preventive maintenance tasks.

$$\frac{\text{Preventive Maintenance Tasks Completed}^{*}}{\text{Preventive Maintenance Tasks Scheduled}}$$

The goal of this indicator is to have 100% completion of the scheduled tasks. While this level is not easily achieved, it should be the goal of all organizations. All preventive maintenance tasks, including tasks performed by maintenance, operations, and even contractors, should be completed.

Strengths

This indicator effectively measures the compliance an organization has with its preventive maintenance program. It is one of the key indicators for any PM program. If the indicator is graphed weekly over a period of six months, then it can be correlated with the percentage of maintenance activities that are breakdown or emergency repairs. What will the graph reflect? As completion rate goes up, the breakdowns and emergencies go down. Conversely, as the completion rate drops, the breakdowns and emergencies increase. If accurately tracked, the correlation is undeniable and can be used to gain support for the preventive maintenance program.

Weaknesses

The weakness is not the indicator itself, but a rather type of PM schedule that obscures or hides the fact that preventive maintenance tasks are not completed. This is the dynamic or sliding preventive maintenance schedule. With this schedule, the preventive maintenance task is based on the last completion date, not on a fixed schedule or a usage counter. This means that if the task is not completed this month, it is not rescheduled until it is completed. There are actually cases where monthly tasks have not been completed for three to six months but do not show up as late or overdue. No organization truly serious about its preventive maintenance program should ever use dynamic or sliding schedules.

5. Preventive Maintenance Estimates Compliance

This indicator compares the estimates of labor and materials costs for preventive maintenance tasks with the actual costs to perform the tasks. This measure points to the accuracy of these estimates. If the estimates are inaccurate, then adjustments can be made so that accuracy can be insured. Accurancy is particularly vital when the maintenance organization is using a scheduling system that is integrated with the production scheduling system. Inaccuracies in such a system will have dramatic negative consequences over time.

$$\frac{\text{Estimated PM Task Cost}^{*}}{\text{Actual PM Task Cost}}$$

The indicator is calculated by dividing the estimated cost by the actual cost. A caution must be highlighted: this should not be measured over a small window of time. On occasion, a task may exceed the estimated cost due to exposed problems. However, if this analysis is performed on a semiannual or annual basis, the results should provide a good indication of the accuracy of the estimates.

Strengths

The strengths of this indicator include its ability to effectively monitor the accuracy of the preventive maintenance task estimates. If the accuracy of individual estimates is not constantly monitored, then the overall accuracy of the estimated labor and materials required to perform preventive maintenance tasks will be inaccurate, leading to budgetary problems.

Weaknesses

The biggest weakness of this indicator is the fact that nonpreventive maintenance tasks are often charged to preventive maintenance activities. For example, if a problem uncovered during the performance of the task is corrected while performing the task, how is the additional labor and material charge billed? If the actual charges, which are repairs, are charged to the preventive maintenance work order, then the estimate is exceeded and the integrity of the estimate is in question. It is a good practice to complete the repair and then charge the costs to a new work order written to identify the work that was actually performed.

6. Breakdowns Caused by Poor PMs

This indicator examines the root causes of breakdowns and then investigates whether those causes should have been detected as part of the PM program. This indicator evaluates both the effectiveness of the preventive maintenance task and the thoroughness of the individual carrying out the task. For example, lubrication-related failures should not occur on equipment that is inspected and lubricated as part of the PM program. The breakdown indicates a failure of the program. Mod-ifications to the task listing, the retraining of an individual, or the addition of some visual control technique may be required to insure that the failure is not repeated.

$$\frac{\text{Number of Breakdowns that Should Have Been Prevented*}}{\text{Total Number of Breakdowns}}$$

This measure compares the total number of breakdowns that could have been prevented or detected by the preventive maintenance program with the total number of breakdowns. The resulting percentage indicates the opportunity for improvement by upgrading or changing the PM program. An additional argument for improvement can be made if the losses incurred by the breakdowns (maintenance costs, equipment damage, downtime costs) are also included.

Strengths

This indicator provides an accurate insight into the effect that preventive maintenance is having on the equipment breakdowns. Monitoring this indicator helps to insure that the preventive maintenance policy is cost effective.

Weaknesses

This indicator's greatest weakness is procedural. The organization must be committed to completing accurate and detailed root-cause analysis of equipment breakdowns. If the root cause is merely assumed or guessed, then the true effectiveness of the PM program is obscured.

7. Preventive Maintenance Efficiency

This indicator examines the amount of work that is generated from the PM program. When carrying out the preventive maintenance inspection, the inspector will uncover components or systems showing signs of wear, or even an impending failure. The inspector will then write work orders to correct the problem before a breakdown occurs. These orders may involve adjustments, changing components, or even a major overhaul. Some work should be generated from the inspections, otherwise the preventive maintenance tasks are probably being carried out too frequently.

$$\frac{\text{Total Number of Work Orders Generated from PM Inspections*}}{\text{Total Number of Work Orders Generated}}$$

Here efficiency is measured by dividing the total number of work orders generated from the preventive maintenance program by the total number of work orders submitted. This measure is generally examined on a monthly basis, although other frequencies can be acceptable, depending on the inspection frequency. The resulting percentage will highlight whether the PM program is effective in proactively finding developing equipment problems.

Strengths

This indicator is effective for preventive maintenance program evaluations. It is viewed as effective if the majority of the work orders submitted are found through the PM program. While this may appear to be performing too much preventive maintenance, this fact will not be established until further factors are applied in the reliability-centered maintenance approach.

Weaknesses

This indicator can be misleading if excessive work is performed by the inspector while actually carrying out the preventive maintenance task. If, rather than writing a work order, the repairs are hidden in the preventive maintenance charges, the effectiveness of the inspections will be called into question. A second problem may be motivating individuals to fill out the necessary documentation to establish the data. If the inspectors would rather do the task than write up a work order, then the amount of work discovered by the PM program is hidden. Another factor may be the lack of good inspection skills. Do the inspectors really know how to inspect, what to look for, and how to find true root causes? These questions can be resolved by good testing and training of the inspectors.

8. Equipment Uptime

This indicator highlights the amount of uptime that is required for the equipment to meet the production forecasts. In a sold-out market condition, the required uptime may be 100%. However, if the equipment is required 100% of the time because the plant has to continually make up production losses caused by unreliable equipment, then the desired uptime may change as the PM program becomes more effective. Requiring 100% uptime makes it difficult to perform the right level of maintenance on the equipment which , in turn, contributes to future problems. This indicator may help determine if the organization has a realistic expectation of the equipment output. If 100% is expected all of the time, then the organization's technical understanding and commitment to the longevity of its assets must be questioned.

$$\frac{\text{Desired Equipment Uptime} - \text{Downtime}^*}{\text{Desired Equipment Uptime}}$$

This indicator is measured by first finding the desired uptime minus the downtime, dividing by the desired uptime. Some organizations refer to this measure as availability. The percentage should be evaluated on a weekly or monthly basis and monitored. A decrease in uptime will indicate a problem with the PM program, possibly indicating a change in the life-cycle phase of the equipment. It can also indicate a possible change in operational schedules, which severely impact calendar-based PM programs.

Strengths

This measure is a good indicator, since ultimately the preventive maintenance program is designed to maximize uptime. Most of the information to calculate the uptime comes from the production or facilities groups. Using this calculation helps to insure their understanding and support of the PM program. This indicator may be superior to the one used previously since all downtime is included. This aspect should foster more departmental support for the indicator, since any downtime related to causes within their control is also exposed, not just maintenance.

Weaknesses

The weakness of this indicator is that all causes of downtime are tracked and used in the calculation, whereas the previous indicator tracked just the maintenance-related downtime. This differentiation requires very accurate data so that the PM program does not get blamed for downtime it can not prevent.

9. Overdue PM Tasks

This indicator examines the number of preventive maintenance tasks that are not being completed on schedule. It is valuable for spotting trends where schedule compliance is beginning to slip. This indicator will forecast problems, since once the schedule begins to slip, the breakdown or emergency requests will begin to rise in the near future. Paying attention to this indicator will allow a proactive approach to managing the PM program. This indicator is most effective when monitored on a weekly basis and then monitored over a rolling six-month time period.

$$\frac{\text{Number of PM's Overdue}^*}{\text{Total Number of PM's Outstanding}}$$

This indicator represents the number of preventive maintenance tasks that are past due divided by the number of preventive maintenance tasks currently in the active backlog. This measure gives an accurate representation of the level of effort required to keep the PM program in compliance. The goal, of course, is to keep this percentage as low as possible.

Strengths

This indicator is required for any company monitoring the progress of their preventive maintenance program. Without this indicator, there would be virtually no way to track the compliance status of the PM program.

Weaknesses

The only weakness of this indicator is the challenge of keeping accurate data. Some organizations cancel preventive maintenance tasks so that they don't clutter the work order backlog. This practice is not recommended, since it can alter the accuracy of the PM program compliance data. It is better to allow the problems to be exposed so that they can be corrected than it is to hide the problems by manipulating the work order data.

10. Percentage of Overtime

Although this indicator is not always a direct measure of the PM program' effectiveness, it can still be hepful. In many organizations, overtime is worked in response to equipment breakdowns or emergency work. High overtime rates can be an indicator of the ineffectiveness of the PM program.

$$\frac{\text{Hours Worked as Overtime}^{*}}{\text{Total Hours Worked}}$$

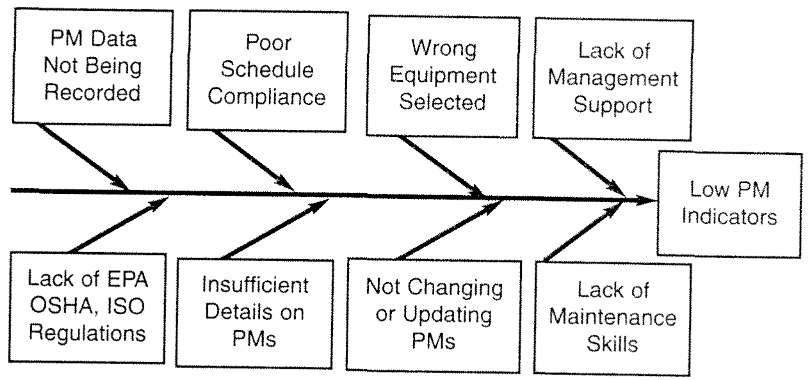
This indicator is derived by dividing the hours worked as overtime by the total hours worked. This percentage then shows the premium (overhead) time that is being used to perform work. Proactive maintenance organizations work 5% or less of their total time as premium time.

Strengths

This indicator will help managers monitor the amount of emergency or breakdown work that requires overtime to complete. This measure is important since the overtime requires a premium cost.

Weaknesses

Some organizations have developed a poor practice of working overtime rather than increasing personnel. This may obscure the amount of overtime worked that is due to a poor PM program.



Preventive Maintenance Program Problems

The following problems are the most common disablers for preventive maintenance programs. If these conditions exist in an organization, then it will be difficult, if not impossible, for a sustainable preventive maintenance program to be implemented.

Lack of Management Support

Management support is the single most critical factor to the success or failure of a preventive maintenance program. If management is not committed to a PM program, it will fail. In turn, all other maintenance initiatives within an organization will be suboptimized.

While there is no magic answer for solving this problem, companies that have management support obtain it with financial justification. Preventive maintenance can address many issues that affect a company's ability to remain profitable. Some of these areas include:

ISO, OSHA, EPA, and PSM. Most of these regulatory programs and others require equipment that is safe to operate and maintain, not hazardous to the environment, and able to hold specifications to produce a quality product.

Total Quality Management (TQM). The support for this program is clearly seen in the ISO-9000 and QS-9000 requirements for good preventive maintenance .

Just-In-Time. Simply, it is impossible to produce products on an exacting schedule without reliable and maintainable equipment. It is impossible to have reliable and maintainable equipment without an effective preventive maintenance program.

Customer Service Orientation. A company cannot satify its customers by producing the lowest cost product, with perfect quality, and deliver it in a timely manner unless it has a PM program that insures equipment reliability.

Capacity Constraints. Preventive maintenance insures not only uptime of the equipment, but also performance efficiency. Thus, when the equipment is operating, it produces at design capacity with the desired uptime; the company does not develop equipment-related capacity constraints.

Redundant Equipment. Equipment that operates as designed and when it is required to operate reduces the need for redundant equipment that backs up unreliable equipment or that supplements the existing equipment capacity. In turn, the return on net assets indicator is kept at a best practice level.

Energy Consumption. Well-maintained equipment requires 6% to as much as 11% less energy than poorly-maintained equipment. When a company considers the cost of heat exchangers, coolers, HVAC systems, steam leaks, and air leaks, it can quickly see the potential for considerable savings.

Usable Asset Life. Well-maintained equipment lasts from 30% to 40% longer than poorly-maintained equipment. Developing a "don't maintain, just replace" attitude with equipment can lead to unnecessary capital expenditures. Just examine how often equipment is replaced in kind—no major upgrade in engineering or technology—just because it wore out. Is it possible that the purchase could have been deferred if proper preventive maintenance had been performed?

By examining these eight areas, it may be possible to convince the appropriate managers to provide the support necessary to have a successful preventive maintenance program.

Lack of Maintenance Skills

This area is developing into one of the major problems facing PM programs today. The skills necessary to inspect and perform basic maintenance tasks on equipment today seem to be deteriorating. These routine tasks include the proper lubrication of bearings, using the right lubricant, the right quantity, and the right frequency, and selecting the right application method.

In many companies, basics such as these are virtually ignored. The problem compounds when proper installation and maintenance of basic components such as belts, chains, gears, and pneumatic and hydraulic systems are included. It does little, if any, good to schedule preventive maintenance activities, if they can not be carried out correctly.

The key to correcting this problem is training (see chapter 7) and enforcement of the learned behavior. This means that the training will have to be made available to anyone required to operate or maintain the equipment. Once the training reaches critical mass, peer pressure and the sense of equipment ownership will be required to assure that good practices are continued.

Wrong Equipment Selected

Selecting the wrong equipment can be a start-up problem for many PM programs. When starting a preventive maintenance program, the critical equipment to the mission should be selected. It is imperative that results be shown early in the PM program. The equipment selected should be constraint equipment (equipment causing a bottleneck) or equipment that has no backup and will severely impact production or availability of the facility if it incurs downtime.

This problem can be overcome by prioritizing the equipment when beginning the PM program, based on the above-mentioned criteria. It may be best to poll different department, managers, and shop floor personnel to develop support for the equipment selected, thereby fostering organizational support for the preventive maintenance program.

Not Changing or Updating the PM Program

This problem develops after the preventive maintenance program has been in place for a time period. The program was probably once effective, but then the level of breakdowns and reactive maintenance started to increase. Even though the PM program is in compliance, results are diminishing.

This change my be due to the fact that the equipment is entering a different phase of its life cycle. What may have been the right level of service and activities in the past, the equipment maintenance needs change as equipment ages. The preventive maintenance tasks should be reevaluated in light of the current equipment problems. It may be that, when the preventive maintenance tasks were developed, the daily, weekly, and monthly tasks were defined, but the service required at semiannual, annual, and biannual frequencies was never developed. Thus, components on the equipment may develop undetected problems and fail.

The preventive maintenance tasks must be evaluated in context with the long-term equipment needs insuring that preventive maintenance occurs for the entire life cycle of the equipment.

Poor Schedule Compliance

Compliance problems occur for several reasons, but always impact the effectiveness of the PM program. When tasks are scheduled and not completed within the assigned time frame, the equipment begins to deteriorate. While the equipment may not begin to fail immediately, it begins to develop multiple deteriorated components. The interaction of the worn component begins to mask problems. Operating the equipment becomes more complicated as it no longer stays in adjustment or holds specifications. The equipment no longer runs at design speed; the deterioration requires it to be slowed 10% or more, reducing its capacity. Troubleshooting the equipment also becomes more difficult as one problem leads to another. The equipment will require a rebuild to reach an acceptable baseline where the preventive maintenance tasks will once again be effective.

The only cure is to fully dedicate the resources needed to keep the PM program in compliance. This cure may require management support, since production schedules may have to be altered or, over time, may have to be authorized.

Insufficient Detail on PM Sheets

Insufficent detail is typically a start-up problem with the preventive maintenance program. Because the proper level of detail is not developed, items are missed on the preventive maintenance inspections or services. Some samples of poor detail include checking the motor to see if it is hot, checking the belt drive, and checking the chain drive

These are examples of vague preventive maintenance inspections. For example, when checking the motor, how hot is hot? The task descriptions should contain temperatures, pressure setting, flow values, and so forth.

Some may argue that this greater level of detail is expensive and time consuming. By itself, that statement is true. However, what does a missed inspection point cost when the equipment fails? The lack of inspection details allows for items to be overlooked or viewed incorrectly, this contributing to breakdowns and overall loss of preventive maintenance efficiency.

One of the greatest causes contributing to the lack of detail is the lack of resources during the initial development of the PM program. For example, how can the resources be calculated? The following information illustrates one approach.

Number of equipment items	1,000
Average number of PMs per item	X 3
Total PMs required	3,000
Average 1 hour per PM for development	X 1
Total manhours required	3,000 or 1.5 man-years of effort

Since most companies do not allocate this level of resource, the preventive maintenance tasks are only partially developed, with the hope of going back someday to finish the development. But in most organizations, this never happens and the preventive maintenance program is ineffective.

The only solution is to dedicate the resources necessary to develop the task details initially. Then the company will realize the full benefits of preventive maintenance.

PM Data Not Being Recorded

Sometimes after the PM program is implemented and the completed inspections are turned in for processing, the inspections are never reviewed and the notations are not permanently documented. This problem usually occurs because there are no resources to transfer the inspection results to a database so that they can be analyzed. Therefore, the comments made by the inspectors are lost and any subsequent work that was to be requested and performed is also lost. This problem prevents evaluation of the PM program's results and effectiveness. In turn the PM program will deteriorate as the equipment ages, unable to meet the equipment's changing needs.

The lack of data recording is also commonly caused by the lack of an easy-to-use computerized maintenance management system. Given scarce resources, any CMMS used to manage data must make it easy to input and analyze data.

This problem has a two-part solution. First, the correct staffing level must be determined, based on the amount of data collection and analysis that the organization is performing. When the department is understaffed, data accuracy ultimately suffers and what is collected is of no

value. Once the correct staffing level is provided, the organization should plan to utilize the most effective CMMS it can afford. This step reduces the amount of frustration that employees would otherwise have when recording and analyzing data on antiquated software.

Lack of Understanding of Government Regulations

This problem stems from a lack of appropriate education. The regulatory requirements for maintenance organizations are complex; they require extensive training for the staff to accurately understand them. However, most maintenance management positions are high-turnover positions, with newer and younger replacements constantly being hired.

This problem places the company under tremendous pressure. If the preventive maintenance is not carried out on the equipment, the company may be in violation of a regulatory standard. However, the maintenance manager may not even have a clear understanding of which preventive maintenance activities require priority. This leads to compliance problems and ultimately a failure of the PM program.

The only solution to this problem is effective education for the maintenance supervisors about regulatory requirements and then the ability to enforce the requirements to collect the data and keep the company equipment in compliance.

Chapter 4
Inventory and Procurement

Maintenance materials is the second most important function in maintenance management, after preventive maintenance. It plays a major role in terms of its contribution to maintenance efficiency and effectiveness. Materials that are improperly maintained are one of the large root causes of equipment downtime and capacity losses. In fact, maintenance, repair, and overhaul of spare parts (MRO) accounts for an average of 50% of the maintenance budget. Therefore, it is essential to examine performance indicators that will insure proper management of the inventory and procurement functions for maintenance.

1. Inactive Stock Showing No Movement in the Last Year

This indicator is used to find spare parts that are no longer needed. These parts may have been purchased for equipment that is no longer in the plant. Occasionally parts were purchased in large quantities on a one time basis, possibly for construction or a project, but were not used and have no further use at the plant or facility. Eliminating these items reduces the inventory value and the subsequent holding cost the company must pay.

$$\frac{\text{Inactive Stock Line Items}^{*}}{\text{Total Stock Line Items}}$$

This measure represents, the number of line items that are inactive divided by the total number of line items carried in the inventory. The percentage shows the opportunity for improvement by eliminating line items from the store inventory.

This measure can also be calculated by dividing the dollar value of the inactive stock items by the total inventory valuation. This percentage would indicate the percentage of value that could be achieved through inventory reduction.

Strengths

This indicator is useful for highlighting opportunities to reduce the overall inventory valuation. In companies where equipment and processes are rapidly outdated by ongoing technology changes, this indicator is especially critical to monitor.

Weaknesses

This indicator doesn't differentiate between a disposable spare part and one that is kept on hand due to lead time and delivery issues. Some equipment spares are kept in stock because they are produced in another country and the lead time needed to obtain them may be months or even a year. (In these instances, keeping the spares is wise, even if they don't move for several years.)

Any time this indicator is used to highlight items for possible removal from inventory, careful research should made to insure that the items don't have a long lead time or are difficult to obtain. These items should never be arbitrarily removed from inventory.

2. Stores Annual Turns (Dollar Amount)

Organizations want to examine the number of times in a year that the dollar value of the stores inventory is actually used. Some spare parts will not be used in a year others will show many turns. This indicator compares the dollar value of the issued items to the total inventory valuation.

This indicator is a widely-accepted benchmark for maintenance stores. The average for companies in the United States is between 1 and 1.2 turns per year. Organizations that practice advanced strategic supplier techniques are working to raise that number much higher. However, many organizations are still below 1 turn per year.

$$\frac{\text{Total Annual Dollar Amount of Stores Usage}^{**}}{\text{Total Inventory Valuation}}$$

The measure shows the total annual dollar amount of stores usage divided by the total dollar value of the inventory. The result,which is expressed as a decimal number, provides the commonly-used *number of turns* indicator.

Strengths

This standard industry benchmark shows whether a company has too large an inventory (in dollars). The indicator can to be used to compare different organizations, since their inventory goals are similar.

Weaknesses

This indicator's greatest weakness is that companies owning a lot of foreign-made equipment will tend to have lower numbers. If the items are arbitrarily removed from inventory to meet some "benchmark number", the company may experience a large increase in downtime and a subsequent large decrease in capacity. This indicator must be used carefully.

3. Spare Parts Controlled

This indicator highlights the uncontrolled spare parts within a company. Reactive maintenance organizations tend to develop personal or pirated stores. These spares are never tracked, yet the company paid for them. In many cases, the stores personnel may be reordering items, even though the parts are already in the plant in several untracked locations. The goal is to have all spare parts in controlled stores in order to insure cost-effective inventory policies.

$$\frac{\text{Total Maintenance Spare Parts in Controlled Stores}^{*}}{\text{Total Inventory on Hand (Controlled + Uncontrolled)}}$$

The indicator represents the dollar value of all controlled stores items divided by the estimated dollar value of all spare parts. The dollar value must almost always be estimated, since the actual cost is rarely available. The closer this measure is to 100%, the better the inventory policies are that a company is utilizing. The indicator tends to be lower when the maintenance organization is reactive.

Strengths

This indicator accurately represents the level of financial control that the inventory and procurement departments have over the maintenance spare parts.

Weaknesses

This indicator is hard to calculate. In most companies, it is difficult, if not impossible, to calculate the value of all of the open storage locations and personal storage locations.

4. Service Level of the Stores

Service level shows the percentage of time that the inventory department is able to fill maintenance requests for spare parts. It is becoming a standard benchmark for comparing performance. Higher percentages reflect better performances of the inventory and procurement groups in meeting their customers' needs.

$$\frac{\text{Total Number of Orders Filled on Demand}^*}{\text{Total Number of Orders Requested}}$$

The indicator represents the total number of orders filled on demand divided by the total number of orders requested. The benchmark value for this indicator is between 95% and 97%. Any performance lower than 95% will contribute to work delays and lead to individuals developing their own storage areas. Values higher than 97% suggest that inventory is carrying too many spare parts.

Strengths

This indicator allows for a fair comparison of stores functions between companies. Accepted internationally, it has little opportunity for error in its calculation, provided the input data is accurate.

Weaknesses

The timing of when a part is considered out of stock can affect the service level. Is the stock out reported when a job is planned and the part is not in stock? In this case, some of the parts might already be in transit and could arrive in time to be used. If a company registers the stock out at the time of planning and still has a 95% to 97% service level, then the overall inventory of parts is likely to be too large.

5. Stock Outs

Stock outs are the inverse of service level. They report the number of times the order could not be filled. Whereas the service level indicator seems to appeal more to customer service-oriented organizations, the stock out indicator seems to be used by organizations with a more technical focus. In reality, it doesn't matter which indicator an organization uses; they both measure basically the same thing.

$$\frac{\text{Total Number of Orders Not Filled on Demand}^*}{\text{Total Number of Orders Requested}}$$

Here the total number of orders not filled on demand is divided by the total number of items requested. The result is then presented as a percentage. The goal is a stock out percentage between 3% and 5%. If the number is too small, then too much inventory is carried. If the number is too large, then delays in work will be experienced.

Strengths

This indicator is also an accepted measure of inventory performance and it allows for a fair comparison between companies. Accepted internationally it has its little opportunity for error in the calculation, provided accurate data exists.

Weaknesses

As with the service level indicator, the timing of when a part is considered out of stock is an especially important factor. Is the stock out reported when a part is actually requested but not available? In this case, the stock out could contribute directly to equipment downtime. However, if the stock out is registered at the time of planning and the inventory has a stock out level ranging from 3% to 5%, then overall inventory is likely to be too large.

6. Rush Purchase Orders

This indicator highlights the amount of reactive ordering that occurs to fill customer orders. If the maintenance organization is reactive, then this drives the ratio of rush purchase orders to a higher level. If the maintenance organization is generally more proactive and the percentage of rush purchase orders is high, then the inventory and procurement department is trying to hold too few spare parts.

$$\frac{\text{Total Number of Rush Purchase Orders}^*}{\text{Total Number of Purchase Orders}}$$

For this measure, the number of rush purchase orders is divided by the total numbers of purchase orders. Higher percentages indicate reactive purchasing functions. This result leads to increased expediting costs and a higher rate of downtime. Lower percentages indicate more proactive purchasing functions, which allow for planned purchases and consolidated purchase orders, further reducing the overall cost of the inventory.

Strengths

This indicator is useful when examining the cost of processing purchase orders. The goal is to keep the percentage as low as possible. However, many factors, such as customer demand, impact this indicator; it should never be used as a single performance indicator for inventory and procurement.

Weaknesses

The weakness of using this indicator was highlighted above; that is, too many outside factors can impact the indicator. For example, if the maintenance organization doesn't plan its work in advance, then the inventory and procurement department may be forced to make rush orders to meet the demand. This would make the evaluation of their service unfair.

7. Percentage of Single Line Item Purchase Orders

The cost of processing a purchase order ranges from below $50 for smaller companies to over $250 for larger organizations. If the purchase order has only one line item on it, then the cost is additional to the price of that one item. When multiple line items are consolidated on a single purchase order, then the cost of processing the purchase order per line itemis less. (Each additional line item on a purchase order raises the processing cost a bit, but not in direct proportion to the number of line items.)

This indicator focuses on the percentage of single line item purchase orders. If the number is high, then the maintenance department is reactive with many rush requests. If the maintenance department is proactive with forecasted demands, then multiple items can be consolidated on a purchase order, reducing processing costs.

$$\frac{\text{Total Number of Single Line Item Purchase Orders}}{\text{Total Number of Purchase Orders}} *$$

In this case, higher percentages suggest more expediting by the purchasing function, while lower percentages suggest more proactive purchasing function.

Strengths

This indicator highlights the opportunity to reduce processing costs by consolidating line items and lowering the total number of purchase orders processed. It is valuable for determining whether the purchasing function is reactive or proactive.

Weaknesses

In trying to meet reactive customer demands, the purchasing function may be unfairly evaluated. This indicator should not be used as a single indicator for the stores and purchasing function, due to the possible impact of outside factors.

8. Maintenance Work Orders Waiting Parts

This indicator highlights the impact the stores and purchasing function has on executing maintenance activities: the higher the percentage, the more maintenance work that is being held up by the lack of spare parts.

$$\frac{\text{Maintenance Work Orders Waiting for Parts}}{\text{Total Number of Maintenance Work Orders}} *$$

This indicator is calculated based on the number of work orders. If the planning function is fully utilized in maintenance, then the hours of work and the cost of the work can also be highlighted.

Strengths

This indicator shows the maintenance work that is on hold due to other parts of the organization other than just the maintenance department. It is not a common indicator, but is useful when trying to decide where work execution is a problem.

Weaknesses

This indicator can be used to place blame if not utilized carefully. There are dynamic issues impacting this indicator and all must be considered before reaching a decision to take action based on this indicator. These dynamic issues include maintenance work not being planned, too much reactive maintenance work, and poor organizational practices from the inventory and procurement departments.

9. Material Costs Charged to a Credit Card

This indicator is used to track the usage of credit cards for small purchases in companies today. While this practice is recent, it is misused in most organizations. Many companies used the credit cards to lower their purchasing costs. While this is a good goal, it often compromises the integrity of the material cost data for the equipment life cycle costs. For example, when replacement parts are purchased on a credit card, how is the cost tracked to the equipment history? Even small items, over time, can add up to a considerable amount. This indicator helps to insure that there are no abuses of the credit card policy.

$$\frac{\text{Maintenance Material Costs Charged to a Credit Card}^{*}}{\text{Total Maintenance Materials Costs}}$$

The indicator is derived by totaling the costs of all items charged to a credit card and dividing that total by the total maintenance material costs. The result is expressed as a percentage. This percentage should be monitored to insure that the charges to the credit cards are not excessive or increasing to a high level.

In addition, this indicator should be compared to the total maintenance material costs not charged to a work order. If the maintenance materials are going in to a black hole then it is likely that credit card usage has become excessive.

Strengths

This indicator helps to keep credit card usage under control. If the indicator is tracked closely, it can be used to spot abuses or negative trends in the card usage.

Weaknesses

This indicator has no major weaknesses. Credit card use is a practice that needs close control.

10. Internal Costs To Process a Purchase Order

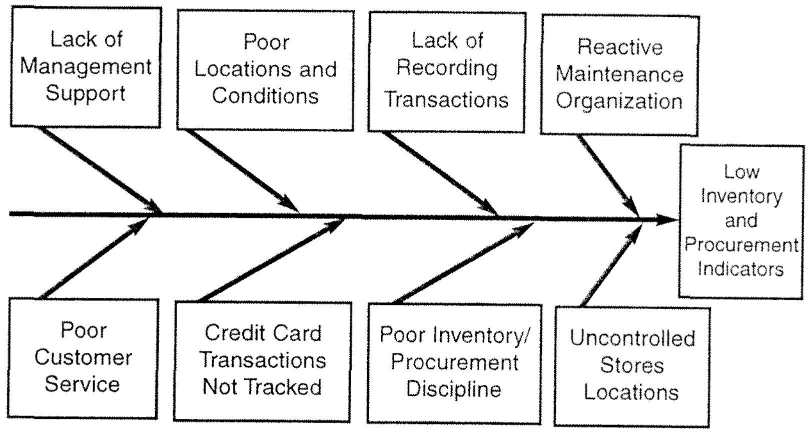
This indicator is not really calculated by a formula, but rather by tracking the internal costs that are associated with processing a purchase order, including the approval levels and time to process. In some organizations, this cost is virtually unknown and so single line item purchase orders are routine since there appears to be no penalty for the practice. Tracking these costs creates awareness and promotes more multiline item purchase orders. This indicator is just a tracking mechanism. There is no calculation.

Strengths

This indicator helps to insure that approval policy and processing procedures are cost effective. It should be tracked by all organizations. A monthly posting with records monitored for a rolling-year time period is typical.

Weaknesses

There are no major weaknesses with this indicator. The only time this indicator is not effective is when an organization is not accurately tracking its internal processing costs.



Inventory and Procurement Problems

The following are common problems preventing the cost effective optimization of inventory and procurement practices.

Reactive Maintenance Organization

Of all the items on this list, a reactive maintenance organization causes the majority of the problems. In fact, it is the key to making the stores and purchasing functions in effective. An inventory and procurement function can not have every spare part that maintenance might need on just a few minutes notice.

An effective preventive maintenance program reduces the amount of reactive or unplanned work to less than 20% of all maintenance activities. When a large percentage of the maintenance work being performed has a two to four week notification time, the inventory and purchasing organization can respond to the needs of maintenance.

Uncontrolled Stores

The cost of inventory loss is not clearly understood. Many companies today use unsecured storage locations. While some theft occurs, it is not the major problem. However when items are used, they are often not recorded. The lack of discipline to record the data causes two problems. First the item is not reordered, creating a stock out and delay the next time the item is needed. Second, the cost of the item is not recorded against the piece of equipment or location where it is used. This creates inaccuracies in the equipment's cost history, invalidating any attempt to do life cycle costing of the affected equipment.

While there have been many attempts to try alternative methods to insure the data is recorded, the only method proven successful over time is to secure and staff the stores locations. In addition, the value of the data recording process must be instilled in each employee. Otherwise, there will be constant problems with inventory levels and data analysis.

Lack of Recording Transactions

This problem is related to the first one, but applies even when secured and manned locations exist. The discipline to record data must be instilled in everyone who has a responsibility of issuing, receiving, or returning inventory items. When the value of data collection is not clearly understood, it may seem to be a non-value added function. The following scenario should be considered:

If the transaction is not recorded, then the data about stock levels is incorrect. If people who are planning a job and relying on the data in the system (whether computerized or manual) make a decision based on the data, they will make the wrong decision. They may have a team of crafts personnel scheduled, a contractor scheduled, and equipment rented. When they go to pick up the part, it is missing even though the system indicates it is there. Meanwhile the costs of the equipment being shut down and the resulting lost production continue to rise.

This cost of not recording the transactions must be clearly communicated. Once a system is put in place, all employees should discipline themselves to utilize it fully. Anything less will create inventory and procurement problems.

Poor Inventory and Procurement Discipline

This problem occurs when the basics of inventory and procurement management are not enforced. These include basics initiating an order, receiving, and issuing and recording transactions. The same rule applies in inventory and procurement management as it does in maintenance: Concentrate on the basics first.

The pattern for inventory management is easy to find in many local auto parts stores. The entire operation is well managed; since it has to be profitable, it is controlled. The analogies are abundant. There are self-service areas; you pick up items and bring them to the counter, where their usage is recorded. There is a secured area, where you cannot enter and get your parts. The stores catalog and parts lists are at the counter, what you need is identified, and the stores attendant goes to get the item and brings it to you and records the transaction. All of your transactions are paid for (charges to an equipment item's account) and typically you go home and perform some work with your purchases.

Many companies today have begun contracting out their stores functions. They claim that there are major financial gains to be realized. The vendor typically takes the inventory off the company's books, and provides staff to manage the stores. However the vendor also adds a per transaction charge to each issue. This cost is accrued in small increments, but adds up to significant amounts when annualized. In fact, in most cases, the charges amount to more than when the company managed its own stores function. This practice is never actually studied and reported in most companies, but since the taxable inventory is gone, the decision to contract out appears to be a good one.

The decision is based on what was good for one department or area, but not for the overall company financials. These decisions should be carefully studied by all departments impacted, before they are arbitrarily implemented by one function within the company.

Poor Stores Locations And Conditions

This problem is an indication of the priority the stores and purchasing function has within a company. Ideally, the company will provide stores locations that provide the type of environment that protects and preserves the spare parts while they are in storage. After all, the investment in spare parts for many companies is considerable. Spare parts that are allowed to deteriorate while in storage contribute to financial waste.

A stores location should be able to protect the spare parts from contamination, moisture, and mishandling by unqualified personnel. Yet, there are companies that store major spare parts in open, exposed, outside storage areas called *Boneyards*. The major components will be exposed to dramatic temperature changes, moisture, and contamination. Yet, when spare parts are needed, individuals wonder why they don't last as long as they should. They lack the knowledge and appreciation for the company's financial investment in the spare parts.

In addition to the condition of the storage, the location of the storage should also be a factor. If the locations are remote, away from the center of the plant, how much time and effort does it require to move the spare parts from storage to the job? This question should provide a basis for choosing an appropriate location for the stores. If there is considerable time and effort involved in moving the spares from storage to the work area, the company will face lower maintenance productivity, increased downtime, and, ultimately, reduced equipment capacity.

Credit Card Transactions Not Tracked

If the credit card transactions are not tracked correctly, with the charges tracked to the equipment for which the spare parts are purchased, then the cost histories of the equipment items are invalidated. When this occurs, the following results:

The ability to make cost-effective equipment replacement decisions is forfeited.

The ability to choose the correct replacement based on repair cost is forfeited.

The ability to monitor life cycle costing is forfeited.

The ability to decide how much to spend reengineering equipment to eliminate chronic problems is forfeited.

The credit cards may be a cost-effective solution for the inventory and procurement departments. However, the impact credit cards have on departments' ability to perform their functions should be considered in depth before any policies are changed. The ability to eliminate the cost of some clerical work in purchasing is insignificant when compared to the overall impact the decision may have on plant capacity.

If credit cards are utilized there must be some mechanism to charge the costs accumulated on the cards to the appropriate equipment history. Otherwise, the credit card system should never be implemented for maintenance spare parts.

Lack of Management Support

Management must understand the stores and purchasing functions and support any policy that enhances the overall competitive position of the company. Thus it does not give the inventory and procurement departments unlimited ability to set policies. They are service departments, providing services to internal customers. Unless they are responsive and cost effective, the customers may go elsewhere (outsourcing).

However, when it come to supporting the basics of good inventory and procurement, management should support any overall cost-effective policies. The proper storage locations, proper staffing, proper procedures, and proper disciplines should always be in place and fully supported. If not, then the stores and purchasing functions will have no chance to fully contribute to company profitability.

Poor Customer Service

A major problem in many companies today occurs when the stores and purchasing functions try to dictate to their customers policies that are conflict with the customer's charter in the company. The inventory and purchasing departments must understand who their customer's really, and what their needs are, and how to meet those needs in a manner that is cost effective for the entire company.

Unless customer service is the focus, untold problems develop with adversarial relations between the customers and the inventory and purchasing groups. It is only when the customers' needs are the focus that an organization can overcome this problem.

Chapter 5 Work Order Systems

The work order system is the information system for the maintenance organization. Without the dedication to record all of the maintenance activities on a work order, the organization does not have the data to perform any meaningful analysis on its policies and practices, or, more importantly, on the equipment it is responsible for maintaining. In addition, without a work order system, it is impossible to plan and schedule maintenance activities.

MONITORING WORK ORDER SYSTEMS

Consider a customer order for a product. This order is transferred to internal company documents, where the labor, materials and equipment resources are all planned and scheduled. Without the production planning and scheduling department, trying to fill multiple customer orders with changing priorities would be chaotic. The same process occurs when attempting to plan, schedule, and, ultimately, control maintenance activities. Without the control document (work order), the maintenance activities quickly become too chaotic.

The following indicators monitor the work order system. A second set of indicators monitor the planning and scheduling activities.

1. Total Maintenance Labor Reported to a Work Order

This indicator checks the accuracy of the maintenance labor reporting. It compares the maintenance department labor records to the accounting labor records for the same time period. This allows the maintenance personnel to find out if there are gaps in their recording of data. While this information is important from the departmental standpoint, it is critical from the equipment standpoint. If the labor costs are not being recorded on the work order, then the labor component of the equipment history is suspect.

$$\frac{\text{Maintenance Labor Costs on Work Orders}^{*}}{\text{Total Maintenance Labor Costs}}$$

The indicator is derived by taking the total of the maintenance labor costs charged to a work order and dividing this by the total maintenance labor costs from accounting. The resulting percentage leads to the following conclusion:

If the indicator is below 100%, then some of the maintenance labor costs are not being posted to the work order.

If the indicator is above 100%, then some of the maintenance labor is being overcharged.

If the indicator is at 100%, then labor records are considered accurate. The resulting information in the equipment's history is also accurate.

This indicator can be calculated on a weekly or monthly basis; it is not likely to be effective outside these ranges. Any trends in reporting accurancy can be tracked over a rolling twelve-month time period.

Strengths

This indicator is essential for any organization striving for data accuracy. Unless it is monitored, individuals may find themselves slipping into bad habits and not recording all necessary data. This indicator is recommended for all organizations.

Weaknesses

The only weakness in this indicator is the misuse of the indicator as a "Big Brother" tool to monitor what individuals are actually doing. The indicator should be used only to monitor the accuracy of reporting. If individuals are having difficulty recording the data, then methods should be implemented to make data collection easier. Training employees how to report the data and selecting an easy-to-use system for reporting can enable better data collection.

2. Total Maintenance Material Costs Reported to a Work Order

This indicator is similar to the labor indicator. It compares the material charges tracked by maintenance to the material charges tracked by accounting. This information will highlight the accuracy of the data collection and reporting of the materials component of maintenance costs. As with the previous indicator, it allows the maintenance department to see if there are any gaps in data collection and reporting. In addition, the impact on the equipment history accuracy can also be seen.

$$\frac{\text{Maintenance Material Costs on Work Orders}^{*}}{\text{Total Maintenance Material Costs}}$$

This indicator is derived by taking the total material costs tracked by the maintenance department and dividing it by the total material costs tracked by accounting. The following can be derived from the results:

If the percentage is below 100%, then there are some gaps in the maintenance data collection that need to be corrected.

If the percentage is above 100%,then the inventory and purchasing departments may need to check their records to insure that proper materials are being charged to the correct account. Also the maintenance department may need to check its data to insure that the materials are being charged to the correct account.

If the percentage is 100%, then the materials costs being posted to the equipment histories may be consideredaccurate.

Strengths

This indicator is essential for any organization striving for data accuracy. Unless it is monitored, individuals may find themselves slipping into bad habits and not recording all data. This indicator is recommended for all organizations.

Weaknesses

This indicator should be used only to highlight the accuracy of reporting. If individuals are having difficulty recording the data, then methods should be implemented to make data collection easier. Training employees how to report the data and selecting an easy-to-use system for reporting can enable better data collection.

3. Total Maintenance Contract Costs Reported to a Work Order

This indicator is used to check the accuracy of the maintenance contractor reporting. It compares the maintenance department contractor records (labor and materials) to the accounting contractor records (probably purchase orders or line items) for the same time period. This allows the maintenance personnel to find out if there are gaps in their recording of data. While this is important from the departmental standpoint, it is also critical from the equipment standpoint. If the contractor costs (labor and materials) are not being recorded on the work order, then this component of the equipment history is suspect.

$$\frac{\text{Maintenance Contract Costs on Work Orders}^{*}}{\text{Total Maintenance Contract Costs}}$$

The indicator is derived by taking the total of the maintenance-recorded contractor costs charged to a work order and dividing by the total contractor costs from accounting. The resulting percentage can raise several issues:

If the indicator is below 100%, then some of the contractor costs are not being captured on a work order.

If the indicator is above 100%, then some of the contractor costs may be overcharged.

If the indicator is at 100%, then the contractor cost records are considered accurate. The resulting information in the equipment's history is also accurate.

The indicator can be calculated on a weekly or monthly basis and is not likely to be effective outside these ranges. Trends can be tracked over a rolling twelve-month time period.

Strengths

This indicator is essential for any organization striving for data accuracy. Unless it is monitored, individuals may find themselves slipping into bad habits and not recording all data. This indicator is recommended for all organizations. The data can be used to monitor contractor usage and effectiveness. If the contractor charges for certain jobs begin to exceed the in-house costs to perform the same work, then negotiations on pricing can occur or the decision may be made to bring the particular job back in-house.

Weaknesses

This indicator has no weakness. If the data utilized is accurate, then it is an effective management tool for contractor evaluation.

4. Total Maintenance Downtime Reported to a Work Order

This indicator is similar to those already described; checks the accuracy of downtime reporting. It compares the maintenance department downtime figures to the production or operations downtime records (probably production reports) for the same time period. Any recording inaccuracies will create conflicts when trying to use the data to influence equipment repair or replacement decisions.

$$\frac{\text{Maintenance Downtime on Work Orders}^{*}}{\text{Total Maintenance Downtime Charged}}$$

The indicator is derived by taking the total of the maintenance recorded downtime charged to a work order and dividing by the total downtime recorded by operations or production. The indicator is tracked by equipment item with data reported in hours or fractions thereof. The resulting percentage can raise several issues:

If the indicator is below 100%, then some of the downtime incidents are not being captured on a work order.

If the indicator is above 100%, then some of the downtime incidents are probably inflated.

If the indicator is at 100%, then the downtime incidents should be considered accurate. The resulting information in the equipment's history is also accurate.

This indicator can be calculated on a weekly or monthly basis, is not likely to be effective outside these ranges. Trends can be tracked over a rolling twelve-month time period. This calculation should be on an equipment item by equipment item basis. There is not real value in trying to perform downtime roll ups.

Strengths

This indicator is essential for any organization striving for data accuracy. Unless it is monitored, individuals may find themselves slipping into bad habits and not recording all data. This indicator is recommended for all organizations. The data can be utilized to monitor problem equipment items. Common reports look at the top ten highest-recorded downtime equipment items. Such reports allow the maintenance department to concentrate its efforts on problem equipment.

Weaknesses

This indicator can be used as a "smoking gun" between maintenance and operations departments trying to fix the blame for poor performance. If the indicator is used for this, accuracy of data and the teamwork required for a successful operation will suffer.

5. Maintenance Labor Costs Charged to a Standing or Blanket Order

This indicator checks the amount of maintenance labor that is charged to a standing work order. Many companies, in an effort to improve maintenance record keeping, set up a series of blanket work orders. If these blankets are set up with a charge code or charged to a department (instead of equipment), then the costs and related information are collected in a manner that will make further analysis of the data difficult. In addition, the cost and repair information is not charged to the proper equipment item and the ability to analyze this equipment data is lost.

$$\frac{\text{Maintenance Labor Cost Charged to Standing Work Orders}^{*}}{\text{Total Maintenance Labor Costs}}$$

This indicator is derived by taking the total of the maintenance labor costs charged to a standing work order and dividing the total maintenance labor costs. The indicator can be tracked by area, craft, or production department. It can be calculated on a weekly or monthly basis; it is not likely to be effective outside these ranges. Trends can be tracked over a rolling twelve-month time period.

Strengths

This indicator is essential for preventing excessive charging to blanket work orders. It is recommended for all organizations. When the percentage of work charged to standing or blanket work orders is high, then much of an organization' ability to manage data is lost. This indicator is useful in highlighting when organizations start to develop the bad habit of taking short cuts on data collection.

Weaknesses

There is no real weakness to this indicator.

6. Materials Costs Charged to a Standing or Blanket Work Order

This indicator parallels the previous indicator, except its focus is the amount of maintenance materials charged to a standing work order.

$$\frac{\text{Materials Costs Charged to a Standing Work Order}^{*}}{\text{Total Maintenance Materials Costs}}$$

This indicator is derived by taking the total of the maintenance material costs charged to a standing work order and dividing by the total maintenance material costs. The indicator can be tracked by area, craft, or production department. It can be calculated on a weekly or monthly basis; it is not likely to be effective outside these ranges. Trends can be tracked over a rolling twelve-month time period.

Strengths

This indicator is essential for preventing excessive charging to blanket work orders. It is recommended for all organizations. When the percentage of materials charged to standing or blanket work orders is high, then much of an organization's ability to manage data is lost. This indicator is useful in highlighting when organizations start to develop the bad habit of taking short cuts on data collection.

Weaknesses

There is no real weakness to this indicator.

7. Costs Changed to a Specific Equipment Item

This indicator checks the amount of maintenance data being recorded to a standing work order for a specific equipment item. Many companies, in an effort to improve maintenance record keeping, set up blanket work orders to accumulate small jobs or material charges. Trying to save time, maintenance craftsmen might use the standing or blanket work order as a type of charge card. They begin charging almost everything to the blanket to avoid writing an individual work order. This practice prevents recording specific information about the labor or material usage and makes future analysis of the data difficult.

$$\frac{\text{Total Charges for a Specific Equipment Item Written to a Standing Work Order*}}{\text{Total Charges for a Specific Equipment Item}}$$

This indicator is derived by taking the total charges (labor, materials, and contractor) for a specific piece of equipment charged to a standing work order and dividing the total charges by recorded against a specific piece of equipment. It can be calculated on a monthly basis, but is not likely to be effective using other windows of time. Trends can be tracked over a rolling twelve month time period.

Strengths

This indicator is essential for preventing excessive charging to blanket work orders. It is recommended for all organizations. When the percentage of costs charged to standing or blanket work orders is high, then much of an organization's ability to manage data is lost. This indicator is useful in highlighting when organizations develop the bad habit of taking short cuts on data collection.

Weaknesses

There is no real weakness to this indicator.

8. Work Distribution by Type of Work Order

This indicator monitors the work distribution for an organization. It shows the focus of the organization and where most of the resources are being consumed. While the terminology may differ among organizations, a typical series of categories are emergency, preventive, and corrective orders. Some organizations may choose to add one or two additional categories (e.g., predictive or overhaul), but the number should be kept small. These figures are calculated and should show a 20/40/40 distribution: the reactive work should be less than 20%, the preventive work should be about 40%, and the corrective work (planned and scheduled) should be about 40%.

$$\frac{\text{Emergency Orders}}{\text{Total Work Orders}} \qquad \frac{\text{Preventive Orders}}{\text{Total Work Orders}} \qquad \frac{\text{Corrective Orders}}{\text{Total Work Orders}}$$

These indicators are derived by taking the total charges (labor, materials, and contractor) for a specific type of work and dividing by the total charges for all types of work. The format of this indicator offers tremendous versatility. The work categories can be used to examine the following:

Labor costs in the three categories
Material costs in the three categories
Contractor costs in the three categories
The three categories by department
The three categories by the area of the plant
The three categories by type of equipment
The three categories by manufacturer of equipment
(for future purchasing considerations)

The indicator is most effective when displayed graphically, first as a pie chart on a weekly basis, then as a bar chart on a rolling annual basis.

Strengths

This indicator format is essential for analyzing work distribution within the maintenance organization. Depending on the priority the manager has in controlling the organization, this format is flexible enough to closely analyze trends, spot developing problems early, and take proactive steps to prevent the organization from sliding into an unbalanced work distribution.

Weaknesses

The real weakness to this indicator is that it may not be useful if the work order system does not allow tracking work types to the necessary categories. While the indicator is useful, the data supporting the calculations must be accurate. If management cannot make decisions based on the data provided for the indicator, then the indicator is useless.

Planning and Scheduling

Once the work order system is being utilized correctly, then the work can be planned and scheduled for maximum efficiency and effectiveness. Planning and scheduling maintenance activities is as important as planning and scheduling production or operational activities. For over a decade, manufacturing resource planning systems (MRPII) have been focused on increasing production efficiencies through better planning, scheduling, and coordination of resources. However, equipment or asset reliability and availability were not closely considered. Ultimately, a company cannot plan manufacturing resources without considering availability of the equipment in the process.

With the emphasis on lean manufacturing, the need for reliable equipment capable of performing at design rates when operating became critical. Planning and scheduling maintenance activities and integrating those activities into the operation schedule gained new emphasis. The following indicators help evaluate and control how effective an organization is in planning and scheduling maintenance.

9. Maintenance Work Orders Planned

This indicator monitors the amount of maintenance work being planned. Planned work costs less to perform than unplanned work, since there is less waste when the work is controlled. Unplanned work often leads to logistic delays getting the equipment shut down, organizing the labor resources, trying to find and deliver all of the spare parts, and, perhaps, even coordinating the job with contractors. Less planning of all of these elements can result in more lost productivity from the workforce. Also, the downtime required to perform the work increases, which further decreases the capacity of the plant.

On the other hand, it is not necessary to plan all maintenance work since the goal is to reduce the amount of time spent performing the work. For example, if the planner takes an hour to plan a job and only saves an hour of labor on the job (and doesn't reduce the required downtime), then the plan was not worth the effort. However, if the planner can plan a job in an hour and save two or more hours of labor or reduce the amount of downtime required or the equipment, then it is worth the effort. Setting the level of jobs to be planned is a management decision, however. All factors (labor savings, downtime savings, reduced costs, etc.) should be considered when setting the level.

$$\frac{\text{Maintenance Work Orders Planned}^{*}}{\text{Total Work Orders Received}}$$

This indicator is derived by taking the total number of work orders planned and dividing by the total number of work orders received. This

indicator will not be 100%, but should be tracked closely to insure the proper number of jobs are being planned. Examining the indicator over several departments, craft lines, and even planners can reveal some interesting trends. Some crafts may have a lower percentage of planned jobs. Some departments may also have a lower percentage. This indicator will provide a manager with opportunities for improvement in the overall planning program. The indicator should be tracked on a weekly basis, and then charted on a rolling six-to-twelve month window.

Strengths

This indicator is valuable for insuring that the proper level of maintenance activities are being planned.

Weaknesses

The weakness of this indicator is misinterpreting the results. Planning 100% of all jobs is not important; however, too low a percentage shows a lack of disciplined planning and the resulting high costs that go with it. The results must be carefully understood to be useful.

10. Maintenance Labor Costs Planned

This indicator is a subset of the previous indicator. However, instead of examining the number of work orders planned, it is focused on the maintenance labor costs being planned. This removes the focus from the smaller jobs, since their costs are a proportionately smaller part of the overall costs, and instead focuses on planning and controlling, the largest portion of maintenance labor costs. Note that for this indicator, preventive and predictive maintenance costs are considered planned and should be included in the calculation.

$$\frac{\text{Maintenance Labor Costs Planned}^{*}}{\text{Total Maintenance Labor Costs}}$$

The indicator is derived by taking the maintenance labor costs charged to work orders that are planned and dividing by the total maintenance labor costs. As before, the indicator will not be 100%, but should be tracked closely to insure the proper number of labor hours are being planned. Examining the indicator over several departments, craft lines, and even planners can reveal some interesting trends. Some crafts may have a lower percentage of planned jobs. Some departments may also have a lower percentage. This indicator will provide a manager with opportunities for improvement in the planning for maintenance labor resources. The indicator should be tracked on a weekly basis, and then charted with a rolling six-to-twelve month window.

Strengths

This indicator is valuable for insuring that the proper level of maintenance labor resources are being planned.

Weaknesses

The weakness of this indicator is misinterpreting the results. Planning 100% of all jobs is not important; however, too low a percentage shows a lack of disciplined planning and the resulting high costs that go with it. The results must be carefully understood to be useful.

11. Maintenance Material Costs Planned

This indicator parallels the last indicator. However, instead of focusing on maintenance labor costs, it focuses on the maintenance material costs being planned. The indicator removes the focus from the smaller jobs, since their costs are a proportionately smaller part of the overall costs, and instead focuses on planning and controlling the largest portion of maintenance material costs. Preventive and predictive maintenance material costs are considered planned and should be included in the calculation.

$$\frac{\text{Maintenance Material Costs Planned}^*}{\text{Total Maintenance Materials Costs}}$$

The indicator is derived by taking the maintenance material costs charged to planned work orders and dividing by the total maintenance material costs. The indicator will not be 100%, but should be tracked closely to insure the proper number of material costs are being planned. Examining the indicator over several departments, craft lines, and even planners can reveal some interesting trends. Some crafts may have a lower percentage of planned jobs. Some departments may also have a lower percentage. This indicator will provide a manager with opportunities for improvement in the planning for maintenance materials and the subsequent impact on stores performance. The indicator should be tracked on a weekly basis, and then charted with a rolling six-to-twelve month window.

Strengths

This indicator is valuable for insuring that the proper level of maintenance materials are being planned.

Weaknesses

The weakness of this indicator is misinterpreting the results. Planning 100% of all materials is not important; however, too low a percentage shows a lack of disciplined planning as well as the resulting high costs and impact on the stores that go with it. The results must be carefully understood to be useful.

12. Schedule Compliance

This indicator begins the transition from the planning aspect to the scheduling aspect of work control. The focus is not on the hours *planned*, but rather the hours that were *scheduled* compared with those actually worked. This indicates whether the schedule and the scheduling process were effective.

Unlike a previous indicator which simply measured the percentage of the resources that were planned, the company's goal for this indicator is for it to equal 100%. If work is scheduled, it should be completed.

$$\frac{\text{Maintenance Hours Scheduled}^*}{\text{Total Maintenance Hours Worked}}$$

The indicator is derived by taking the maintenance hours scheduled and dividing by the total maintenance hours worked. Examining this indicator by departments, craft lines, supervisors, and even planners can reveal some interesting trends. Some departments and crafts may have a lower percentage of schedule compliance. This indicator will provide a manager with the opportunities for improving schedule compliance and its impact on the organization. The indicator should be tracked on a weekly basis, and then charted with a rolling six-to-twelve month window.

Strengths

This indicator is valuable for insuring that the proper level of maintenance is being worked as scheduled.

Weaknesses

There is no major weakness to this indicator. It is recommended to all organizations as a measure of scheduling effectiveness.

13. Overtime

This indicator which is not always a direct indicator of the planning and scheduling program measures a company's overtime. In many organizations, overtime is worked in response to poor planning and scheduling. In other cases a high level of overtime compensates for a shortage of labor resources. This practice is not recommended and should be closely monitored. Excessive overtime can have an impact on the efficiency of the workforce. High overtime rates can indicate of a problem with the planning and scheduling disciplines.

$$\frac{\text{Hours Worked as Overtime}}{\text{Total Hours Worked}} *$$

This indicator is derived by dividing the hours worked as overtime by the total hours worked. This percentage shows the premium time (overtime) that is used to perform work. Proactive maintenance organizations work 5% or less of their total time as premium time.

Strengths

This indicator is valuable for insuring that no excessive maintenance overtime is being utilized.

Weaknesses

This indicator has no major weakness. It is recommended to all organizations as an indicator.

14. Planning Compliance

This indicator checks the accuracy of the estimates for the work that is on the weekly schedule. The indicator is important for organizations moving toward an integrated scheduling program, where the maintenance and operations schedules are combined. Any inaccuracies in the maintenance schedule would have a direct impact on the production or operations schedule. In organizations without integrated scheduling, this indicator is still beneficial since the maintenance schedule will still have some impact on the production or operations schedule.

$$\frac{\text{Total Hours Estimated on Scheduled Work Orders}}{\text{Total Hours Charged to Scheduled Work Orders}} *$$

The indicator is derived by dividing the hours estimated for all of the work orders on the weekly schedule by the actual time needed to perform

the work orders. The tracking system should give a manager the ability to examine the data to see which work orders cause any discrepancies.

Strengths

This indicator is valuable for insuring the accuracy of the maintenance schedule.

Weaknesses

There is no major weakness to this indicator. It is recommended to all organizations using an integrated schedule. It is also advisable for any organization to use as a performance check on scheduling accuracy.

15. Work Orders Completed within 20% of Planned Labor

This indicator checks the accuracy of the labor estimates for the work that was completed. This indicator helps monitor performance on at least three levels.

The planner's performance: Were any discrepancies due to the planner's lack of skills or knowledge?

The supervisor's (or coach's) performance: Were any discrepancies due to the supervisor's lack of skills or knowledge?

The craft technician's performanc: Were any discrepancies due to the craft technician's lack of skills or performance?

This indicator tracks problems that impact the labor estimate of the planned job. Most companies start with a goal of plus or minus 20% and then narrow the margin to 10% as it becomes more efficient.

$$\frac{\text{Number of Work Orders Completed Greater than 20\% of Estimated Labor}}{\text{Total Number of Maintenance Work Orders}} *$$

This indicator is derived by taking the work orders that are over the estimated labor by more than 20% and dividing by the total number of work orders. The tracking system should then allow managers to identify those problem work orders that exceeded the labor estimate by more than 20% so that they won't reoccur.

Strengths

This indicator is valuable for insuring the accuracy of the maintenance schedule.

Weaknesses

There is no major weakness to this indicator. It is recommended to all organizations trying to improve the accuracy of their estimating techniques.

16. Work Orders Completed within 20% of Planned Material Costs

This indicator is used to check the accuracy of the material estimates for the work that was completed. This indicator is useful for monitoring performance on at least three levels. They are:

The planner's performance: Were any discrepancies due to the planner's lack of knowledge or skills?
The supervisor's (or coach's) performance: Were any discrepancies due to the supervisor's lack of skills of knowledge?
The craft technician's performance: Were any discrepancies due to the craft technician's lack of skills or performance?

As is obvious, the indicator is used to track problems that impact the material estimate of the planned job. Most companies start with a goal of plus or minus 20% and then narrow the margin to 10% as the organization becomes more efficient.

$$\frac{\text{Number of Work Orders Completed Greater than 20\% of Estimated Material}^*}{\text{Total Number of Maintenance Work Orders}}$$

This indicator is derived by taking the work orders that are over the estimated materials by more than 20% and dividing by the total number of work orders. The tracking system should then allow managers to identify those problem work orders that exceeded the materials estimate by more than 20% so they won't reoccur.

Strengths

This indicator is valuable for insuring the accuracy of the maintenance schedule.

Weaknesses

There is no major weakness to this indicator. It is recommended to all organizations trying to improve the accuracy of their estimating techniques.

17. Work Orders Overdue

This indicator checks the timeliness of the work order completion. When a work order is initiated, the goal is to finish the work in two to four weeks. This level keeps the backlog current and prevents a perceived lack of responsiveness on the part of the maintenance organization. The goal is zero work orders overdue. Although this goal is difficult to achieve, lower percentages indicate a better performance by the maintenance organization.

$$\frac{\text{Work Orders Overdue}^*}{\text{Total Work Orders}}$$

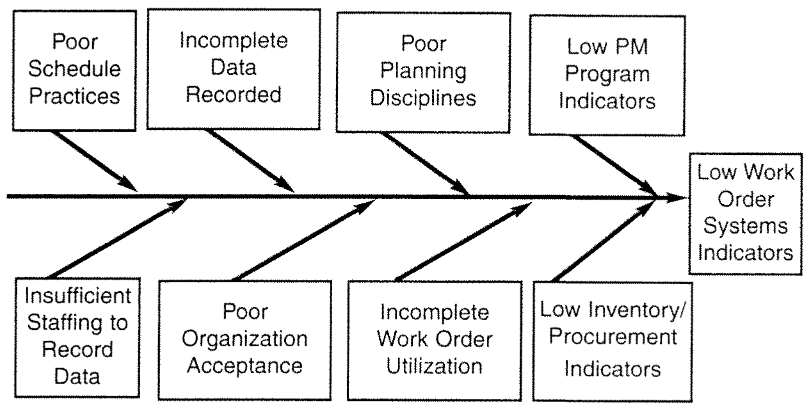
This indicator is derived by dividing the number of work orders overdue (exceeding the two to four week backlog) by the total number of work orders. The percentage highlights the amount of work not being performed in a timely fashion. The managers should then have the ability to examine the individual work orders to see what can be done to expedite completion.

Strengths

This indicator is valuable for insuring the timely service of the maintenance department.

Weaknesses

There is no major weakness to this indicator. It is recommended to all organizations trying to improve their responsiveness.



Work Order Problems

In the United States, fever than one-third of the maintenance organizations are satisfied with their work order performance. Why is the satisfaction rate so low? Below are the common reasons for poor work order, planning, and scheduling satisfaction:

Low PM Program Indicators

Although it may seem unlikely, the poor performance of the preventive maintenance program is the leading cause of a poor work order system. Strong preventive maintenance programs reduce the amount of reactive maintenance activities to a level that allows the work order system to function. Unless the majority of the maintenance work can be requested in a proactive mode, the work order system will be ineffective. The proactive organization can take the time to properly utilize the work order, filling in the detail necessary to make the work order usable for later analysis. A work order that says *"It's broke, fix it"* and comes back with the information *"I did and it took two hours"* has little if any usable data on it for root cause failure analysis. The preventive maintenance program must reduce the amount of reactive maintenance to less than 20% of all activities before any work order system or planning and scheduling system can be truly effective.

Low Inventory and Procurement Indicators

This cause of work order problems is closely related to the previous one. Unless the inventory and procurement system is functioning correctly (95% or higher service level), the maintenance plan will not be successful. It does little good to plan and schedule a job if, when it comes time to perform, the materials are not available, out of stock, or not even ordered. Unless the inventory and procurement functions are working at a satisfactory level, the work order, planning, and scheduling function will be perceived to be ineffective.

Poor Planning Disciplines

If the planning disciplines are not effective, the work order system will not be effective. For example, if the planner constantly underestimates the labor resources to perform work, then the schedule is inaccurate and the overall organizational perception is that the maintenance work order system is not working. If the planner underestimates the materials required to perform work, then the work will always experience delays and the craft technicians will become frustrated. This leads to a lack of trust in the planner and, ultimately, failure of the planning and scheduling system. Planners should always receive adequate training and have refresher training as needed to remain effective.

Incomplete Work Order Utilization

This problem results from the lack of organizational acceptance and then the discipline to fully utilize the work order system. All parts of an organization must be disciplined to use the work order system to request, plan, schedule, and complete maintenance work. Unless full commitment is in place, the work order is only partially utilized by the organization, viewed as something that only the maintenance department uses. Ultimately the system will be used as a work log book and little else.

Incomplete Data Recorded

The incomplete recording of maintenance data typically stems from a failure to understand the value of that data. If the data is not valued, then the time and resources required to collect all of the data necessary to calculate mean time between failure, mean time to repair, and life cycle costing will not be allocated. This will suboptimize the effectiveness of the work order system and lead to the ultimate failure of the program. Education related to the value of maintenance and equipment history data is required at all levels of the organization.

Poor Organizational Acceptance

Even if the data is collected and the work order system is fully utilized, the data must be used to make technical and financial decisions about the equipment and facility. If not, then support for both the work order system and the planning, and scheduling system dwindles and falls into partial or incomplete usage, leading to failure of the entire system. The organization must value the technical data and blend it with financial information to make value-based decisions.

Poor Scheduling Practices

The lack of organizational discipline to adhere to the schedule is based on several factors. First, the schedule may not be accurate due to poor estimating, poor stores, or an overall reactive organization. Individuals then take matters into their own hands and have the work performed that they feel is important. This practice leads to confusion and, ultimately, a failure of the scheduling discipline. Another factor is the autonomy that many supervisors (both maintenance and operations) feel they have when it comes to work control. If they arbitrarily change work schedules that have previously been accepted, the organization develops a reactive mentality. Overall productivity falls, and the scheduling practice fails. There must be commitment to the schedule at all levels in the organization for it to be successful.

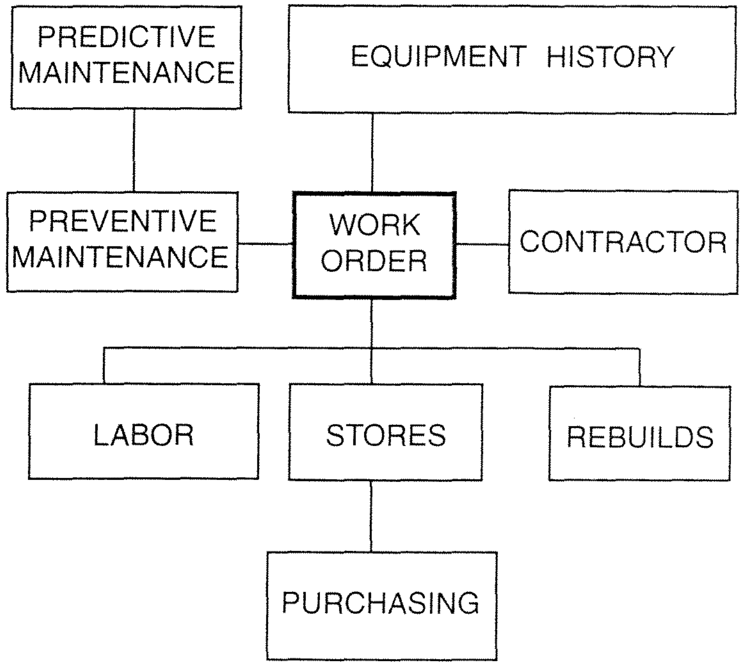
Insufficient Staff To Record Data

The current trend of downsizing organizations has led to insufficent staff to record data. Since the staff reductions are often made by people who have few technical skills and too limited an understanding of the technical requirements of their organization, many of the reductions happen in the maintenance and engineering groups. The technical staff is reduced to the point that it doesn't have the resources to collect the data, much less analyze it. Thus, many of the cost benefits of a competent technical component of an organization go unrealized. In turn, the overall competitiveness of a company is reduced. In the long term, the company may not be a viable business. Proper appreciation of the cost benefits delivered by the maintenance and engineering groups must be developed in all organizations. That appreciation begins with education.

Chapter 6
Computerized Maintenance Management Systems

The Computerized Maintenance Management System (CMMS) is, in reality, nothing more than a computerized version of a maintenance information system. In fact, anything that can be done with a CMMS can be done with a manual system. In theory, though the CMMS should make it faster and easier to collect data and then manipulate it into a meaningful report format.

The following flow chart highlights the basic components of a CMMS.



The work order is the key feature of the system. It collects all of the labor data, the materials data, the contractor data, and the preventive maintenance data that is written against a piece of equipment (or a facility, a building, floor, or room locator). The information collected is then stored in a database called the equipment history. It is here that all of the data is drawn to produce all of the reports needed by the organization to manage the equipment or assets.

However, a study conducted by Engineer's Digest in 1992 highlighted a problem. The majority of organizations owning and using a CMMS only used approximately 50% to 60% of it. The question now is: What parts of the CMMS can you not use, without compromising the integrity of the data in the equipment history database? For example:

If you don't record labor data, is the cost history accurate?
If you don't record material data, is the cost history accurate?
Can you perform life cycle costing?
Can you calculate the MTBF?
Can you calculate the MTTR?

The answer is, of course, no. The CMMS must be used fully if any usable data is to be collected. The following indicators should be utilized to insure full and accurate data collection.

1. Maintenance Labor Costs Recorded in CMMS

This indicator compares the maintenance labor costs captured in the CMMS to the maintenance labor costs captured in the accounting system. If the CMMS is part of or integrated to an Enterprise Resource Planning system (ERP), then the reconciliation is not optional; the costs must match. This indicator insures that all labor costs are being recorded correctly.

$$\frac{\text{Total Maintenance Labor Costs in CMMS}^{*}}{\text{Total Maintenance Labor Costs from Accounting}}$$

This indicator is derived by taking the maintenance costs recorded in the CMMS and dividing by the maintenance labor costs in the accounting system. The resulting percentage is the degree of accuracy the labor data has in the CMMS. If the percentage is above 100%, then somehow the maintenance department is overbilling for its services. If the percentage is below 100%, then the maintenance department is not recording all of its labor activities.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of its maintenance labor charges.

Weaknesses

The weakness of this indicator is that sometimes it forces a maintenance organization to try to balance the numbers. At times, the organization may open a standing or blanket work order as a quick fix to try to cover the differences in the systems. This action should not be taken. The real issue is that somewhere the labor data is not being recorded accurately. The errors should be traced and corrected.

2. Maintenance Material Costs Recorded in CMMS

This indicator, similar to the previous one, compares the maintenance material costs captured in the CMMS to the maintenance material costs captured in the accounting system. If the CMMS is part of or integrated to an ERP or even a general ledger system, then the reconciliation is not optional; the costs must match. This indicator insures that all material costs are being recorded correctly.

$$\frac{\text{Total Maintenance Material Costs in CMMS}^{*}}{\text{Total Maintenance Material Costs from Accounting}}$$

This indicator is derived by taking the maintenance material costs recorded in the CMMS and dividing that figure by the maintenance material costs in the accounting system. The resulting percentage is the degree of accuracy the material cost data has in the CMMS. If the percentage is above 100%, then somehow the maintenance department is overbilling for spare parts. If the percentage is below 100%, then the maintenance department is not recording all of its spare part transactions and costs.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of its maintenance material charges.

Weaknesses

The weakness of this indicator is that sometimes it forces a maintenance organization to try to balance the numbers, often by opening standing or blanket work orders as a quick fix. This action should not be taken. Somewhere the spare parts data is not being recorded accurately. The errors should be traced and corrected.

3. Maintenance Contracting Costs Recorded in CMMS

This indicator is similar to the previous two. It compares the maintenance contractor costs captured in the CMMS to the maintenance contractor costs captured in the accounting system. If the CMMS is part of or integrated to an ERP or even a general ledger system, then the reconciliation is not optional; the costs must match. This indicator insures that all contractor costs are being recorded correctly. Many organizations do not acccurately record contractor costs to specific equipment items. This is an area of concern, especially if a company uses a high proportion of outside contractors. In some companies, because contractors are paid from a different account, the maintenance department never even sees the actual costs. This issue may need attention in many companies.

$$\frac{\text{Total Maintenance Contracting Costs in CMMS}^*}{\text{Total Maintenance Contracting Costs from Accounting}}$$

This indicator is derived by taking the maintenance contractor costs recorded in the CMMS and dividing by the maintenance contractor costs in the accounting system. The resulting percentage is the degree of accuracy the contractor cost data has in the CMMS. If the percentage is above 100%, then somehow the contractor costs are excessive. If the percentage is below 100%, then the maintenance department is not recording all of the contractor costs.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of its maintenance contractor charges.

Weaknesses

As with the previous indicators, this indicator sometimes forces a maintenance organization to try to balance the numbers. Instead, errors should be traced and corrected.

In addition, not all CMMS (or ERP) systems accurately track contractor costs. In some systems, entries must be manually posted. If a company utilizes many outside contract services, a CMMS that supports this function should be selected and implemented to insure accurate data collection.

4. Equipment Coverage by CMMS

This indicator examines how many of the equipment items that are in the plant are also covered by the CMMS equipment history. During implementation of a CMMS, many companies take a short cut and only enter critical equipment into the CMMS. This shortcut leaves second- and third-tier equipment without CMMS coverage. The costs that should be charged against this level of equipment are instead charged to a standing or blanket work order. The information is virtually unusable for data analysis, equipment troubleshooting, or life cycle costing. Eventually all equipment, even if it is at a system level, must be entered into the CMMS.

$$\frac{\text{Total Number of Equipment Items in CMMS}^*}{\text{Total Number of Equipment Items in the Plant}}$$

This indicator is derived by taking the total number of equipment items entered into the CMMS and dividing by the total number of identified equipment items in the plant or facility. Some equipment systems are broken down to the component level. Others (especially non-critical units) can be left at the system level. This choice allows for data collection against the equipment item without making the process too detailed. The alternative of not collecting any data is unacceptable.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of the maintenance data. It is a valuable tool for insuring complete equipment coverage.

Weaknesses

The weakness of this indicator is that sometimes it forces a maintenance organization to try to balance the numbers, often by opening standing or blanket work orders as a quick fix. This should not be done. The real issue is that the proper time and resources must be devoted to CMMS implementation. If the data in the CMMS is to be accurate, then all equipment items must be included, even if noncritical items are at the system level.

5. Stores Coverage by CMMS

This indicator examines the extent that inventory and spare parts items in the plant are covered by the CMMS. During implementation of a CMMS, many companies take a shortcut and only enter critical or major spare parts into the CMMS. This leaves the majority of stores items (usually over 50%) without CMMS coverage. The costs for these spare parts are difficult to reconcile, so these items are charged to standing or blanket purchase orders. The information is virtually unavailable for data analysis, equipment troubleshooting, or life cycle costing. Eventually all spare parts must be entered into the CMMS.

$$\frac{\text{Total Number of Part Items in CMMS}^*}{\text{Total Number of Part Items in the Plant}}$$

This indicator is derived by taking the total number of spare parts (also called stores line items) entered into the CMMS and dividing by the total number of identified spare parts in the plant or facility. While this information may be difficult to derive, it is usually available from the procurement department.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of the inventory and procurement data and being able to charge the parts cost to the appropriate equipment history. It is a valuable tool for insuring complete cost accuracy.

Weaknesses

The weakness of this indicator is that sometimes it forces a maintenance organization to try to fabricate information. In many cases, the part number is unknown or parts are bought directly from vendors. In other cases, the information about a part, its cost, and the vendor is never recorded. These cases makes accurate data tracking impossible. They also lengthen procurement times, since the next time the part is required, someone will have to look up all of the ordering information. Tracking all of the spare parts through the CMMS can help shorten the lead times for procurement.

6. PM Coverage by CMMS

This indicator examines the level of preventive maintenance coverage in the CMMS. By examining the total number of equipment items and comparing it to the average number of preventive maintenance tasks for an equipment item, a theoretical goal can be derived. Comparing the

actual number of preventive maintenance tasks to this goal, one can get an approximation of the level of coverage. A piece of equipment may have the following tasks intervals: daily, weekly, monthly, quarterly, semiannual, annual, and others.

Few, if any, equipment items will have all of these tasks. But what if they each had on average three tasks? Then the number of equipment items multiplied times three would be the theoretical number of preventive maintenance tasks for the plant or facility. In reality, most companies don't put this level of detail into their preventive maintenance programs.

$$\frac{\text{Total Number of Preventive Maintenance Tasks}^*}{\text{Total Number of Equipment Items in the Plant} \times 3}$$

This indicator is derived by dividing the total number of preventive maintenance tasks identified in the CMMS by the total number of the equipment items in the CMMS multiplied by three. The goal is 100%. This indicator provides a theoretical check, but over fifteen years of usage has shown it to be fairly accurate.

Strengths

This indicator is essential for any company striving to insure that the preventive maintenance program completely covers the equipment entered into the CMMS.

Weaknesses

This indicator is just an average guideline. Even though time has proven it to be accurate, some companies will fewer than three preventive maintenance tasks per equipment item. Others will average more. This indicator should never be used as a performance indicator, but only as a suggested guideline.

7. Maintenance Information Recorded at the Equipment Level

This indicator examines the amount of cost information that is recorded at the equipment level compared to untracked or unspecified cost information. This indicator is useful for discovering how much of the maintenance cost cannot be traced to a specific equipment item for data analysis, equipment troubleshooting, or life cycle costing.

$$\frac{\text{Total Maintenance Costs Charged to Individual Equipment Items*}}{\text{Total Maintenance Costs from Accounting}}$$

This indicator is derived by taking the total maintenance costs charged against an individual equipment item and dividing by the total maintenance costs from accounting. The resulting percentage represents the costs that are traceable to equipment items. The other costs are most likely charged to a standing or blanket work order or else go unrecorded.

Strengths

This indicator is mandatory for any company striving to insure complete accuracy of maintenance cost tracking.

Weaknesses

The weakness for this indicator is that sometimes it forces a maintenance organization to try to fabricate information. The organization may charge equipment costs that were not actually incurred, trying to account for all the costs and make the indicator look good.

8. Supervisory or Coaching Staffing Ratios

This indicator monitors the span of control for a front-line maintenance supervisor. In a traditional organization, the proper ratio is one supervisor for every eight to twelve maintenance technicians. Some organizations have tried to extend the ratio, but efforts usually result in wasted labor productivity that incurs greater cost than the original savings.

$$\frac{\text{Number of Maintenance Employees or Full-Time Equivalents *}}{\text{Number of Supervisors or Coaches}}$$

This indicator is derived by taking the total number of maintenance employees or full-time equivalents and dividing by the number of maintenance supervisors. The ratio should range from 8:1 to 12:1. Any ratio over 12:1 results in ineffective supervision. If the ratio is less than 8:1, there is not sufficient work to justify the supervisor. The exception to this goal comes when the total number of maintenance employees is less than 8:1. Then the maintenance supervisor may still be required.

Strengths

This indicator is mandatory for any company striving to insure proper supervisory levels for the maintenance organization.

Weaknesses

The weakness for this indicator is that organizations try to de-emphasize the span of control of its supervisors and coaches by hiding under the concept of empowerment. The typical organization using this excuse has little understanding of what the legal requirements under the National Labor Relations Act and OSHA regulations actually involve. If these requirements are clearly understood, many companies could save themselves OSHA fines and civil lawsuits.

9. Planner Ratios

This indicator is used to monitor the span of control for a maintenance planner. In a traditional organization, the proper ratio is one planner for every fifteen to twenty maintenance technicians. Some organizations have tried to extend the ratio, but efforts usually result in wasted labor productivity that incurs greater cost than the savings from elimination of a planner's position.

$$\frac{\text{Number of Maintenance Employees or Full-Time Equivalents}}{\text{Number of Planners}}$$

This indicator is derived by taking the total number of maintenance employees or full-time equivalents and dividing by the number of maintenance planners. The ratio should range from 15:1 to 20:1. Any ratio over 20:1 results in ineffective planning. If the number is less than 15:1, there is not sufficient work to justify the planner full time. The exception to this goal comes when the total number of maintenance employees range from 8 to 15. Then the maintenance planner may still be required.

Strengths

This indicator is mandatory for any company striving to insure proper levels of planning and scheduling for the maintenance organization.

Weaknesses

The weakness for this indicator is that organizations try to de-emphasize the span of control of the planners by hiding under the concept of empowerment. The typical organization using this excuse has little understanding of what impact planning has on labor productivity. In organizations without planners, the hands-on or wrench time is low. When the work is planned, the wrench time is higher. Imagine a NASCAR pit crew working effectively without planning. The pit stop would be in minutes, not seconds. Planners have a similar impact on maintenance labor productivity and equipment uptime.

10. Maintenance Support to Direct Maintenance Costs

This indicator is used to monitor the support personnel required for the maintenance hourly technicians. In a traditional organization, the proper ratio is one support person for every three to five hourly maintenance technicians. Some organizations have been able to extend the ratio by applying easy-to-use CMMS for data collection and analysis. However, a CMMS that is not easy to use and is keystroke intensive may actually lower the ratio.

$$\frac{\text{Total Hourly Maintenance Personnel}^{**}}{\text{Total Number of Maintenance Overhead Personnel}}$$

This indicator is derived by taking the total number of hourly maintenance personnel and dividing by the number of maintenance overhead personnel. The ratio should range from 3:1 to 5:1. Any ratio over 5:1 results in ineffective staffing. For example, it is more economical to pay a maintenance clerk to enter information than it is to pay a maintenance technician $20.00 or more an hour to enter the same data. A company does not want to staff the overhead roles too heavily, but it is just as costly to staff them too lightly.

Strengths

This indicator is mandatory for any company striving to insure proper levels of support for the maintenance organization.

Weaknesses

The weakness of this indicator is that organizations try to de-emphasize the support for the organization by hiding under the concept of empowerment. The typical organization using this excuse has little understanding of what impact the overhead function has on the accuracy of the equipment maintenance data. If an organization desires to be competitive by utilizing maintenance data, it will provide the proper level of maintenance overhead personnel.

***expressed as a ratio*

Reasons for the Lack of CMMS Effectiveness

As noted earlier, the overall usage of the CMMS as a tool is poor by the majority of organizations. Couple this with the fact that about 50% of all CMMS's are deemed to have failed after less than two years of operation. Clearly there are issues that must be addressed for the CMMS to be an effective tool for most organizations. The eight most common reasons are explained next.

Lack of Maintenance Dedication

This problem develops when the maintenance organization lacks clear definition of its roles and responsibilities. The organization may actually believe that maintenance is a necessary evil, insurance, or just an overhead expense. Instead of focusing on value-added functions, it focuses on reactive maintenance. This type of maintenance organization needs education on what equipment management really entails. Unless it develops a proactive attitude by understanding the impact it can make on the company's profitability, it will never be dedicated to "best practice" maintenance concepts (including full usage of its CMMS) and will never improve.

Poor or Incomplete Implementation

This is a typical problem for organizations that never fully understood the implementation costs for a CMMS. In general, the cost of the software itself is only one-fith to one-third of the total cost of the implementation. If there was insufficient budget for the implementation, the data collection and training of the end users is eliminated. The organization assumes employees can figure out how to use the software: after all, the salesman said it was easy to use. The organization also assumes that the hourly technicians can gather the data as they work. This never happens. Thus, the CMMS is underutilized and the implementation fails; the return on investment in the CMMS is never realized.

Lack of End User Training on CMMS

This deserves special mention. No matter how easy a CMMS appears to be, ***never*** shortcut the end-user training. Microsoft Windows

is supposed to be very easy to use, but how many casual users ever realize its full power? The same is true for any CMMS. Unless the end users are properly trained, the full power of the system is never realized. This lack of training is the single biggest factor in the overall failure of the CMMS as a maintenance tool.

Lack of Sufficient Resources

If a company is to be successful in utilizing a CMMS, it must remember that "Someone must feed the monster." The system requires certain amounts of data to be entered every day if it is to be effective. Unless the support resources are in place to insure data entry, the data is not input. In turn, the CMMS has nothing of value with which to manage maintenance. The labor resources to properly operate the CMMS must be clearly defined during the implementation. They then must be provided on an ongoing basis to insure there is value added in the data being provided by using the CMMS; otherwise another failure results.

Inaccurate Data in the CMMS

This problem is typically caused by partial or casual use of the CMMS. If there is no dedication to entering accurate data, the expression *garbage in garbage out* finds fulfillment. Any decisions made based on the data in the CMMS are wrong, and the maintenance department loses credibility. In most cases, the rest of the organization knows the information in the maintenance system is inaccurate and it is never allowed to influence decisions. Therefore CMMS is ruled a failure. Unless the resources and disciplines are in place to insure accurate data collection and usage, the CMMS will fail.

Not Utilizing the Data in the CMMS

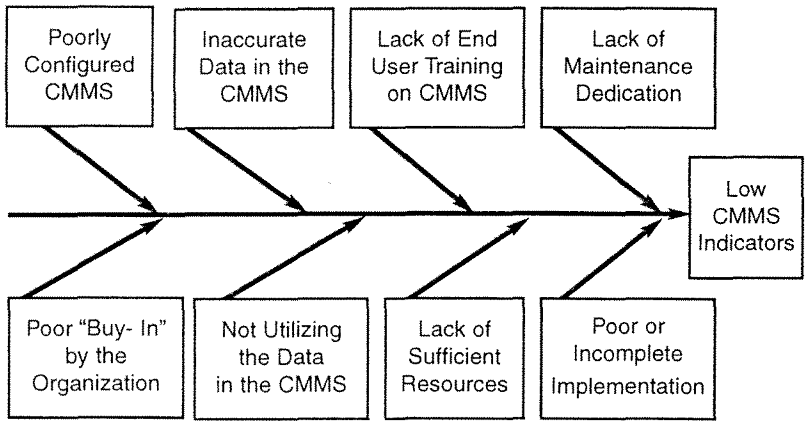
This problem reflects a trap that organizations fall into when they lose focus of the real value of the CMMS: to manage maintenance and the organization's equipment. The maintenance organization may collect accurate data, but never have the time or the resources to analyze it. Thus, it is collected but never used. Eventually, the CMMS falls into a lack of use, since no one ever saw any value to collecting the data. The only way to eliminate this problem is to plan from the beginning to use a maintenance or reliability engineer to analyze the data that will be collected. Without this focus, the CMMS will eventually fail.

Poorly Configured CMMS

This problem is a software issue. The vendor did not design the CMMS correctly and the system is difficult to configure. The program may not cleanly integrate data between the work order and the stores and labor modules. Added clerical support will be required. Since this wasn't planned for, it is not in the budget and is usually not provided. In turn the CMMS will fail. Before any CMMS is purchased, the end users should be asked what they want the CMMS to do for them and how it should do it. Functionality should be approved before the CMMS is ever purchased. If not, another failure will result.

Poor Acceptance by the Organization

Here, the rejection is organizational, not just by the maintenance department. In some cases, the CMMS is viewed as something just the maintenance department uses, not as an organizational tool for managing the company's equipment. In other cultures, the CMMS is viewed as an Equipment Management Information System (EMIS), which focuses not just on maintenance, but on managing the equipment. This view reinforces the idea that the CMMS is not just a maintenance tool, but is an organizational tool. Unless the organization can see the value of the CMMS, the system will not receive the acceptance it requires to be useful. This problem is overcome by the organization being educated to the value of good maintenance and data collection.



Chapter 7 Technical and Interpersonal Training

The training and education of today's workforce, whether salaried or hourly, is a major issue. Many organizations have aging workforces and the skills of those entering the workforce are below the standard that will be necessary to replace those who are exiting the workforce. Training and, in some cases, retraining are essential if the skills required to operate and maintain the high-tech equipment now being installed in plants and facilities today are to be developed.

Consider how hard it is to classify the new technicians. Are they white collar workers? Are they blue collar workers? In reality, they will be known as gold collar workers since they will be able to name the company they want to work for, what area of the country they want to work in, and what wage they want to work for. If this seems unrealistic, consider what it takes to hire a skilled electronics technician today. They are rare; they will receive almost any wage they ask for, since their skills are in such high demand. The same is true of the mechanical technicians who understand operating dynamics of their equipment.

The present rate of technology change is leaving some work forces falling behind in technical skills. It is estimated that the technical skills of those working in the plants today will be outdated within the next three to five years without retraining. While this will be may seem too quick for some industries, there are others where the process technologies change so quickly that they are replacing equipment every year with newer models with increased technology.

Consider your automobile. Would you want an auto technician who had not been trained or retrained in the last three to five years working on your latest model? Probably not. First, they might not understand the new design features, let alone be able to do anything with them. Second, unless they had the latest diagnostic equipment and knew how to use it, they would be limited in evaluating many problems.

A recent study of the job market the fastest growth job market for the next decade will be the plant technicians; people who can operate and maintain high tech equipment.

How is training justified? There are examples of companies that have initiated specialized training for employees and tracked the results from a financial perspective. One company saved over $4.5 million by training its maintenance technicians in the proper installation and maintenance of bearings. Another company saw its maintenance costs for forklifts drop 20% after training the workforce in how to properly operate the forklifts. Each manager should carefully reflect on how much damage is done to the equipment in a plant because the operational and maintenance technicians are not properly trained.

With these points in mind, it is beneficial for each manager to ask "How is my workforce doing in keeping pace with the changing equipment technologies?" An honest evaluation will be beneficial for all managers. The following indicators will help in the evaluation.

1. Dollars per Employee

This indicator examines the actual average training dollars being spent per employee per year. Many companies will train a select group of employees, such as upper managers, but how much is actually spent on the entire workforce, where a large return on investment is waiting for most companies? The importance of management training is not being minimized, but rather the focus is shifting to the operators and maintenance technicians and their training. Averages for this indicator range from $1,200 to $1,500 per employee per year.

$$\frac{\text{Total Training Dollars}^{**}}{\text{Total Number of Employees}}$$

This indicator, which can be derived by dividing the total training expenditures by the total number of employees, gives in dollars the rev-

enue per employee spent on training. The indicator can be calculated on a monthly basis and reviewed over time to insure that proper attention is being given to the training needs of the organization.

Strengths

The indicator is useful for monitoring the training expenditures and insuring that the proper overall level of training is being funded.

Weaknesses

The indicator fails to address the issue of training needs. In other words, is the training that is funded the right training for the needs of the workforce at the current time? If this indicator is utilized exclusively, then a false sense of achievement may be realized by some organizations.

2. Hours per Employee

This indicator examines the actual average training hours being allocated per employee per year . Many companies train employees with "soft" skills, such as diversity and team building, but how much time is allocated for the technical training? Certainly soft skills training is important since it helps improve organizational effectiveness. However, how much is being expended for pure technical training for the operators and maintenance technicians? Technical training is essential if the workforce is to be effective operating and maintaining the company's high tech equipment. In fact, studies have shown that technical training and interpersonal training should be given an even 50-50 split.

$$\frac{\text{Total Technical Training Hours}^{**}}{\text{Total Number of Employees}}$$

$$\frac{\text{Total Interpersonal Training Hours}^{**}}{\text{Total Number of Employees}}$$

These indicators can be derived by dividing the total training hours in each category by the total number of employees. This gives in hours the time per employee spent on each type of training. The indicator can be calculated on a monthly basis and monitored over time to insure the proper attention is being given to the training needs of the organization.

Strengths

The indicator is useful for monitoring the training time by type of training and insuring that the proper overall level of training is being funded.

Weaknesses

While these two indicators are more effective than the first one, the indicators still fail to address the issue of training needs. Again, is the training that is funded the right training for the needs of the workforce at the current time? Also, if these indicators are utilized exclusively, then a false sense of satisfaction may be achieved by some organizations.

3. Grade Reading Level

This indicator is more confidential then the previous two. It examines the overall grade reading level for the plant and expresses it as an average. This information is disturbing to some plants the first time they conduct a reading level assessment. Informal surveys conducted with seminar attendees over several years suggest that the average reading level in most plants today is about eighth grade. The ranges are from a low of a third-grade level to a high of second-year college.

A more disturbing statistic is the illiteracy level in some plants. It has been found there are plants in which one-third of the maintenance workforce is functionally illiterate. It does little good to print out a work order that the maintenance technician can't read. On the other hand, one computer chip manufacturer requires its maintenance technicians to have a four-year college degree.

There is no formula for this standard. It is derived through standard testing and averaging the plant totals.

Strengths

The indicator is useful for highlighting the company's standard in the area of basic skills. If the results are low, then some remedial training in basic skills is required.

Weaknesses

If the testing and results are not kept confidential, the technicians may view it as a way to humiliate individuals or to highlight those who the organization may want to replace. The goal should never be anything like this. Instead, the goal should be to identify if the plant has an overall problem in this area. In addition, the goal should be to identify what basic skills needs are in the organization and what training steps must be taken to insure those needs are filled.

4. National Test Averages

This indicator examines the actual skill levels of individual employees by using nationally recognized testing. The company can then evaluate how its employees match up with the averages in its own area or even in the areas where its competitors are located. A highly skilled and trained workforce allows a company to do many things that a company with a marginally trained workforce can not. If a company's competitors have workforces with higher levels of skills, they may be able to move into multi-skilling, operator involvement, or other high performance initiatives. There is no formula for this indicator.It is derived from national testing results.

Strengths

This indicator is useful for comparing workforce skills from plant to plant within a company, or for geographical comparisons with a competitor's workforce.

Weaknesses

This indicator is simply averages which may vary. A highly-trained workforce may exist in one area, raising what would otherwise be a lower score. This effect can skew results when trying to compare areas. The averages are worth considering, but no comparison should be viewed as absolute.

5. Correspondence Training and Testing

This indicator examines the actual training scores of the plant employees in various technical courses. Managers can then identify and utilize the skills and talents of the various employees. If the training and testing are part of a pay-for-knowledge or a pay-for-skills program tied to a needs/task analysis, then the scores can be used to promote individual technicians or to increase their pay based on applied skills.

There is no formula for this indicator. It is derived from the testing results.

The indicator will be the test scores themselves. The scores can be used to identify individuals with high skill levels who can be deployed in tasks that require the higher level skills and abilities. If the training and testing is tied to a job needs/task analysis, the results can be used to move individuals into a pay-for-applied-skills and knowledge program, encouraging the technicians to constantly improve their skills.

Strengths

This indicator is useful for tracking the skills of individual employees.

Weaknesses

The indicator can be used to compare employees and rate them with their peers in an open forum. It should *never* be used that way. The testing and training progress of the employees should be kept at the highest confidence level. Any failure to provide security for this information can result in a complete lack of workforce support for any training or improvement program. A breach of confidentiality could also lead to lawsuits from angry employees.

6. Number of Training Employees Compared to Maintenance Employees

This indicator examines the actual number of training employees per maintenance employee. This ratio will help an organization insure that the training programs for maintenance are staffed properly for success. Otherwise, the right amount of training will not be administered, since the staff will not be available to deliver or coordinate the training.

$$\frac{\text{Total Number of Training Employees **}}{\text{Total Number of Maintenance Employees}}$$

This indicator can be derived by dividing the total number of training employees by the total number of maintenance employees. Depending on how much of the training is delivered by in-house instructors instead of contractor instructors, this indicator can vary dramatically. For example, the ratio can average from as many one training person for every 150 employees to as few as one training person for every 400 employees. In establishing a ratio goal for a plant, the workload for the training staff person should be closely monitored to insure effectiveness of the training.

Strengths

The indicator is useful for monitoring the level of staffing of the training department.

Weaknesses

The indicator has such a broad range that a company may feel that as long as it is within that range, the training department is staffed satisfactorily. Without careful monitoring of the training workload, the training staff may find themselves overloaded. This overload condition will impact the overall effectiveness of the training and the company will fail to see the results from the training that should have been achieved.

INDICATORS SPECIFIC TO TECHNICAL TRAINING

The following indicators should be valuable to organizations attempting to cost justify their training programs. As it had often been said,

If you think training is expensive, try to calculate the cost of naivete.

The following indicators will help a company calculate the cost of ***not*** training its employees; they will further strengthen the business case for increased technical training.

7. Downtime Related to Operator Training

This indicator examines the actual downtime on equipment that is caused by operators' skill deficiencies. In many cases, extensive training programs do not exist for operators. Although regulatory programs such as Process Safety Management (PSM), OSHA regulations, and ISO-9000 certification require extensive operator training, few companies actually have documented standard operating procedures. If the maintenance and engineering department personnel were surveyed, what would be the equipment downtime caused by a lack of knowledge or skills on the part of the operations personnel? What if the cause could be recorded in the CMMS and totaled across a department or even the entire plant for a month? For a year? What amount of downtime would be identified?

$$\frac{\text{Total Downtime Attributed to Operational Errors*}}{\text{Total Downtime}}$$

This indicator can be derived by dividing the total downtime attributed to operational errors by the total downtime. This indicator is flexible; it can be used for an area, a department, or an entire plant.

One of the most valuable alternatives to using the raw indicator is to calculate what the cost of an hour of downtime is worth to the company. It varies from type of equipment and type of process. The cost of downtime includes not only the cost of the lost product or throughput for the hour, but also the cost of idle labor or overhead for the hour. Improvements in quality came only after someone calculated what the cost of nonconformance or poor quality actually cost a company.

Estimates for the cost per hour of downtime range from $1,000 for simple machining operations to over $40,000 for line costs in a brewery, and over $100,000 in a computer chip manufacturing plant. If the hours of downtime attributed to operational errors are multiplied by these figures, then the training programs become easier to cost justify.

Strengths

This indicator is useful for tracking the hours of downtime caused by operational errors. However, it is even better for tracking the reduction in downtime hours once a training program has been implemented. The organization can then easily calculate the return on investment for the training.

Weaknesses

This indicator is easy to use as a tool to identify operations personnel making mistakes and punish them. But training programs should be used to improve their performance. If the indicator is used as a tool for punishment, then the operations personnel will find ways to cover the root cause of the problem; the losses will never be identified and eliminated. If this indicator is to be utilized, it must be with the proper goals.

8. Downtime Related To Maintenance Training

This indicator is similar to the previous one with the exception that it focuses on maintenance skill deficiencies. In many companies, apprentice programs for maintenance do not exist. Some companies have no structured training programs in place to progressively improve the current level of technical maintenance skills. Although, regulatory

programs such as Process Safety Management (PSM), OSHA regulations, EPA requirements, and ISO-9000 certification require extensive maintenance training and documentation, few companies actually have documented standard maintenance training and procedures. If the maintenance and engineering department records were surveyed, what would be the equipment downtime caused by a lack of knowledge or skills on the part of the maintenance technicians? What if the cause could be recorded in the CMMS and totaled across a department or even the entire plant for a month? For a year? What amount of downtime would be identified?

$$\frac{\text{Total Downtime Attributed to Maintenance Errors}^{*}}{\text{Total Downtime}}$$

This indicator can be derived by dividing the total downtime attributed to maintenance errors by the total downtime. This indicator is flexible; it can be used for an area, a department, or an entire plant.

Factoring the cost of downtime into the indicator can also provide the same benefits that it did in the operations example.

Strengths

This indicator is useful for tracking the hours of downtime caused by maintenance errors. However, it is even better utilized by tracking the reduction in downtime hours once a training program has been implemented. It is then easy to calculate the return on investment for the training.

Weaknesses

It is easy to use this indicator as a tool to identify maintenance personnel making mistakes and punish them rather than using the training programs to improve their performance. If the indicator is used as a tool for punishment, then the maintenance personnel will find ways to cover over the root cause of the problem and the losses will never be identified and eliminated. If this indicator is to be utilized, it must be with the proper goals.

9. Lost Productivity Related to Maintenance Training

This indicator examines the productivity losses in maintenance activities caused by a lack of skills and knowledge in the maintenance work force. This indicator is more difficult to calculate than the previous two since the measure is typically a subjective assessment by a supervisor or manager of the actual work activities of a maintenance technician. The items highlighted here would be any time that is lost because an individual does not have the skills or knowledge to perform the work in the most effective and efficient manner.

$$\frac{\text{Estimated Lost Time Due to Lack of Knowledge or Skills}^*}{\text{Total Time Worked}}$$

This indicator can be derived by dividing the estimated time lost due to a lack of knowledge or skills by the total time worked. This indicator can be tracked by type of work, specific job, specific skill, or any other parameter that might be useful in identifying a potential training need. The training needs can then be prioritized based on the amount of time lost. The wage rate and impact on the time to perform the task (including the downtime of the equipment) can all be calculated in dollars and the required training can be cost justified.

As the training is conducted, the increased productivity can be tracked and the results expressed in dollars saved. This measure is effective for calculating return on investment for the training program.

Strengths

This indicator is useful for identifying training needs, cost justifying the training, and calculating the return on investment once the training is conducted.

Weaknesses

This indicator requires a subjective opinion about the amount of lost productivity attributed to a lack of knowledge or skills. The opinion may be disputed by some in the organization. However, if similar work can be found in other departments and plants, and comparisons can be drawn from these examples, then some of the disputes can be eliminated.

This indicator also can be used to make comparisons between individuals. While this used in itself is not wrong, if someone uses this data to reprimand or even criticize an employee, then the use of the indicator will be eventually be discontinued. Proper focus and understanding of the indicator's use is critical to its success.

10. Maintenance Rework Related to Maintenance Training

This indicator examines the amount of rework that is performed by the maintenance workers. Rework is defined as work that because it was not done completely and correctly the first time, must be adjusted, changed, or perhaps done completely over again. The organization must identify what amount of this type of work occurs because there was a lack of knowledge or skills on the part of the technician who performed the work the first time. This type of rework can be eliminated through a focused training program.

$$\frac{\text{Maintenance Rework Due to Lack of Knowledge or Skills}^*}{\text{Total Maintenance Work}}$$

This indicator can be derived by dividing the total hours of maintenance rework by the total hours of maintenance work. The resulting percentage highlights the opportunity for improvement by training the technicians so they can do the job right the first time. The losses in labor costs and material costs can be calculated for the rework and used as justification for the training program. In addition, the cost of the downtime incurred during the rework should also be factored in the savings potential. The return on the investment for the training can be calculated by monitoring the decrease in maintenance rework. The return on investment is calculated by the cost of the training program compared to the savings in reduced maintenance labor, materials, and plant equipment downtime.

Strengths

This indicator is useful for calculating the potential benefits of eliminating or reducing maintenance rework by increased maintenance training.

Weaknesses

The only weakness is a slight chance that some of the maintenance rework will not be properly identified. This information must not be misused as a way to punish technicians, instead of using it to focus the training effort.

11. Average Training Versus Payroll

This indicator examines the actual average training dollars being spent compared to actual payroll. It is similar to the training dollars per employee calculation. However, this indicator looks at the actual training cost as a percentage of plant payroll. In general, about 3% of the plant payroll should be spent on training. Decisions must be made about the type of training (and for whom) and the balance among management training, interpersonal training, and technical training. The indicator is calculated as follows:

$$\frac{\text{Total Training Dollars}^*}{\text{Total Plant Payroll}}$$

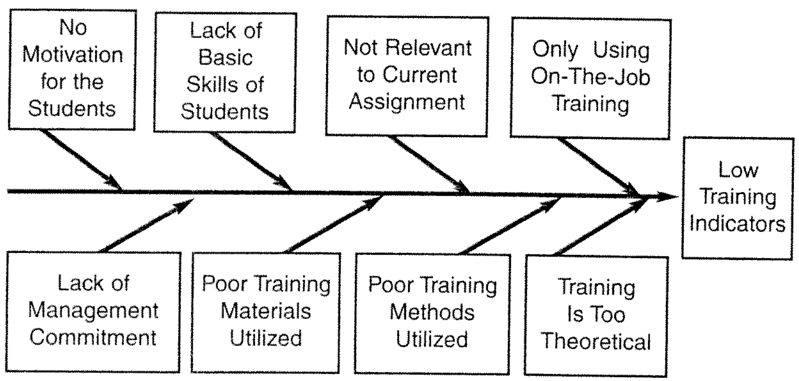
This indicator can be derived by dividing the total training expenditures by the total plant payroll. The resulting percentage shows the amount of the plant payroll allocated to training.

Strengths

The indicator is useful for monitoring the training budget as the plant payroll increases or decreases. It insures that the proper level of training is budgeted.

Weaknesses

The indicator has no major weaknesses. It is essential to have plant management commit to the proper percentage. Then, as the plant payroll increases or decreases, the proper level of training is assured.



Problems with Technical Training Programs

With the challenges described at the beginning of this chapter, it is apparent that most training programs are experiencing problems, if not outright failure. The most common reasons for training program failures are discussed in the following material.

Only Using On-The-Job Training (OJT)

This is a common problem in organizations without the resources to develop a structured and documented training program. The managers rely on other technicians showing an operator how to run equipment or, for a maintenance person, how to maintain, troubleshoot, and repair the equipment. Since the technicians giving this on-the-job instruction also have other jobs, they are hurried to convey the minimum of what the trainees need to perform the basics of the job.

The detailed instruction that makes a technician efficient and effective is never provided. The trainee may make great personal efforts to perform the job, but they are never efficient and effective. In addition to wasted labor resources, the equipment operation is affected and plant capacity suffers.

Companies that use only on-the-job training should remember that the method also teaches trainees someone else's bad habits. On-the-job training is never successful unless it is supplemented by additional training.

Training Is Too Theoretical

In some training programs, the information is taught directly out of textbooks and never supplemented with any actual application of the material to the technician's work assignment. The technician must make the application. Some will be able, but most will not. The effectiveness of the training and the return on investment will be impacted in that improved technician performance will not be realized.

The solution is to make the training job relevant. This may involve a duty or task analysis of the job and blending theory, hands-on lab activities, and on-the-job training to assure the trainees will be able to master the new skills being taught. Without making the training job relevant, there is little chance for retention on the part of the trainees.

Training Not Relevant to Current Assignment

Once training has taken place, it is important that the trainees put their new skills and knowledge to use. If they must go weeks or even months before they can use training on the job, their retention rate falls to a very low level. In fact, if months have elapsed, they may need retraining.

The message here is short and concise: provide the right training at the right time and at the right level. Unless these criteria are met, the organization will waste its training expenditures.

Poor Training Methods Utilized

This problem results from a lack of flexibility in the training delivery. A good training program uses a blend of materials and presentation styles. These include traditional classroom settings, computer-based training modules, video-based training modules, self-paced correspondence materials, and satellite training broadcasts.

If one style of presentation is used exclusively, then trainees may become bored and uninterested. By using a blend of techniques, the instructors can insure the training program always holds the attention of the trainees.

Lack of Basic Skills of Students

Unfortunately, this lack of preparation is becoming a large problem in many companies today. As individuals leave high school, they lack the basic skills in reading, writing, and mathematics. In turn, the companies have no choice but to develop internal basic training programs designed to insure a minimum competency in the workforce. While some companies do not have a problem in this area, due to acceptance testing, other companies do not have favorable geographic locations, compensation systems, or work environments to assure they a pool of highly-qualified candidates from which to select employees.

Poor Training Materials Utilized

Poor training materials may be an indication that there is insufficient funding for the training program. Some training programs use photo-

copies of copyrighted materials. In other cases, materials that are many years old are used and even recirculated among trainees. If a training program is to be effective, appropriate training materials must be provided. Many quality sources provide excellent training materials.

No Motivation for the Students

This area is sensitive for many companies. What are the incentives for an employee to want to learn new skills? Some factors include:

Will training lead to a pay increase?

Do the new skills lead to a new job?

Is training required to perform the current job due to a technology upgrade of the equipment?

Is the training just to insure the employability of the technician?

The motivation may be all of these, some of these, or even none of these reasons. Keep in mind that no matter what is used, something will have to motivate each employee to take the training and apply it. It is up to the management of each organization to find the right motivation for its workforce.

Lack of Management Commitment

One fact is clear: training is expensive, but ignorance is even more costly. In many cases, however, when cost reductions are made, cuts often begin in training and maintenance.These cuts are really a problem if you are in maintenance training. Management needs to be committed to training its employees if the company is to be competitive in the next decade.

Training needs to be focused on the return on investment the company will receive. This means training will be focused on resolving identified issues. These issues will have to be rated by the financial impact they have on the company. The issues will have to have a training needs analysis performed to identify the training requirements. The training will have to be developed or purchased. The results of the training will have to be tracked. The improvements will have to be expressed in a dollar amount so that the return of the training investment can be calculated and the effectiveness of the training evaluated.

Unless these activities are undertaken in a detailed and structured format, management will never commit to a sustainable training program.

Chapter 8
Operational Involvement

Most organizations today face a shortage of maintenance technicians to perform much of the technical work that needs to be performed on the equipment. In addition, many times the equipment isn't operating correctly since it doesn't get the level of attention and service it needs from the maintenance department.

Faced with these problems, many organizations are looking for activities in which they can involve equipment operators or other operational and facilities personnel. In this way, they can free their maintenance resources to concentrate on other activities where their technical skills can be better utilized, such as the predictive and reliability activities detailed in subsequent chapters.

First, though, what are some of the activities in which operators or operations personnel can be involved, and that can free up maintenance resources? The activities vary from company to company, but they include start-up inspections, cleaning, routine lubrication, mechanical fastening, minor maintenance, and data collection.

Start-up inspections require nothing more than a visual check of all of the start-up conditions of the equipment. This check would include looking for proper lubrication levels; proper, tight connections on all air, water, and hydraulic hoses; proper connections on lubrication lines, particularly grease lines; proper torque or tightness of all mechanical fasteners; and proper pressure, flow, and temperature of process equipment.

These may seem like little things. Yet how many maintenance resources would be required to make these checks at the beginning of an operational shift? The resources would be considerable. But now, with the operators performing these checks, the maintenance resources can be redeployed to other activities.

Equipment cleaning is a second activity in which many companies have operators involved. In fact, it is the primary activity in most companies. Clean equipment is easier to inspect, it decreases contaminate related wear, and it raises morale. Yet there is also a technical reason that clean equipment is required. Operators, helping to insure removal of contamination from their equipment, can do much to relieve extra work from the maintenance department. As an example, gearcases, motors, and hydraulic systems are required to be kept clean to prevent heat buildup. If contamination is allowed to buildup, then the thermal transfer process (allowing heat dissipation) is interfered with, and heat build up begins. As the temperature increases, the life of the component decreases. While equipment breakdowns don't occur immediately, they happen in a fraction of the design life of the component.

A third activity in which operators can be involved is the routine lubrication of their equipment. This dos not mean the operators have to walk to the storeroom and try to find the right oil or grease for their equipment. In many companies it is the responsibility of the maintenance department to insure the proper lubricant is close to the equipment; it takes little time and effort for the operators to get the lubricant they need for their equipment. Dispensers and filling equipment should also be conveniently provided as should instructions on quantity and application method of the lubricant. If the operator lubrication program is properly structured, it can relieve a large portion of the maintenance labor to be redeployed.

A fourth activity for the operators involves proper fastening and tightening procedures. The majority of mechanical breakdowns are due to poor fastening procedures. Lack of proper torquing techniques is a major issue. Operators are taught to look for loose fasteners and to either report or repair them before they start to loosen and create wear. This action reduces the need for a maintenance technician to be involved in this level of activity again freeing up more time for the maintenance technician to concentrate on other activities.

In some companies, the operators are trained to perform minor maintenance on their equipment. The tasks that they perform must be carefully selected, since training will be required for each task. Generally, companies will select the top five to ten nuisance tasks. These are tasks that generally take less time to perform than is needed to get a maintenance technician to the equipment.

These tasks are typically small items, like realigning a photocell, adjusting a mechanical stop, or resetting a stop switch. Each of the tasks

are carefully outlined, detailing each step and identifying all of the possible safety issues, what small tools may be required, and a visual diagram of the task. The operator is then trained how to do the task by the maintenance technician responsible for the equipment. When the training is complete, the task sheet is kept in a notebook at the operator's station for further reference each time the job needs to be performed. This process insures the operator is trained to work safely and the task is performed correctly.

One additional task in which some companies are involving the operators is using the CMMS for data collection. In these companies, rather than forwarding a hand-written request (or even a telephone request), the operators actually enter work requests into the CMMS. The request is then processed by someone in the maintenance department (usually a planner) and is converted into a work order. Some companies will even have the operators enter the minor maintenance they perform on their equipment directly into the CMMS. In other companies the operators record downtime amounts and causes. Again, the focus is on activities that free maintenance resources.

How does one monitor the effectiveness of operational involvement in maintenance activities? The following are some suggested indicators and performance measurements.

1. PMs Performed by Operators

This indicator examines the preventive maintenance program and what percentage of the work is being performed by the operations group. This indicator is valuable for insuring that some of the preventive maintenance is being performed by the operators. In most companies this level ranges from 10% to 40% of the preventive maintenance workload.

$$\frac{\text{Hours of Preventive Maintenance Performed by Operators}}{\text{Total Preventive Maintenance Hours}}$$

This indicator can be derived by taking the total hours of preventive maintenance performed by operators and dividing by the total hours in the PM program. In calculating this indicator, it is best to use a weekly total and then analyze the indicator over a six-to-twelve month window.

Strengths

This indicator is useful for insuring there is operational involvement in the PM program. It helps all employees in the organization to focus their efforts on performing the most maintenance on the equipment that they can with the best results.

Weaknesses

The weakness of this indicator is that sometimes someone has a target level for the involvement that operators should have in the PM program. As a result operators are encouraged to do too much or too little. When determining the correct level, the focus should be on the high time/lower skill activities that can easily be transferred to the operators. This insures the correct level of operational involvement.

2. Savings Due to Operator Involvement

This multipart indicator focuses on the value derived from the operators' involvement in maintenance activities. The areas are:

INCREASED UPTIME

This indicator examines the increased uptime that equipment is experiencing due to the operators' activities. The indicator looks at the maintenance downtime for the current year and divides it by the maintenance downtime for last year for the same time period. The result is the percentage increase in uptime. This helps the operations and maintenance technicians clearly see the benefits of operational involvement.

$$\frac{\text{Maintenance-Related Equipment Downtime (current period)}}{\text{Maintenance-Related Equipment Downtime (previous year same period)}}$$

This indicator can be derived by dividing the total hours of maintenance-related equipment downtime for the current period this year by the maintenance-related equipment downtime for the same period for the previous year. In calculating this indicator, it is best to use a monthly total and then monitor the indicator over a twelve month window.

Strengths

The indicator is useful for highlighting the benefits of operator involvement in the maintenance activities.

Weaknesses

The weakness of this indicator is that, in all probability, not all of the increase in uptime will be directly attributed to the operator involvement. However, even if the increased uptime is due to some predictive maintenance or reliability activity, the operator involvement still contributed by freeing up the resources to engage in these activities.

INCREASED CAPACITY

This indicator examines the increased capacity for the equipment due to the operators' activities. The indicator looks at the equipment throughput for the current year and divides it by the equipment throughput for the same time period the previous year. The result is the percentage increase in throughput (capacity). This indicator is different from the previous one in that the last one focused on equipment uptime whereas this indicator focuses on capacity, which is the, performance efficiency of the equipment and the quality of the product. This indicator helps the operations and maintenance technicians clearly see the benefits of operational involvement.

$$\frac{\text{Actual Equipment Throughput (current year)}}{\text{Actual Equipment Throughput (previous year same period)}}$$

This indicator can be derived by dividing the total throughput for the equipment for the current period this year by the total output for the equipment for the same period for the previous year. In calculating this indicator, it is best to use a monthly total and then monitor the indicator over a twelve month window.

Strengths

The indicator is useful for highlighting the direct production benefits of the operator involvement in the maintenance activities.

Weaknesses

The weakness of this indicator is that, in all probability, not all of the increase in capacity will be directly attributed to the operator involvement. However, even if the increased capacity is due to some predictive maintenance or reliability activity, the operator involvement still contributed by freeing up the resources to engage in these activities.

A second weakness is the possible variance in market demand for the product between the two years. Fluctuating demand can have an impact on the throughput, in turn, impacting the indicator. If this is the case, the calculation may need to be adjusted to a combination of target and actual design capacity to insure a realistic indicator.

NOTE: The indicators above help show the maintenance and operations technicians the value of their involvement. However, before using the indicators to show upper management the benefits, they should be converted to a financial indicator showing the impact on profitability that the increase in uptime or capacity has had across the year.

MAINTENANCE RESOURCES MADE AVAILABLE

This indicator examines the increased maintenance resources available due to the operators' activities. The indicator looks at the percentage of maintenance activities the operators are performing this year compared to the same time period last year. The result is the percentage increase in maintenance resources available. This shows the operations and maintenance technicians the benefits of operational involvement.

$$\frac{\text{Hours of Maintenance Activites Performed by Operators (current year)}}{\text{Hours of Maintenance Activities Performed by Operators (previous year same period)}}$$

This indicator can be derived by dividing the total hours of maintenance activities performed by the operators for the current period by the total hours for the same period for the previous year. In calculating this indicator, it is best to use a monthly total and then monitor the indicator over a twelve month window.

Strengths

The indicator is useful for highlighting the change in operator involvement in the maintenance activities.

Weaknesses

The weakness of this indicator is that, in all probability, over time the percentage increase will level out and decrease as the operators assume all of the maintenance duties that they can fit into their

schedule. Thus, as the indicator decreases in size, the reason must be clearly communicated. Any increase after saturation will be incremental, but would show a continuous improvement in attitude.

3. OPERATOR TIME SPENT ON EQUIPMENT IMPROVEMENT ACTIVITIES

This indicator examines the amount of time that operators spend on equipment improvement and compares it to the total operator's time.

$$\frac{\text{Hours of Equipment Improvement Performed by Operators}}{\text{Total Hours Worked by Operators}}$$

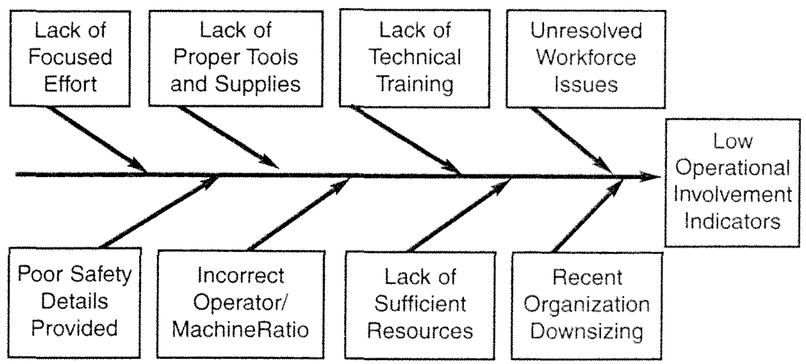
This indicator can be derived by taking the total hours of equipment improvement activities performed by the operators and dividing by the total hours worked by operators. The resulting percentage can be analyzed over time to show the level of operator involvement in equipment improvement activities. In calculating this indicator, it is best to use a monthly total with a twelve month window.

Strengths

This indicator, useful for highlighting the level of involvement in equipment improvement activities, helps to insure that the improvement activities are consistent. It prevents the program from losing focus. If any negative trends are noted, they can be corrected before serious damage is done to the equipment improvement program.

Weaknesses

This indicator has no major weakness. It should be used by any organization utilizing continuous improvement tools.



Problems With Operational Involvement

While the Majority of companies today see the benefits of involving their operations groups, few accomplish this involvement successfully. In fact, surveys have shown that, on average, only about 30% of the companies achieve the results they intend. Why is the success rate so low? The following are common problems to operational involvement.

Unresolved Workforce Issues

This problem can be referred to as unresolved labor-management issues. In most cases, successful operations involvement programs have cooperative relations between labor and management. But when management and the workforce have a high level of grievances and unresolved issues, it is difficult to initiate operations involvement in maintenance or equipment improvement activities.

Typically, the involvement of operations personnel in maintenance activities, requires crossing boundaries between what has been two separate organizational functions. Even when management and workforce relations are good, the start-up can be somewhat rocky. If the relations are already strained, then initiating discussions about operators being involved in maintenance activities may worsen the situation.

When the negative issues are not resolved, discussions often reach an impasse, preventing any positive progress toward operational involvement. If the involvement of operations personnel in maintenance and equipment improvement activities is the goal of an organization, then positive management-workforce relations must be developed and nurtured. Without a mutual trust and a focus on being competitive in the world market, a company will not initiate any sustainable operations involvement program. Both labor and management should always remember that the real competitors are outside the company, not inside.

Recent Organizational Downsizing

A negative trend in most companies has been the downsizing of the workforce. While it is true that some organizations have grown heavy with excess employees, many have cut too deeply into their employee base. An honest evaluation should be made as to whether the reductions are truly part of a focused reengineering effort or just a way to convince Wall Street to raise the stock price.

If the workforce is concerned about downsizing and whether there is going to be more in the future, starting any operations involvement activity will be difficult. Some employees may feel that if they take on any tasks that maintenance personnel currently perform, the maintenance department might lose more people. The maintenance personnel will feel the same and only partially train the operations personnel to do the transferred tasks. The result is that equipment suffers and more problems occur, insuring that the maintenance personnel will have enough work to keep the current staff busy.

If the workforce is concerned about losing more personnel through operational involvement in maintenance activities, then there is little chance of success. If operational involvement is to be successful, company management must address issues around job security for the workforce. Unless company management is willing to do this, it will be in the best interests of all concerned to wait until another time to begin operational involvement in maintenance activities.

Lack of Technical Training

Many companies lack the appreciation for the skills required to be proficient in performing maintenance activities. For example, some companies have provided operators with grease guns to lubricate their equipment but never provided any training on lubrication techniques. Thus, some bearings were found with no grease, others had their seals blown out from excessive grease, and still others had the wrong grease. The number of bearing failures and the resulting equipment downtime increased dramatically, affecting the equipment capacity and the morale of the workforce.

If a company is going to involve operators in any maintenance or equipment improvement activities, then technical training must be provided. Unless the company clearly understands that maintaining and improving a technology (which is what a piece of equipment is) requires technical skills, little, if any, benefits will result from operational involvement in maintenance activities.

Lack of Sufficient Resources

This particular issue focuses on the resources required to perform any activities assigned to the operators. Suppose the equipment to be maintained is on a manufacturing line, and the line requires four operators to run it. If only four operators are scheduled, how will they find the time to perform any maintenance activities? If their assignment on the line does not include some free time to perform the maintenance activities, then they must shut the equipment down to perform the maintenance activities. Is this cost effective? Do the downtime losses outweigh the benefits derived from the operator-based activities? Without proper resources, the maintenance activities are not likely to be performed since they are viewed as lower priority than the production throughput.

Many companies actually overstaff their lines or processes with an extra person (or more, depending on workload) to perform maintenance activities and other functions assigned to the operators. This overstaffing alleviates the strain on the resources and insures the equipment receives the correct level of attention. For continuous run processes, the activities are divided into run maintenance and down maintenance. The run maintenance activities can actually be performed when the equipment is operating, further reducing the amount of downtime required to perform maintenance. These activities further reduces the resource strain when the equipment is down. The company must examine methods to eliminate the strain on resources and still keep the equipment properly maintained.

Lack of Proper Tools and Supplies

Many companies don't realize that they require tools and supplies to perform maintenance on the equipment. The maintenance department is typically autonomous in obtaining its supplies. The operators are not as adept. Therefore someone needs to insure that the operators have the tools and supplies they need to perform their assigned tasks.

The solution is not complicated. Either maintenance can supply the operators' needs or a means can be provided for them to easily procure their own supplies and tools.

Incorrect Operator/Machine Ratio

In many companies, the operators are required to work in manufacturing cells: one operator may run multiple pieces of equipment to produce a product. This involves considerable time and effort on the part of the operators. The company must ask whether they have additional time to properly perform maintenance activities on the equipment? It may be assumed that they can take a few minutes here and there to complete the maintenance tasks. Yet, if they are pushed to meet their production goals, will they take the time?

In companies where operators are required to run multiple equipment items, the level of maintenance activities assigned to them may have to be reduced. This may be a resource issue, but it is better to insure that maintenance is being performed.

Lack of Focused Effort

The lack of focused effort can also be tied to a lack of training.The operators will lose focus if they do not understand they are being asked to undertake maintenance activities in an attempt to make more maintenance resources available for other activities, while at the same time insuring that the correct level of maintenance is still being performed on the equipment. Futhermore, if management does not stay focused and clearly communicate to the operators the value of the activities that they are performing, the operators will lose focus.

The problem is overcome when the organization itself assumes the proper focus and then instills the organizational discipline that insure the operators stay focused on results.

Poor Safety Details Provided

If operators are going to perform even small amounts of maintenance on their equipment, they need training to be safe. This training goes beyond the basic operational lock-out tag-out training they may have received. They need maintenance level training in these issues. They need to be aware of the second-and-third level energy systems that they may need to lock out before they do maintenance work. They need to be aware of the OSHA regulations impacting work.

The solution to this problem is a good training program, coupled with some supervised practice, to insure they are aware of all of the safety issues.

Chapter 9
Predictive Maintenance

Predictive maintenance (PDM) is the monitoring of equipment operating conditions to detect any signs of wear that is leading to a failure of a component. The goal of the predictive maintenance program is to track the component wear with a methodology which insures that any impending failure is detected. Once detected, the component wear is tracked more closely. The component will then be scheduled for replacement before it fails during a scheduled run.

The monitoring of the operating condition of the equipment can be accomplished by examining its operating dynamics. The most common techniques for measuring operating dynamics are vibration analysis, thermography, ultrasonics, and oil analysis, both lubricant condition and wear particles.

Vibration analysis measures the physical operating vibrations of rotating equipment. Based on the type of equipment, the analysis can indicate problems with bearings, belts, chains, gears, shaft misalignment, and out-of-balance conditions. The major impact that vibration monitoring has in most plants is its use in detecting bearing problems. By knowing days, weeks, or even months in advance that a component is wearing and will fail, the maintenance department can change the part with minimal impact on the operations department.

Thermography measures the temperature of a component. Analzing temperature over time indicates wear, since increased wear is generally accompanied by a rise in temperature. The thermographic equipment can be anything from a small temperature strip to an infrared imaging system. The level of detail, coupled with ability to measure the parameter safely, quickly and accurately determines the cost of the tool required. Thermography is typically utilized for finding potential problems (usually poor connections) with electrical and electronic systems. However, it is also being used in high temperature applications like furnaces and heat exchangers. It is also used to indicate misalignment in drive couplings.

Ultrasonic inspections are used to check for high frequency noise that is typically created by leaks. Ultrasonic detectors can be used to find air leaks, steam leaks and other fluid leaks. Using stationary detectors, ultrasonic detectors can also be used to inspect pressure vessels and other containers. While ultrasonics tends to be used as an instantaneous check, the data, especially for pressure vessels can be analyzed to show rate of wear.

Oil analysis refers to at least two different techniques. The first examines the lubricant itself. The analysis reveals whether the oil has become contaminated, is losing its lubrication qualities (corrosion resistance, wear resistance, load rating, etc.), or has been damaged from overheating. The second examines wear particles in the lubricant. These particals indicate the type of wear occurring in the unit being lubricated. If the wear particles show an accelerated wear rate, then the unit can be more closely inspected to find the cause of the wear and correct it. This leads to extended life of the component by detecting a problem before any damage is done to the component.

Since each of these predictive techniques are used to check for a particular type of wear, a mix of the techniques is typically used in a predictive maintenance program. The PDM focuses on the following steps:

Track equipment conditions not easily inspected in the preventive maintenance program.

Reduce the amount of effort in the PM program by using technology instead of disassembly.

Reduce the spare parts required to be on hand for unexpected equipment breakdowns or component failures.

Allow for a high level of planned and scheduled maintenance work, lowering the amount of conflict with the production schedule.

Increase the equipment capacity by insuring it is technically capable of performing at design specifications.

Some of the indicators that can be used to determine if the predictive maintenance program is successful follow.

1. Predictive Maintenance Activities

This indicator examines the percent of maintenance activities that are predictive compared to the other categories of maintenance work. There are two ways to view the indicator. The first is by total hours of predictive maintenance (PDM) time compared to all other hours of maintenance work. The second is by total expense for the program compared to the total dollars spent on maintenance. Most of the PDM work involves labor-intensive inspections. There are few spare parts used. However, if the work tracking system can be used to highlight corrective work resulting from predictive inspections, then the ability to compare additional cost benefits will be available.

$$\frac{\text{Hours of Predictive Maintenance Activities}^*}{\text{Total Maintenance}}$$

$$\frac{\text{Predictive Maintenance Costs}^*}{\text{Total Maintenance Costs}}$$

These indicators can be derived by dividing the total hours (or costs) of the predictive maintenance activities by the total hours (or costs) worked by the maintenance department. The resulting percentages can be analyzed over time to show the level of hours or costs invested in the PDM program. In calculating this indicator, it is best to use a weekly total over a twelve-month window.

Strengths

These indicators are useful for highlighting the level of predictive maintenance activities and insuring that they are consistent. The indicators prevent the PDM efforts from losing focus. If any negative trends are noted, they can be corrected before serious problems develop with the PDM program.

Weaknesses

There are no major weaknesses with these indicator . They should be used by any organization serious about the predictive maintenance program.

2. Savings Attributed to Predictive Maintenance Activities

This indicator highlights the savings attributed to the predictive maintenance program. It should include equipment breakdowns that were eliminated or prevented due to a predictive inspection. While these savings may be difficult to calculate, a genuine attempt should be made to quantify them, thereby insuring the ongoing organizational support for the PDM program. The major areas of saving are:

Increased equipment uptime (downtime avoidance cost)
Increased equipment capacity (increased of the equipment)
Decreased maintenance expense
(less expensive to repair in a planned mode)
Dollars saved due to predictive maintenance (month-to-date)

This indicator is calculated on a monthly basis and reviewed over a year. The indicator should also provide an annual summary of the yearly savings since the program's inception.

Strengths

The indicator is useful for obtaining and maintaining organizational support for the predictive effort. It can also be used as an educational tool, helping the organization understand the impact that equipment reliability has on the profits of the company.

Weaknesses

The major weakness of this indicator is the difficulty in calculating the cost avoidance. It may be easier if the cost data for a previous breakdown was accurately recorded in the CMMS. The downtime should have been a part of that record; the loss can then be calculated from that figure. Capacity increases can compare current production rates to the rates before the predictive program was started.

3. Decreased Maintenance Expenses Attributed to PDM Activities

This indicator examines the maintenance expense reduction for operating in a predictive mode compared to a reactive or preventive mode. The reduction, which occurs because of the longer planning cycle lowers the inventory on hand since the order can be placed and the materials received, just before they are required for the repair. Because the jobs can be scheduled so far in advance, production disruptions are minimized and less maintenance overtime will be required. The two major areas of savings are labor (improved and more reliable scheduling) and spare parts (forecasted demand, not stores and use as needed).

$$\frac{\text{Current Maintenance Costs}^{*}}{\text{Maintenance Costs Prior to Predictive Program}}$$

This indicator can be derived by dividing the current maintenance labor and materials costs (monthly maintenance expenditures) by the benchmarked maintenance costs prior to starting the predictive program. This indicator can be monitored over a rolling twelve months, with the lowest and highest months displayed as the range.

Strengths

The indicator is useful for developing and maintaining support for the PDM program. It helps educate the organization about the financial benefits of predictive maintenance to the profitability of the company. It is also useful for insuring that there is an ongoing return on investment for the predictive maintenance activities.

Weaknesses

The only major weakness of this indicator is collecting the cost data so that it is accurate enough to be accepted the organization The data should be able to be correlated to the accounting data.

4. Decreased Breakdown Frequency

This indicator examines the mean time between failure (MTBF) calculation for selected critical equipment items. The effectiveness of the PDM program is determined by having fewer equipment breakdowns. On an equipment-by-equipment basis, the number of breakdowns is divided by the time period, producing mean time between failure.

$$\frac{\text{Number Equipment Breakdowns}^{**}}{\text{Total Hours in Time Period}}$$

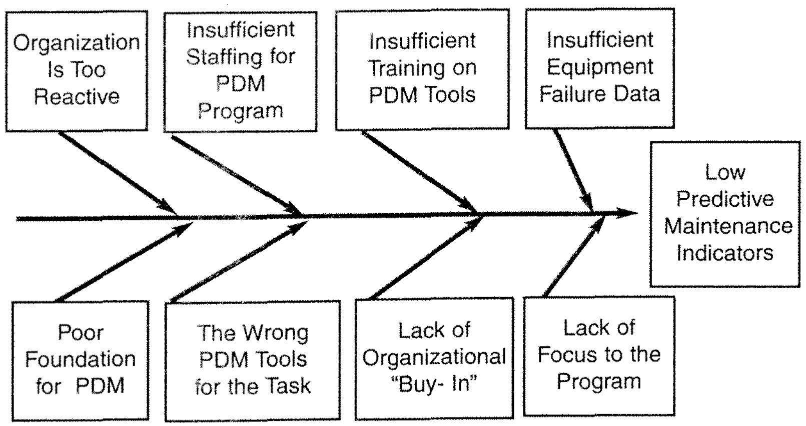
This indicator can be derived by dividing the total number of breakdowns by the total time in the examined period. The resulting ratio (MTBF) can be reviewed over time to show the level of improvement. If the predictive program is working, the MTBF will increase. If it does not increase, then the predictive program needs adjusting. The time frame to use for the calculation is equipment specific. It should depend on the frequency of the failures upon starting the program.

Strengths

This indicator is useful for highlighting the impact that PDM activities have on the equipment failures. It is beneficial to use this indicator to keep the predictive program effective. As long as the MTBF is increasing the predictive program is effective. If the MTBF decreases, then some adjustments are required.

Weaknesses

There is no major weakness in this indicator. It should be used by any organization utilizing a PDM program. By the time the organization reaches this level of maturity, the data collection system should be accurate enough to develop the MTBF calculation.



Problems with Predictive Maintenance Programs

Predictive maintenance programs typically produce results, but many never achieve thefull range of benefits. Why is it difficult to obtain full predictive maintenance? The following are common problems with PDM programs.

Insufficient Equipment Failure Data

This problem occurs when an organization has started the predictive maintenance program without building a foundation of the maintenance basics. The organization is not fully using the work order system and/or the CMMS, so it does not have the data to produce the predictive program indicators.

The solution is to go back to the basics and insure they are in place if the predictive program is to be effective and sustainable.

Lack of Focus to the Program

This problem occurs when an organization becomes involved in predictive maintenance because of interest in the "toys of technology." The predictive instruments were purchased, and they were initially used on specific problems, but a structured and disciplined program was never implemented. Therefore the maintenance department has the tools, but it was never trained to be proficient.

This problem is remedied only when a predictive effort is properly scoped for the organization. This means that a study of the equipment, its operating dynamics, and its failure modes must all be performed. Based on the data gathered during the study, the appropriate predictive tools are purchased to detect the equipment problems. The scope of the program, the equipment to be included, the schedule of the inspections, and the process for recording the data must all be defined. Once the predictive tools are purchased, extended training must be planned and implemented for the maintenance technicians. As the predictive program continues, adjustments are made to insure its effectiveness, based on the indicators.

Insufficient Training on the PDM Tools

In many companies, the permission to purchase maintenance tools is given to several people. In some companies, if an employee needs something, he or she buys, it; a lot of justification is not required. However, sending someone for training or bringing some training to the plant is another matter. The request must go through several layers of approvals, with each one asking more questions and cutting a small amount out of the appropriation. When the process is finished, there is not sufficient funding to get the best training, so compromises are made and less than optimal training is provided. With less than optimal training comes less than optimal results. The effectiveness of the predictive program is impaired and the benefits are never realized. Management then moves on to another program with more promise.

The only way to prevent this problem is to create the proper understanding of the requirements of a successful predictive program when developing the plan. In this way, when the request for training is generated, it is already approved.

Lack of Organizational "Buy-In"

This problem occurs when the maintenance department never really sold the predictive program to the rest of the company. The maintenance department personnel know what to do and what the benefits will be, but this information is never clearly understood by the rest of the organization. Then when the maintenance department says the equipment needs to be taken off-line for an imminent failure, no one believes them. The equipment then fails and the maintenance department is driven into a reactive mode.

The only way to insure that this does not happen is to clearly communicate the benefits and scope of the predictive program prior to starting it. Sufficient examples from other companies (usually available from the PDM vendors) with success stories should be communicated to the organization. Sample scenarios of what will happen in a predictive program should be developed, based on others' experiences. Then when issues are raised, they will be easier to resolve.

Insufficient Staffing for the PDM Program

This problem is related to several of the previous issues, but begins with a lack of a complete plan to implement the predictive maintenance program. Without the plan, requirements are never understood, proper staffing among them. Maintenance departments should never be asked to do predictive maintenance instead of some other aspect of the maintenance program. Predictive maintenance must not be a program with the motto "In your spare time, do this".

When starting the PDM program, a business plan must be put together, with resource requirements and a return on investment study. Without this, proper staffing will always be a problem.

The Wrong PDM Tools Being Used for the Task

One cause for the wrong PDM tool being used could be that the manager is only knowledgeable about one PDM technique. Therefore, the sole focus of the program is on that technique. Another cause could be cost. With a limited budget, maybe only one predictive tool could be purchased and implemented. Whatever the reason, the predictive program will have limited success if it has a single focus. A futher complication comes if the wrong technique is used to solve an equipment problem. The rest of the organization is observing what is taking place. If the predictive program doesn't work (because of using the wrong tool), then the organization develops the attitude that all of the tools don't work.

This problem has a simple solution: use the right tool for the right job. While this seems easy to say, it is not always easy to do. Someone in the organization will need a good knowledge of the various predictive techniques available. He or she will also have to know the strengths, weaknesses, and application of the predictive tools. Only in this way will the right technique be used for the right problem.

Organization Is Too Reactive

The predictive maintenance program should not be introduced before the maintenance organization is mature enough to effectively use the tools. Suppose the maintenance organization is still performing over 20% of its work in a reactive mode. If this is the case, the work order data is inaccurate. The cost data will be inaccurate. Thus, no true cost justification or return on investment study can be conducted. Predictive tools may be purchased, but no real structure and discipline to the program is developed. Results will be fragmented and not sustainable.

The solution is to insure that the basics are in place and that the maintenance organization is ready to implement predictive maintenance. If the maintenance organization is not ready, then it is highly unlikely that the rest of the organization will be ready. Build the foundation first and then mature the maintenance program.

Poor Foundation for PDM

The pyramid of performance indicators, seen earlier in the book, helped show that the foundation must be in place before the predictive program can be effective. It is mandatory for the improvement process to be followed if the entire maintenance improvement effort is to be successful. A flawed foundation will ultimately result in suboptimization of the entire effort and a lack of a competitive maintenance program.

Predictive maintenance is one of the most valuable tools enabling maintenance to make long-term plans and increase the equipment mean time between failures. But it must always be built on a solid foundation.

Chapter 10
Reliability-Centered Maintenance

NOTE: This chapter does not presume to define in detail Reliability-Centered Maintenance. For a detailed approach to RCM, see the second edition of RCM II by John Moubray, published by Industrial Press, 1997.

Reliability-Centered Maintenance (RCM) is an evolutionary approach to equipment reliability. It focuses on the optimization of the preventive and predictive maintenance programs to increase equipment efficiency (uptime, performance, and quality) while minimizing the related maintenance costs. The Reliability-Centered Maintenance approach can be highlighted by the following decision tree:

Will the failure cause a safety, health,
or environmental issue? --------- YES --- Define appropriate preventive and/or predictive maintenance tasks
|
NO
|
Will the failure cause considerable
downtime and costly lost production? ----YES----------
NO
Will the failure cause considerable
collateral damage and be expensive ------- YES --------
to repair?
|
NO
|
Run to failure

In the decission tree, the consequences for failure are taken into consideration when evaluating the preventive and predictive maintenance tasks. For example, if a regulatory issue such as the safety of an employee or the environment would be endangered by the failure, the preventive and predictive programs would be modified in such as way that the consequence could:

be prevented by proper preventive maintenance,

be monitored by predictive techniques so that the time of the failure could be identified and the defective component could be changed before the failure occurred, or

be designed out by changing the equipment design to eliminate the component that would have failed.

If the failure would cause a major production stoppage or process loss, then the same process would be applied to eliminate the problem.

If the answer to the first two decision tree questions is were no, then the last question is: Would the failure cause considerable damage to the equipment and be expensive to repair. If yes, then the preventive and predictive process would be applied.

If no, then run to failure is an acceptable alternative. (Run to failure is the philosophy that equipment should be run until it breaks down rather then having preventive maintenance performed on it.)

In reality, while appearing simple, significant analysis goes into each step of the process. Consider the understanding of the operating dynamics of the equipment that is necessary to identify the possible component failures and all of the consequences each failure. Then consider the level of understanding of preventive and predictive techniques to make decisions about which technique would prevent or detect a failure.

Thus the reason why most RCM projects are undertaken as a team is that no one individual has all of the knowledge to make all of the decisions in the RCM process.

Since RCM is an advanced technique that should be used by organizations, how is its performance monitored? The following indicators help monitor RCM.

1. Repetitive Equipment Failures

This indicator compares the repetitive failures on critical equipment to the total failures. The resulting percentage highlights the opportunity

to focus on failure elimination through the RCM process. The focus should be on critical equipment items first, but can be expanded to second-and third-tier equipment as resources become available.

$$\frac{\text{Number of Repetitive Equipment Failures*}}{\text{Total Number of Equipment Failures}}$$

This indicator can be derived by dividing the number of repetitive equipment failures by the total number of equipment failures. The resulting percentage represents the opportunity to reduce equipment failures through the RCM process. The indicator should be tracked by individual equipment item, but can be rolled up to a higher line, process, department, or area level. The information can be tracked monthly or (for more proactive organizations) quarterly. It can be analyzed over a rolling twelve months; it should indicate a declining percentage, based on the improvements RCM is making in the repetitive failure rate.

Strengths

The indicator is useful for highlighting potential opportunities for RCM analysis in the areas of repetitive equipment failures.

Weaknesses

There are two major considerations when using this indicator. First accurate data on the equipment failures is a prerequisite before starting the process. Second, this indicator should not be the sole focus of the RCM effort. It is only one area in which RCM may be useful. Other indicators will highlight the other opportunities.

2. Equipment Failures Where Root Cause Analysis is Performed

This indicator compares the number of equipment failures on which root cause analysis is performed to the total number of equipment failures. The resulting percentage highlights the opportunity to focus on failure elimination through the RCM process. The focus should be on critical equipment items first, but can be expanded to second-and third-tier equipment as resources become available.

$$\frac{\text{Number of Failures Where Root Cause Analysis Was Performed*}}{\text{Total Number of Equipment Failures}}$$

This indicator can be derived by dividing the number of equipment failures where root cause analysis was performed by the total number of equipment failures. The resulting percentage represents the opportunity to start the RCM process where preliminary data exists. Common root causes can be identified and opportunities for major improvement by addressing causes of multiple failures highlighted. The indicator should be tracked by individual equipment item, but can be rolled up to a line, process, department, or area level. The information can be tracked monthly or (for more proactive organizations) quarterly. It can be analyzed over a rolling twelve months; it should indicate an increasing percentage as failure analysis becomes more common.

Strengths

The indicator is useful for highlighting potential opportunities for RCM analysis in the areas of repetitive equipment failures with common root causes.

Weaknesses

There is only one major consideration when using this indicator. Accurate data on the equipment failure causes is a prerequisite before starting the process. There can be no guess work in root cause analysis, otherwise costly mistakes will be made.

3. PM Program Activities Audited Annually for Effectiveness

This indicator examines the number of preventive maintenance tasks that are audited for effectiveness each year. It compares the number of PM tasks audited to the total number of PM tasks. This indicates the level of preventive maintenance tasks that are actually being compared to the equipment history and the root causes of breakdowns; it, insures that the correct procedures are on the preventive maintenance tasks and that they are being performed at the correct frequency.

$$\frac{\text{Number of Preventive Maintenance Tasks Audited}^{*}}{\text{Total Number of Maintenance Tasks}}$$

This indicator can be derived by dividing the total number of preventive maintenance tasks audited by the total number of preventive maintenance tasks. The result should be expressed as a percentage. It

can be calculated annually and over a multi-year period. To be meaningful, the effort would have to be ongoing for several years.

Strengths

The indicator is useful for insuring that the PM program is closely monitored. The indicator can be reviewed by craft, equipment, area, or even department. This allows for focused efforts in the PM program.

Weaknesses

This indicator is a lagging indicator. It could be used by dividing the total number of preventive maintenance activities by twelve and calculating on a monthly basis, but this is usually more effort than it is worth.

4. PDM Program Activities Audited Annually for Effectiveness

This indicator examines the number of predictive maintenance tasks that are audited for effectiveness each year. It compares the number of PDM tasks audited to the total number of PDM tasks. This indicates the level of tasks that are actually being compared to the equipment history and the root causes of breakdowns; it insures the correct inspections are on the predictive maintenance tasks.

$$\frac{\text{Number of Predictive Maintenance Tasks Audited}^{*}}{\text{Total Number of Predictive Maintenance Tasks}}$$

This indicator can be derived by dividing the total number of predictive maintenance tasks audited by the total number of predictive maintenance tasks. The result should be expressed as a percentage. It can be calculated annually and over a multi-year period. To be meaningful, the effort would have to be ongoing for several years.

Strengths

The indicator is useful for insuring that the PDM program is closely monitored. The indicator can be reviewed by craft, equipment, area, or even department. This allows for focused efforts in the PDM program.

Weaknesses

This indicator is a lagging indicator. It could be used by dividing the total number of predictive maintenance activities by twelve and calculating on a monthly basis, but this is usually more effort than it is worth.

5. Savings Attributed to the RCM Program

Several indicators examine the savings that are realized by the RCM program. This series of indicators is vital to companies wanting to maintain the resources necessary to sustain an ongoing RCM program. As with other parts of the maintenance program, a financial return on the investment in the program is necessary before management will allow it to continue. The RCM program produces a financial return in at least these three major areas:

Equipment Uptime. Since the equipment is closely monitored by the PM and PDM programs, there are few, if any, breakdowns and, therefore, maximum uptime for the plant equipment. Since the equipment is on-line consistently, the production throughput is increased. When the cost of the increased production is calculated, it should show a significant return on the investment in RCM.

Equipment Capacity. In addition to increasing uptime, the RCM program improves performance efficiency. The equipment now operates at one set of design speeds and capacities, for instance 70% or 80% of what the equipment was designed to produce. This leaves 20% to 30% of the return on the asset as lost production. If this production is realized, the savings can be significant. The RCM process can help to recover this lost capacity.

Maintenance Labor Resource. By this stage of maturity, the maintenance organization is not fire fighting. Savings do not come from increased labor productivity. Instead, the savings come from eliminating maintenance work in the form of ineffective preventive maintenance tasks, preventive maintenance tasks that are done too often, or predictive inspections that are done too often or are unnecessary.

There are no direct formulas for calculating these indicators. Each is tracked by individual equipment item. The first step is to develop an initial benchmark of the uptime, capacity, or labor hours for the time that the effort is initiated. Ongoing tracking would highlight the benefits achieved in each area tracked by the indicator. The financial performance can be tracked for each part of the indicator; these results can then be totaled to determine the combined savings. Because of differences in production processes and accounting procedures within companies, there is no standard way to perform these calculations.

Strengths

These indicators are mandatory for developing and maintaining organizational support for the RCM program. They can also be useful for educating the organization about the financial benefits of RCM and how it contributes to the profitability of the company. These indicators also insure that there is an ongoing return on investment for the RCM activities.

Weaknesses

The only major weakness of this indicator is collecting the cost data so that it is accurate enough to keep the organization from debating the data. It should be able to be correlated to the accounting data. Collecting the data takes a lot of effort, something that should not be underestimated when starting data collection and tracking.

6. Reduction in Regulatory Violations and Non-Conformance

These indicators examine the reduction in regulatory violations and nonconformance penalties from implementing the RCM program. Since reducing unplanned failures and their impact on the operations is the goal of RCM, regulatory issues related to consistent and safe operation of the equipment will be dramatically reduced. The three major areas to monitor are OSHA, EPA, and ISO-9000.

OSHA Citations: Notices Per Inspection (Current Year)
OSHA Citations: Notices Per Inspection (Previous Year)

EPA Citations: Notices Per Inspection (Current Year)
EPA Citations: Notices Per Inspection (Previous Year)

ISO-9000: Notices of Nonconformance Per Inspection (Current Year)
ISO-9000: Notices of Nonconformance Per Inspection (Previous Year)

These indicators can be derived by comparing inspection results from the last year to the inspection results for the current year. These inspections may be made by regulatory inspectors or by internal inspectors. This can be analyzed over several inspections as the RCM program remains in place over time.

Strengths

These indicators are useful for developing and maintaining support for the RCM program. They can also be useful for educating the organization about the regulatory benefits of RCM and the impact it has on the business. They also help to insure continuing management support for the RCM program.

Weaknesses

The only major weakness of this indicator is the effort required to track and collect the data.

7. Extension of Equipment Life and Increased MTBF

This indicator examines both the Mean Time Between Failure and the lengthening of the overall service life of the equipment. The first is easy to track; the second more difficult. The MTBF calculation for selected critical equipment items is identical to the calculation in the section on predictive maintenance. On an equipment-by-equipment basis, the number of breakdowns is divided by the time period and a mean time between failure result is produced.

$$\frac{\text{Number of Equipment Breakdowns**}}{\text{Total Hours in Time Period}}$$

This indicator can be derived by dividing the total number of breakdowns by the total time in the examined period. The resulting ratio (MTBF) can be analyzed over time to show the level of improvement. If the RCM program is working, the MTBF will increase. If it does not increase, then the RCM program needs adjusting. The time frame to use for the calculation is equipment specific. It should depend on the frequency of the failures upon starting the program.

Strengths

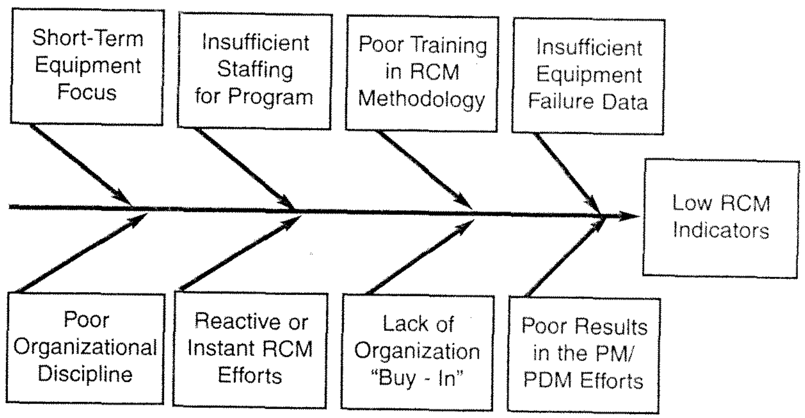
This indicator is useful for highlighting the impact the RCM activities have on the equipment failures. It is beneficial to use this indicator to keep the RCM program effective. As long as the MTBF is

increasing, the RCM program is effective. If the MTBF decreases, then some adjustments are required.

Weaknesses

The major weakness here is the ability to separate what impact the RCM program has on the MTBF calculation independent of the predictive program. The two are so closely linked, it may be difficult to determine which program is having the impact.

The extension of equipment life is more difficult to determine. The cost to perform maintenance must be compared to the benefit gained by avoiding failure; this measure is easier to calculate for the preventive and predictive programs. However, what is the worth of lengthening the life of the equipment by five years? The value of deferring the capital investment must be factored. Money can be invested in other priority purchases or added to the profits for the year. Again, this area is one where the company's financial advisors would need to be closely consulted to see what savings are achieved for the company by increasing equipment life.



Reliability-Centered Maintenance Problems

Most organizations today, outside of the airline and nuclear industry, have no real RCM efforts in place. They may try a small project in one place or another, but they have no real organized or structured approach to RCM. Why is it that most companies are not successful with RCM? The following are eight common problems leading to the lack of success with RCM.

Insufficient Equipment Failure Data

In order for the RCM program to be effective, it needs to have historical data about equipment failure: the types of failures, the frequency of failures, and the root cause of failures. Without this data, the RCM program is based on guesswork. RCM is an applied engineering function. Engineering information is not successfully estimated in other engineering disciplines; it shouldn't be estimated in RCM either.

The reason most people want to try RCM with the equipment failure data is that they are trying to incorporate RCM too early in the improvement process. RCM is an advanced technique that is used only when effective preventive and predictive programs are in place. In this case, a work order system or CMMS is already collecting equipment failure and repair data. Without these tools in place, the RCM program has virtually no probability of success.

Poor Results in the PM and PDM Efforts

The preventive maintenance program has the goal of reducing the reactive maintenance activities to less than 20% of all the maintenance work. The predictive maintenance program has the goal of eliminating all unplanned breakdowns. If these two programs are not producing results, why would any company want to move on to RCM? Probably it is trying the "flavor of the month" or playing the "alphabet soup game". As has been shown in the sections dealing with PM and PDM programs, such programs are successful when they are implemented with a disciplined approach.

If the disciplines are not in place to make the PM and PDM programs successful, how could any company think that it could be successful with an engineering approach to maintenance that requires structure and discipline? In such a case, introducing an RCM program would reflect a lack of understanding of the evolution of maintenance. The company might also lack the organizational discipline to make any improvement initiative successful. Concentrating on the basics and maturing the improvement program in a focused manner will make the RCM program successful.

Poor Training in the RCM Methodology

RCM has a structured and logical approach. It does not allow an individual to jump around and try one piece or another. Focus is required as is a methodology which must be learned if a company is to be successful. There are several approaches to the RCM methodology. Some have flexibility, whereas others are more rigid. Some require a lot of data, others less. Some approaches are more successful in one industry than another. It is up to the company to select the RCM approach that fits its needs. However, once the approach has been decided upon, all of the employees involved in the RCM effort should be trained to a high degree of proficiency in the appropriate RCM techniques.

One of the major factors contributing to a lack of training is a failure to understand the complexity of RCM. If it is thought of as just another "maintenance" thing, then the complexity may be misunderstood. The RCM program may be viewed like one of the many things that maintenance does and the employees can figure it out. But with RCM, this is not the case. The investment in training will be paid for many times over by the RCM effort. Without the training the RCM effort will never achieve maximum benefits for the organization.

Lack of Organizational Buy-In

This problem is related to the previous one. The lack of organizational buy-in or support is created by a lack of understanding of what RCM really is and the benefits that can be achieved from a successful RCM program.

There are two major issues: training and salesmanship. The training focuses on developing the business case for RCM. What are the opportunities? What are the current losses? How much could the losses be reduced? How much will RCM cost? These are questions that must be answered to achieve long-term management support.

Salesmanship involves putting the business case together in such a manner that upper management can understand it clearly enough to support it. When selling management on the concept of RCM, remember that few plant managers or controllers really understand what MTBF and MTTR (Mean Time To Repair) mean. However, if you show a cost-benefit analysis or a return-on-investment case study, then you have their attention. Using terms and tools they understand sells the program.

Insufficient Staffing for the Program

RCM is not a spare time activity, nor is it undertaken instead of other maintenance initiatives. It is an additional task that requires additional funding for tools and personnel. After all, it will produce additional savings. Despite current trends of not adding personnel, if the RCM program is to be successful, then a company will have to staff the program. If not, the individuals performing RCM will take shortcuts and produce less than optimal results. The return on investment that was possible will never be realized.

Most companies would certainly spend $200,000 to make $1 million within a year. They would line up at an investment bank to get that deal. The same deal exists in their plants, yet it isn't even advertised. What the companies must do is change their thinking about staffing levels.

Reactive or Instant RCM Efforts

This problem arises after a company experiences a failure on a piece of equipment and someone reads an article about how RCM solved another company's problem with breakdowns. The person and the company then get hooked on the term reliability, but never understand it. All they know is that it might be the "silver bullet" that will solve the problem. RCM is not a silver bullet. It is however, a valuable tool, especially when coupled with a disciplined maintenance improvement program.

Anyone who thinks RCM is a quick fix or a short-term effort should remember that a full maintenance improvement program takes an organization from reactive to world class maintenance. This journey takes three to five years with no successful shortcuts. It takes this long to learn the discipline and to change organizational patterns.

Short-Term Equipment Focus

This problem occurs when individuals in the organization lack technical insight and do not understand the true life cycle of their equipment

and related components. This lack of understanding leads to perspectives such as "This one lasted longer than the last one. So our V-belts wear out every six months; we think that's pretty good! Those bearings actually lasted two months this time". The real questions should be: What is the design life of these basic components? Are companies really getting the full life out of the components or are they just glad they lasted as long as they did?

For companies to be successful with RCM, they must understand that their equipment can last longer than it currently does before it breaks or wears so much that it must be changed. They need to be concerned with how to make equipment last longer and perform better. Companies willing to use up, wear out, or accept substandard performance from their equipment will not survive in today's competitive environment.

Poor Organizational Discipline

This problem is related to lack of focus. The organization needs to be so focused on its vision, the improvement plan and the implementation methodology needed to achieve its goals, that it can not be distracted. Today a lot of management changes are made as people come and go from an organization. These changes can cause a lack of focus or vision. The relentless management changes in some companies inspired the term bungee manager. With this type of turnover, the organization develops the attitude, " We don't like these changes; let's wait a while and a new manager will replace this one; maybe we will like his or her ideas better".

The organization never develops the discipline to stick to any improvement methodology. Any improvement effort is not in place long enough to become ingrained in the company's culture. Thus, no commitment develops and long-term improvements are never made. Strong, committed leadership is critical to developing a disciplined and focused organization.

Chapter 11
Total Productive Maintenance

This chapter examines one of the most misunderstood and misapplied concepts in modern organizations. Total productive maintenance is not as much a maintenance initiative or improvement program as it is a strategic operational philosophy.

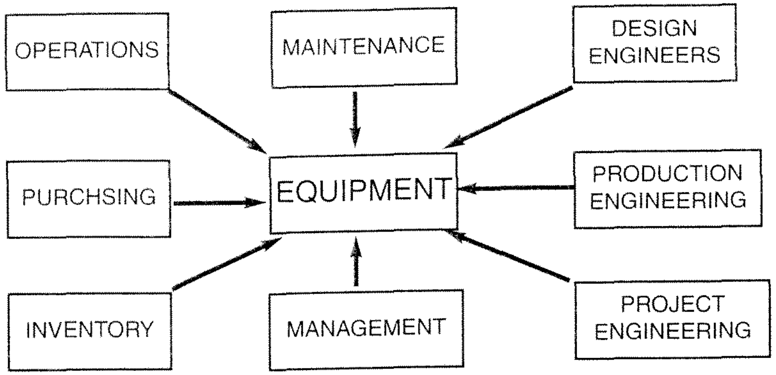
Total productive maintenance (TPM) involves everyone in the organization, from operators to top management, in equipment improvement.

Equipment improvement does not mean just incremental improvements, but also optimum utilization of the equipment. The goal is to eliminate all equipment losses. There are many theories on the exact types of equipment losses, but the basic six to eliminate are:

breakdowns
set-up and adjustment losses
idling and minor stoppage losses
start-up and shutdown losses
reduced speed or capacity losses
quality defects or rework

Eliminating these losses from the equipment operation insures maximum overall equipment efficiency. However, eliminating these losses is beyond the ability of any one department. This is the reason why TPM is an operational philosophy; all departments that in some manner impact the utilization of the equipment are involved and must be part of the TPM program. The figure on the next page illustrates the TPM philosophy.

All departments must focus on how they impact the equipment. The diagram is the same one used to illustrate the Total Quality Management



(TQM) process, with the exception that, instead of focusing on the product, TPM focuses on the equipment. In fact, companies that were successful with the TQM process are usually successful with the TPM process. However, those companies that typically had difficulties with TQM, also have difficulty with TPM.

Currently, one of the biggest problems facing TPM is one that created problems for TQM as well: downsizing. Downsizing undermines employee motivation, which is a critical success factor for TPM implementation and continuance. If there are not sufficient, highly-motivated and highly-skilled employees involved, TPM has little chance of succeeding.

If TPM is an operational philosophy, then what are the goals and objectives for the process? There is really one goal and four supporting initiatives. The goal is to continuously improve equipment effectiveness. The company wants to insure that nowhere in the world does any other company have the same equipment or processes that it has or is able to get more throughput out of its equipment or processes than the company can. Otherwise, the competitor will be the low-cost producer, leaving the company in second place.

A common illustration compares a company's equipment and processes with a NASCAR racing team. In a NASCAR event, all of the cars are basically the same, similar to a company and its competitors having the same equipment. The winner is determined by how the team (pit crew, design engineers, driver, fabrication technicians, etc.) all work together and focus on winning the race. The low-cost producer in competitive markets today is determined by how the organization works

together and focuses on getting more out of the same assets as its competitors. This focus is the philosophy of TPM.

The philosophy is supported by four improvement activities:

1. Improve maintenance efficiency and effectiveness.
2. Focus on early equipment management and maintenance prevention.
3. Train to improve the skills of all personnel involved.
4. Involve the operators in some daily maintenance on their equipment.

Improving maintenance efficiency and effectiveness insures that the maintenance department is as effective and efficient as a NASCAR pit crew. The performance of a pit crew is measured in tenths of a second. Any wasted time during a pit stop, as little as one tenth of a second, can mean the difference between winning and losing. Every tenth of a second crossing the finish line represents two car lengths. Races are won and lost every season by two car lengths. How much time do a company's maintenance crews waste each day? It is enough to make a difference in profit or loss to the bottom line?

Focusing on early equipment management and maintenance prevention means examining equipment for ways to make it more maintainable or to eliminate the maintenance activity completely. New automobiles are the best example of this activity. Compared to the models of the 1970s, the cars need less maintenance (tune-ups), yet performance was not sacrificed. Design changes were made based on engineering studies. The same can apply with production equipment in plants today. Engineering studies can be made to find better materials, methods, and even ways to make maintenance faster to perform.

Training has been mentioned in an earlier chapter. It is critical to train employees for the new tasks that they will be performing. Without training, the tasks will be performed partially or incorrectly. This leads to poor results and may actually create equipment problems. Any time operators are asked to perform new tasks, they must be trained.

Involving the operators in some daily maintenance on their equipment, as mentioned previously, relieves some of the maintenance technicians' time to concentrate on higher-level activities. However, the focus here is also to involve the operators in tasks that make the equipment perform better. Again, the focus on continuously improving equipment effectiveness must never be lost when defining the task for operators.

Since TPM really is an operating philosophy, what are some of its performance measures? The following are some suggested indicators.

1. OEE Tracked on Critical Equipment?

The overall equipment effectiveness (OEE) is the main benchmark for any TPM process. If the real goal of TPM is to continuously improve equipment effectiveness, it only makes sense that the main indicator measures equipment effectiveness. The OEE compares the equipment availability, performance efficiency, and quality rate. The formula is as follows:

$$\text{Availability} = \frac{\text{All Downtime}}{\text{Scheduled Time}} \quad \text{(should be at least 90\%)}$$

$$\text{Performance Efficiency} = \frac{\text{Actual Output for Scheduled Time}}{\text{Design Output for Scheduled Time}} \quad \text{(should be at least 95\%)}$$

$$\text{Quality Rate} = \frac{\text{Total Production minus Defects or Rework}}{\text{Total Production}} \quad \text{(should be at least 99\%)}$$

Goal for Overall Equipment Effectiveness: 90% x 95% x 99% = 85%

The first three formulas represent the goals for the individual components of the OEE. The goal for the OEE itself, which is found by multiplying the three percentages together, is 85%. There are many factors that go beyond the scope of this presentation. This indicator is so flexible that it can be used for daily, weekly, and even monthly time periods for its calculation.

Strengths

This indicator is necessary for any company beginning a TPM initiative.

Weaknesses

The indicator has no weaknesses, except for misuse. The calculation was originally intended for the operators and maintenance personnel to use to track their progress improving the equipment. To be effective this indicator must focus on equipment, not the plant, department, or area. Other uses are to often drawn up by consultants wanting to build a new market for themselves.

2. Early Equipment Management & Maintenance Prevention

This indicator examines the percentage of critical equipment that has been or is currently being studied for opportunities to make design improvements. These improvements might reduce the maintenance requirements or reduce the time needed to perform maintenance on the equipment.

$$\frac{\text{Critical Equipment Items Covered by Design Studies}^{*}}{\text{Total Number of Critical Equipment Items}}$$

This indicator is derived by taking the number of critical equipment items covered by the design improvement studies and dividing by the total number of critical equipment items. The goal is 100%. When all other activities have been optimized on the equipment, the design studies can highlight even further opportunities for improvement.

Strengths

This indicator is essential for any company striving to insure maximum equipment effectiveness. All things being equal, changing the design to increase throughput may make the final competitive difference.

Weaknesses

There is no major weakness to this indicator.

3. 5 S's Practiced on Critical Equipment

This indicator examines the percentage of critical equipment that has been or is currently included in the 5 S program. These activities focus on cleaning and organizing the workplace. They uncover ways to make the workplace more efficient or uncover problems with equipment, since clean equipment is easier to inspect.

$$\frac{\text{Critical Equipment Items Covered by 5 S Activites}^{*}}{\text{Total Number of Critical Equipment Items}}$$

This indicator is derived by taking the number of critical equipment items covered by the 5 S activities and dividing by the total number of critical equipment items. The goal is 100%. These activities can highlight basic opportunities for improvement. They should never be overlooked, since they are usually low cost and can produce some good cost benefits.

Strengths

This indicator is essential for any company striving to insure good employee involvement. The activities are basic in nature, but give everyone a chance to be involved. The indicator insures that no equipment is missed or no operators are left out of the activities.

Weaknesses

The major weakness of this indicator is that it may cause some to focus too much on just cleaning and organizing. This is a trap that some companies have been led into by those who think cleaning is all the improvement their equipment requires. It certainly is a good place to start, but not to stop.

4. Savings Attributed to TPM Efforts

This indicator is calculated by quantifying the increase in overall equipment effectiveness. For example, if the OEE increases from 45% to 55%, how much additional product is made or processed? Maybe it is 5,000 more plastic cases at a value of $10 each. This represents $50,000 worth of additional product. Does the market exist to sell the additional items or are sales tied to a fixed contract? Such issues impact the true value to the company of the increased production. Perhaps the only benefit is that the product is produced at a lower cost due to the increased efficiency. However, maybe the market demand does exist for the product and every additional part that is made can be sold. In either case, the study needs to be made and the savings needs to be calculated. The two major areas to examine are increased capacity and increased quality.

While the OEE is the real indicator, the results need to be converted to dollars. Then on a weekly or, at most, a monthly basis, the improvement results need to be reviewed (in dollars) and posted at the equipment where the employees can see the results of their efforts. This form of recognition motivates and stimulates individuals to look for even more improvement opportunities.

5. Decreasing Cost of Production (Manufacturing) per Unit

This indicator is closely tied to the previous one. Instead of being able to sell the additional capacity that is generated from the TPM effort, some companies focus on lowering the cost to produce. This approach is generally used by companies with fixed markets. In such cases, the profit margin is still impacted positively since the cost to produce is an expense. The expense avoidance, or cost reduction, is converted to profit on a dollar-for-dollar basis.

Tracking the cost to produce on a weekly basis and reviewing it over rolling twelve-month window can provide some interesting stimulation for managers interested in improving the company's profits.

6. Absenteeism

Absenteeism is a good indicator of employee morale. If a work force is highly motivated, they are more participative and productive. If they are not motivated, but almost adversarial, they tend not to be as productive. High absenteeism tends to indicate lower morale. Low absenteeism tends to indicate higher morale. The indicators are total hours absent and total hours scheduled.

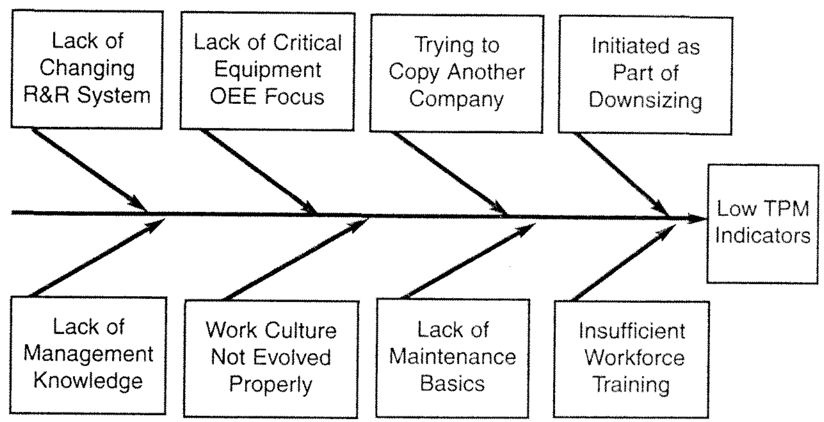
This indicator is derived by dividing the total hours absent by the total hours scheduled.

Strengths

This indicator is good for any company to monitor, not just for morale but also for organizational efficiency.

Weaknesses

There are factors that lead to absenteeism other than low morale. These factors could impact the indicator and lead to false conclusions.



Problems with TPM

Most organizations today have partial or unfocused TPM efforts. They may have operational involvement, but lack the OEE focus. Conversely, they may track OEE, but don't perform root cause analysis to solve equipment problems permanently. The follow eight common problems underlie the lack of success with TPM.

Initiated as Part of a Downsizing Effort

Some organizations view TPM as a way to get operators involved in maintenance so that in time some of the maintenance personnel can be furloughed. This approach to TPM creates distrust among the workforce; the motivation that is required to make TPM successful is never generated. After all, how many people want to suggest themselves out of a job?

This problem is overcome only when the organization has the correct understanding that TPM is not a downsizing initiative. The focus of TPM is continual improvement of the equipment. If workforce reduction is the goal of the company, it should not try to start TPM; it will fail.

Insufficient Workforce Training

TPM requires the maintenance and operations personnel to come up with ideas of how to improve their equipment. In many cases, the equipment is increasingly technical. Since the equipment technology is increasing in complexity, the knowledge and skills of the individuals involved in TPM have to increase as well. Unless the proper training is required for those involved, few, if any, benefits will result.

Trying to Copy Another Company

TPM is not a "copycat" program. It is not implemented the same way in each company since there are variables that make each company unique. Some of these variables include skill levels of the employees, type of equipment or processes, type of operation (continuous or batch), operator-to-machine ratio, and work culture.

If the companies have differences and the TPM effort is copied, then TPM won't fit. It is only when a company examines its own equipment and decides what it needs to do for itself to make it more effective that TPM is truly successful.

Lack of Maintenance Basics

TPM is built around doing the basics right. In fact, studies have shown that almost one-half of all equipment breakdowns in a plant are related to the basics of maintenance, such as cleaning, inspecting, lubricating, and proper fastening procedures. If the basics are neglected, then the results are never realized, since the TPM process is built on a flawed foundation.

Lack of a Critical Equipment OEE Focus

This problem illustrates the expression "a mile wide, but only an inch deep". Sometimes the resources in the plant involved in TPM are spread too thin, trying to do too much. When this happens, the results are small and have no major impact on plant or equipment throughput. Without the hard, tangible results, the TPM effort loses momentum and ultimately fails.

The focus of the TPM program, particularly during the early stages, must be on the critical, bottleneck, or constraint equipment. Unless this is the case, the results are not noticeable and the TPM initiative never produces quantifiable results. Without results, the TPM resources are deployed in other company initiatives that are producing results.

Work Culture Not Evolved Properly

Work culture is an issue in some plants that may have had adversarial workforce-management relations in the past. It takes time and effort on the part of both sides to rebuild the trust and mutual understanding that is necessary for TPM to be successful. If either the workforce or management feel that the other has a hidden agenda in implementing TPM, then the mutual trust and cooperation will not develop.

Only by developing a common focus on improving equipment effectiveness and to be the best will the proper work culture and cooperation ever develop.

Lack of Changing the Rewards and Recognition Systems

If the company does not change the reward and recognition system to reflect the new focus that TPM provides, then the new behavior is not reinforced. Without the old behaviors in the plant changed, it is only a matter of time until everyone goes back to the old way of doing things.

If having operators involved in some daily maintenance on their equipment is valued, then the company must find a way to reward it. If having maintenance technicians conduct more predictive and reliability analysis on the plant equipment is valued, then the company must find a way to reward it. Most companies have always rewarded its heroes, in this case, those individuals who can quickly fix the equipment or those who can make it run (even if at less than design speed) until the end of the shift. If this behavior is rewarded, then this behavior is what the company will receive. However, if proactive and reliability work is what is valued, then the reward and recognition system must also be changed to reflect these priorities.

Lack of Management Knowledge of TPM

This problem is created when management does not know what TPM really is, what resources are involved, and what changes are necessary to implement it in a plant or facility. In some companies, management takes the "fairy godmother" approach to implementing TPM. It comes into a room, waves its magic wand over the group, blesses the TPM initiative, and then leaves the room, believing that this is all it needs to do to make the TPM effort successful.

The way to overcome this problem is training and education about what TPM is and what it isn't. This training is best done with mixed groups of upper, middle, and first-line management together and trained in TPM with the hourly workforce. This approach insures that everyone in the organization hears the same message, understands the issues, asks questions, and gets the answers in front of coworkers. Thus, any miscommunication and misunderstanding of the TPM concepts are prevented.

Chapter 12
Statistical Financial Optimization

This chapter covers a hybrid technique that blends statistical techniques with financial methodologies, allowing the most cost-effective solutions to be derived for a company's asset management policies. The concepts are based on quantifying maintainability and reliability calculations in financial terms. Some of the areas in which this technique can be applied include:

Setting preventive maintenance inspection schedules
Age replacement policies
Preventive maintenance block replacement policies
Capital equipment replacement policies
Equipment overhaul policies
Critical spares stocking levels
Routine spares stocking levels

The first five of these are related to maintenance policies and schedules. Even a company that has followed the stops of maintenance improvement is still making its decisions intuitively, supplemented by RCM data. However, the decisions are probably not being made based on the financial impact they have on the total company. The RCM process has not considered this aspect of reliability principles. For instance, the MTBF (Mean Time Between Failure) may be known from an RCM analysis, but the following questions are not addressed by RCM:

What is the cost to prevent the failure?
(preventive maintenance labor and materials)
What is the cost when equipment fails?
(repair costs and lost production costs)

What is the correct number of spare parts to keep in stock to insure availability when required?
(holding costs, storage costs, and stores labor costs, compared to the downtime costs for the stock out)

For routine spare parts, what is the reorder point?
(holding costs, storage costs, stores labor costs, and discounted prices for quantity orders, compared to the downtime costs for the stock out)

In these areas the RCM tools fall short. These areas also highlight why statistical financial optimization is implemented after TPM. The optimization takes data from all parts of the organization (RCM from maintenance and engineering, stores costs from inventory and procurement, downtime costs from operations, and overhead and labor costs from accounting). Unless the organization has progressed through the levels described in the decision tree, it is not likely to have the maturity and focus needed to utilize the optimization techniques.

It is beyond the scope of this text to detail the various formulas utilized in the statistical optimization process; however for reference purposes, they are found in most maintainability, reliability, and operational engineering textbooks.

There are also engineering software packages that perform the mathematical calculations for statistical financial optimization.

Some of the indicators used to evaluate the effectiveness of the statistical financial optimization process follow.

1. Statistical Financial Optimization Implemented on Critical Equipment Maintenance Tasks

This indicator examines the number of critical equipment maintenance tasks that are audited for financial effectiveness each year. It compares this number to the total number of critical equipment maintenance tasks, indicating the level of tasks that are actually being financially optimized each year. It is important to review these decisions annually since cost data, such as downtime (due to market changes), can vary periodically. In addition, parts costs increase, lead times change, and so forth. Annual analysis insures financial optimization.

$$\frac{\text{Number of Critical Equipment Maintenance Tasks Audited}}{\text{Total Number of Critical Equipment Maintenance Tasks}}$$

This indicator can be derived by dividing the total number of critical equipment maintenance tasks audited by the total number of critical equipment maintenance tasks. The result should be expressed as a percentage. This can be calculated annually and reviewed over a multiyear period.

Strengths

The indicator is useful for insuring that the statistical financial optimization program is closely monitored.

Weaknesses

The only major weakness is the availability of accurate data. The most serious mistake would be to guess any of these numbers. If the data is not available, it is best to consider an alternative technique.

2. Statistical Financial Optimization Implemented on Critical Equipment Major Spares Stocking Policies

This indicator examines the number of critical equipment major spare parts that are audited for financial effectiveness each year. It compares this number to the total number of critical equipment spare parts, indicating the level of parts that are actually being financially optimized each year. It is important to review these decisions annually since cost data, such as downtime (due to market changes), can vary periodically. In addition, parts costs increase, lead times change, and so forth. Annual analysis insures financial optimization.

$$\frac{\text{Number of Critical Equipment Major Spare Parts Audited}}{\text{Total Number of Critical Equipment Major Spare Parts}}$$

This indicator can be derived by dividing the total number of critical equipment maintenance major spare parts audited by the total number of critical equipment maintenance major spare parts. The result should be expressed as a percentage. This can be calculated annually and reviewed over a multiyear period.

Strengths

The indicator is useful for insuring that the statistical financial optimization program is closely monitored.

Weaknesses

The only major weakness is the availability of accurate data. The most serious mistake would be to guess any of these numbers. If the data is not available, it is best to consider an alternative technique.

3. Statistical Financial Optimization Implemented on Critical Equipment Routine Spare Parts Stocking Policies

This indicator examines the number of critical equipment routine spare parts policies that are audited for financial effectiveness each year. It compares the number of critical equipment routine spare parts audited to the total number of critical equipment routine spare parts, indicating the percentage of critical equipment routine spare parts that are actually being financially optimized each year. It is important to review these decisions annually since cost data such as downtime (due to market changes) can vary periodically. In addition parts costs increase, lead times change, and so forth. Annual analysis insures financial optimization.

$$\frac{\text{Number of Critical Equipment Routine Spare Parts Policies Audited}^{*}}{\text{Total Number of Critical Equipment Routine Spare Parts}}$$

This indicator can be derived by dividing the total number of critical equipment routine spare parts policies audited by the total number of critical equipment routine spare parts. The result should be expressed as a percentage. This can be calculated annually and monitored over a multiyear period.

Strengths

The indicator is useful for insuring that the statistical financial optimization program is closely monitored.

Weaknesses

The only major weakness is the availability of accurate data. The most serious mistake would be to guess any of these numbers. If the data is not available, it is best to consider an alternative technique.

4. Statistical Financial Optimization Savings Generated Through Changes in Equipment Management Policies

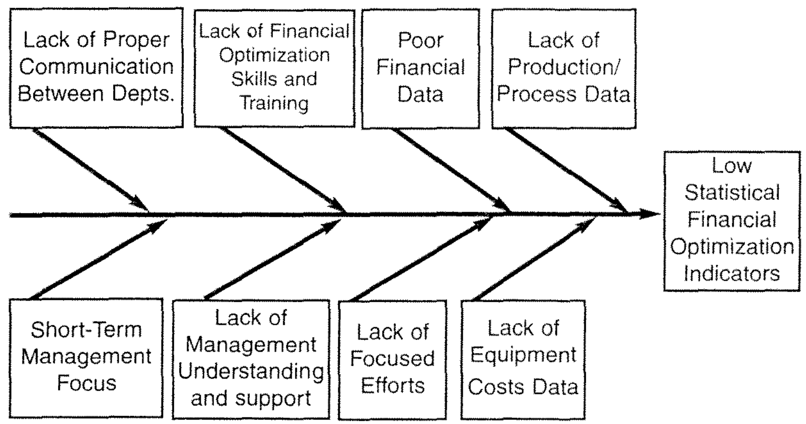
This indicator calculates the total savings from all statistical financial optimization studies. These savings will help an organization focus on continuously improving its equipment management policies since the financial rewards are always highlighted. The indicator has no real formula; it is merely totaling all of the statistical financial optimization studies conducted throughout the company. The results should be calculated annually and reviewed over a multiyear period.

Strengths

The indicator is useful for insuring that the cost benefits of statistical financial optimization program are closely monitored.

Weaknesses

The only major weakness is the difficulty of collecting all of the data when multiple groups are performing the analysis.



Problems with Statistical Financial Optimization

The techniques of statistical financial optimization are valuable, yet they are not utilized by many organizations. The following problems are the most common reasons.

Lack of Production and Process Data

In many companies today, the production and process data is not kept in enough detail. Even companies with extensive distributed process control systems in place find that flow rates, operating speeds, and operating efficiencies are not closely monitored and reviewed over time. For instance, the actual sensors on the equipment might not be working or even be electrically connected. In this case, the accurate data required to study the impact of falling flows and pressures on process is not available.

If the problem of falling efficiencies over time compared to the cost of lost throughput was financially optimized, then the data would be invalid. Any decision to repair, replace, or overhaul would be invalid. The production data play a critical role in most calculations. Without it, there is little chance of accurate results. The only solution is to dedicate the resources to accurately monitor and record the production or process data.

Lack of Equipment Costs Data

This data is the information typically found in the equipment history. It contains the labor, material, and other costs associated with the maintenance of the equipment. If this data is not accurate, it indicates a problem with the data collection discipline in the organization. Furthermore, the analysis using the data will also be inaccurate. The only solution to the lack of equipment data is to go back and enforce the basics of data collection. The disciplines must be developed and enforced.

Poor Financial Data

The finance and accounting departments typically keep the relevant financial data. This information includes the original purchase price of the equipment, the current value of the equipment, the replacement value of the equipment, and, possibly, the cost of downtime or lost production. If this data is inaccurate or unavailable, then financial optimization cannot be performed.

Another problem in organizations that have not matured to world class levels is the lack of sharing data between departments. In companies where the value of data has not yet been understood by all departments, there are financial departments that refuse to provide downtime costs or to fairly calculate the cost of lost production. In these companies, the educational process needs to be developed to insure a clear understanding of the costs involved in equipment failures or inefficiencies.

If a company is at a level of maturity that it is utilizing statistical financial optimization, then the issue of not sharing data should never be a problem. If, however, sharing data is a problem, then the company is not ready to use the optimization tools.

Lack of Focused Efforts

This problem arises with a company just starting the statistical financial optimization program. The individuals performing the analysis might persue simply what they perceive as the largest opportunity. This lack of discipline dilutes the resources and produces fragmented results. It also creates problems, since the total analysis skills have not been developed. As the analysts work on problems, they make errors because they are not communicating with each other. The mistakes go undetected and the savings from the analysis are less than optimum.

The solution is for the individuals to stay focused and work as a team until both the analysts' skills and a complete plan for the analysis are fully developed.

Lack of Financial Optimization Skills and Training

Proper training in maintainability, reliability, and financial concepts must be provided to for anyone doing any of the statistical financial optimization analysis. If the skills are not properly developed, mistakes will be made. These mistakes will cost the company substantial amounts since operational policies are being changed based on the erroneous analysis.

Lack of Management Understanding and Support

This problem is related to the previous one in that education is critical. This does not mean that upper management will need to go through the detailed technical training, although they could if they want to invest the time. However, they do need training to the level that they understand the costs of statistical financial optimization and the benefits that will be achieved by properly using the tools. Without this training, the support required to change policies is never developed and the program fails due to the lack of support.

Lack of Proper Communication Between Departments

A communication problem should not exist if an organization is at the level of maturity that it is considering statistical financial optimization. In the chapter on Total Productive Maintenance, the diagram showing the focus on the equipment highlighted the need for each department to communicate with the others to maximize the equipment effectiveness.

Short-Term Management Focus

This problem of focus is actually created by our financial systems, starting with Wall Street. Investors expect quarter-to-quarter earnings increases. However, some equipment improvement programs require an initial investment that is not paid back for six to twelve months. If a company does not have the resources to invest in the improvement program, then the profits suffer and the stock value drops. On the other hand, if the investment is not made, the company starts a long-term downward spiral, since the technical decisions and improvements cannot be made.

There is no short-term easy solution to this problem. The only real solution is to be able to convince the stockholders that the improvement initiative is an investment. Like any other investment, it has a payback period. If this can be clearly communicated to the stockholders, then the problem may diminish. If so, then the next real challenge will be to insure the payback.

Chapter 13
Continuous Improvement

PERFORMANCE INDICATORS AND BENCHMARKING

Continuous improvement is the process of never accepting the status quo of an organization. It is the ongoing challenge to look for incremental improvement that can be made to increase the company's competitiveness. Continuous improvement is focused on improving the company's internal capabilities and capacities. These activities take place in a dynamic, ever-changing business environment. Any continuous improvement activity should be considered in light of what impact it will have on the customer and how it helps to differentiate the company from its competitors.

One of the most effective continuous improvement tools for maintenance is benchmarking. In short, benchmarking is the ongoing process of a company comparing itself with another company anywhere in the world that is considered the best and then taking knowledge gained to continually improve. Once an improvement is made, the process starts over again.

LESSONS LEARNED FROM BENCHMARKING

1. Identifying performance indicators for each functional process is essential for any benchmarking. This is the key to under standing the relationship between benchmarking and performance indicators. Benchmarking projects cannot be quantified unless the performance is measured and the improvements are tracked.
2. It is difficult to find hard measures for soft areas. Utilizing tools such as process mapping and maturity grids requires considerable effort. If something can't be measured, it can't be man-

aged. Soft areas are difficult to quantitatively measure, there fore, improvements are difficult to track.

3. All information needs to be evaluated for applicability to each organization. Adaptation is a critical skill. No two organizations are exactly alike. Workers must be able to take what they learn during benchmarking,then adapt and apply it to their their organization.
4. Benchmarking is a systematic and continuous process that, once started, never stops. This is why it is part of continuous improvement.

Benchmarking Steps

1. Understanding your organization. The self analysis can use performance indicators as a starting measurement.
2. Identifying partners. Who does it the best? A company's performance indicators should be compared to a competitor's performance indicators.
3. Analyzing differences. Apples to apples: an in-depth comparison with a competitor's indicators is made by actually looking at the calculations and where the numbers come from.
4. Developing and implementing improvements. The implementation plan is developed by adapting and applying the information to the organization in order to make improvements.
5. Evaluating and quantifying results. The improvements are measured by monitoring the change in the performance indica tor. The functional and financial impact will be seen in the com pany's profits.
6. Starting over. Continuous improvement calls for finding the next area for improvement and starting the process over again.

This flow for a benchmarking project highlights the relationship between performance indicators and the benchmarking comparison process. The performance indicators highlight the process or those parts that need improvement. They can be remotely compared to others to identify which one is the best in the process (or part) that needs improvement. The starting performance indicator can then be used to quantify the improvements as they are made.

The performance indicators are the key to the continuous improvement process. All of the material in this book builds to this point.

If performance indicators are to be used for continuous improvement, what are some of the indicators which show that improvements are being made by the organization? The performance indicator used to track the process would be the primary indicator.

The following indicators should be used as general indicators to show the organizational attitude toward continuous improvement.

1. Savings Realized from Improvements Implemented by Employee Suggestions

This indicator examines the savings realized by employee suggestions. It is vital to companies wanting to gauge the effectiveness of their employee involvement activities. As with other aspects of improvement, a financial return on the investment in the program should be able to be shown. If not, then it will be necessary to investigate how to improve the suggestion program to make it more effective.

There is no direct formula for calculating this indicator. It is simply the total cost savings that have been achieved due to employee suggestions that have been implemented.

Strengths

The indicator is useful for tracking the benefits realized by employee suggestions and involvement. It is also beneficial for helping to motivate employees; they can clearly see their successes and contributions.

Weaknesses

The only major weakness to this indicator is collecting the data so that the benefits of employee involvement can be clearly seen.

2. Savings Realized from Improvements Implemented Benchmarking Activities

This indicator examines the savings realized by implementing improvements identified during benchmarking activities. The indicator is vital to companies wanting to monitor the effectiveness of their benchmarking activities. A financial return on the investment in benchmarking should be shown. If not, then it will be necessary to find the problem. Benchmarking projects should produce results.

There is no direct formula for calculating this indicator. It is simply the total cost savings that have been achieved due to the benchmarking efforts. It may be that the improvement in the benchmarked performance indicator can be used to track the benefits.

Strengths

The indicator is useful for tracking the benefits realized by benchmarking projects. It can help foster support in the company for benchmarking projects when they are properly quantified.

Weaknesses

There are no major weaknesses to using this indicator. The benefits should have been quantified as part of the benchmarking project; thus, data collection should not be a problem.

3. Critical Equipment Involved in the Continuous Improvement Effort

This indicator examines the percentage of critical equipment items that have been impacted as part of continuous improvement process. It compares the number of affected critical equipment items to the total number of critical equipment items. This percentage indicates the level of continuous improvement efforts that are focused on critical equipment. It is important to review the focus of the continuous improvement program annually to insure the maximum benefits from the efforts.

$$\frac{\text{Number of Critical Equipment Items with Continuous Improvement Activities}^{*}}{\text{Total Number of Critical Equipment Items}}$$

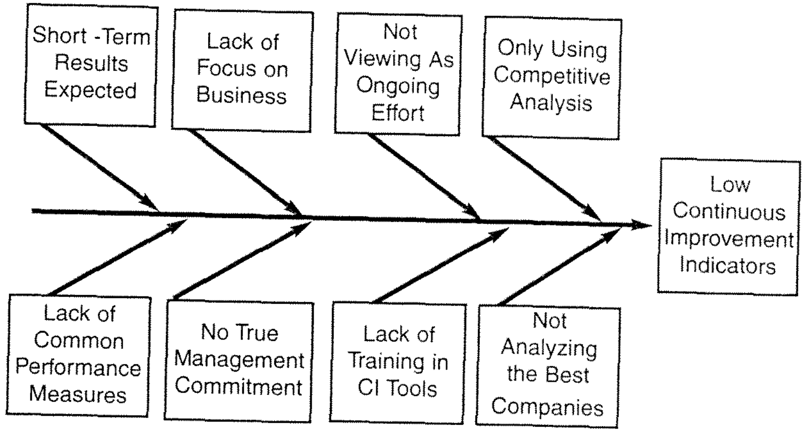
This indicator can be derived by taking the total number of critical equipment maintenance items on which continuous improvement (CI) activities were performed and dividing by the total number of critical equipment items. The result should be expressed as a percentage. This indicator can be calculated annually and analyzed over a multiyear period.

Strengths

The indicator is useful for insuring the monitoring of the continuous improvement program.

Weaknesses

The only major weakness is quantifying the benefits. The tracking, which may need to be supported with the cost-benefit results, may be more difficult to obtain.



Problems for Continuous Improvement Activities

The following problems are common to continuous improvement efforts. While the majority focus on problems with benchmarking programs, most have application to all forms of continuous improvement.

Only Using Competitive Analysis

This problem occurs when a continuous improvement effort focuses on doing only what competitors are doing. Some companies want to benchmark only with their competitors. In reality, major improvement often comes when a company goes outside its industry, finds a best practice, and then is the first to adapt it to its industry. If companies only chase their competitors, there will only be incremental improvements.

In continuous improvement, companies must look beyond their competitors.

Not Analyzing the Best Companies

In some continuous improvement efforts, and especially benchmarking, some companies pick up the local telephone book to find some company to visit and observe. This approach is not effective, especially in benchmarking. How would a company know if the other company was good, average, or bad? What would it hope to learn from them? When starting a continuous improvement program, especially benchmarking, a company must always focus on others with the best practice, not simply those companies that are conveniently located.

Not Viewing as an Ongoing Effort

Some companies talk about having done benchmarking. When asked about the results, they point to a three-ring binder on the bookshelf as the result of the study. They have the data, but they never did anything with it. The benchmarking effort failed because the effort was viewed as a one-time information gathering activity. The way to overcome this problem is to start with education on what benchmarking is and what improvements are going to result from the effort.

Lack of Training in the Continuous Improvement Tools

There are numerous continuous improvement tracking and monitoring tools available. They include:

- affinity diagrams,
- matrix diagrams,
- force-field diagrams,
- cause and effect diagrams,
- tree diagrams,
- process flow charts,
- scatter diagrams, and
- histograms.

No one may use all of these types of diagrams, but the list highlights how many continuous improvement tools are available. For continuous improvement projects to be successful, the right tools must be used at the right time. Proper training is the answer to this problem.

Lack of Focus on the Business

This problems occurs when a continuous improvement effort is not connected to the business. There is no clearly defined business reason for the project. This leads the project team into activities that are interesting, but not necessary. Examples are painting the worker's lunch area, relandscaping the front of the building, or rearranging offices. While these may improve morale, they are not focused on the business. Surveys have shown that seven out of ten teams fail to produce the results the team was formed to produce. The main reasons were lack of focus on the business and lack of proper training. Having a business focus in the continuous improvement process is important to the success of continuous improvement.

No True Management Commitment

This problem occurs when continuous improvement activities are part of a program-of-the-month type of management. The program may be the latest thing someone read about in a magazine or book and, as a result, the company is going to get into some type of continuous improvement or benchmarking program. As soon as the cost of a project is truly understood, managers look for some cheaper way to do the project or they start looking for another project.

The solution here is to research and educate before starting any new improvement initiatives. This insures that everyone has a clear understanding of the level of effort and cost before any new project is undertaken.

Short-Term Results Expected

This problem occurs when proper education about what continuous improvement and benchmarking really mean is not completed before starting the project. Without a clear understanding that continuous improvement is a long-term project, with some, but limited short-term benefits, management applies pressure to see immediate results. The improvement teams take shortcuts; in doing so, they reduce or eliminate the benefits that they should have achieved.

Lack of Common Performance Measures

This problem occurs in benchmarking, typically when someone wants to benchmark after reading an article or report with a benchmark number in it. The person pushes the organization to try and achieve that number. The problem is that the organization may be in a different business, have different operating conditions, or even a dissimilar workforce. Unless time is taken to make a fair evaluation, the benchmark is useless and the organization will suffer trying to achieve it. Education and training are necessary if this problem is to be avoided.

Chapter 14
Developing Performance Indicators For Maintenance Management

Having looked closely at the maintenance function and its various functional components, as well as the related functional performance indicators, it will be beneficial to review the performance indicator pyramid presented in the introduction. The correct way to develop performance indicators is to work from the top or corporate level and then develop indicators at each subsequent level to allow the indicators to be connected. If the indicators are selected at the bottom and then built upward, they may be conflicting rather than supportive.

CORPORATE INDICATORS

These indicators are the long-term strategic indicators that upper management utilizes for business planning. The window of planning is typically for the three-to-five year strategic plan.

Total Cost to Produce (Manufacture)

This indicator compiles all the costs needed to produce a product. It is used to calculate the profit margin: the difference between this cost and the sales revenue is profit. This cost is further analyzed by the financial indicators.

Total Cost of Occupancy

This is a facility measure; it compiles all the costs needed to occupy a facility. This cost includes the maintenance function and is further analyzed the financial indicators.

Return on Net Assets

This indicator compares the profit earned to the net value of the company assets. The impact that maintenance has on profits is a major factor in calculating the return. This will be highlighted by the financial indicators.

Return on Fixed Assets

This indicator compares the profit earned to the net value of the fixed company assets. The impact that maintenance has on profits is a major factor in calculating the return. This will be highlighted by the financial indicators.

FINANCIAL INDICATORS

These indicators are used to insure that the departments in a company are meeting the financial goals set in the strategic plan. The indicators are monitored annually. If the annual figures are not in compliance with the forecast, then the analysis would start at the next level in the hierarchy. No organization will use all of these following indicators (which monitor the maintenance department), but will choose the ones that support the selected corporate indicators.

Maintenance Cost per Unit Processed, Produced, or Manufactured

This indicator is a common measure of maintenance performance, although not necessarily one of the best. It divides maintenance costs by the volume of production. Production volumes vary for reasons not under the control of the maintenance department. If the maintenance department is held accountable for this indicator, then poor decisions will be made that will impact the maintenance strategies. The organization could be upsized or downsized due to the fluctuations of the indicator. This indicator is good for broad analysis over time, but it should never be used as a sole performance indicator.

Maintenance Costs per Total Process, Production, or Manufacturing Costs

This indicator compares maintenance costs to the total costs of manufacturing, not the per unit manufacturing costs. Maintenance will generally be a fixed percentage of the cost. The actual percentage of this cost can be reviewed over time. If it increases, then the efficiency and effectiveness indicators should show which maintenance area caused the increase.

Maintenance Costs per Sales Dollar

This indicator is also an accurate measure since maintenance is generally a fixed percentage. The indicator is easy to review over time. If the percentage of maintenance costs increases, then the efficiency and effectiveness indicators should show which maintenance area casued the increase.

Maintenance Cost per Square Foot Maintained

This indicator is also an accurate measure for facilities; the cost is usually fixed. The indicator is easy to review over time. If the percentage of maintenance costs increase, then the efficiency and effectiveness indicators should show which maintenance area caused the increase.

Maintenance Cost per Estimated Replacement Value of the Plant or Facility Assets

This indicator is becoming a standard one. It is an accurate measure for plants and facilities since the cost is usually fixed. This indicator is easy to review over time. If the percentage of maintenance costs increases, then the efficiency and effectiveness indicators should show which maintenance area caused the increase.

Stores Investment per Estimated Replacement Value

This indicator is also becoming standard for the measure of stores investment. The indicator is easy to review over time. If the percentage of stores costs increases, then the efficiency and effectiveness indicators should show what maintenance or stores function caused the increase.

Value of Asset Maintained per Maintenance Employee

This indicator is another measure for plants and facilities since the asset cost is usually fixed. This indicator is easy to review over time. If the value of the asset maintained shows a decrease, then the efficiency and effectiveness indicators should show which maintenance area caused the decrease.

Contractor Costs per Total Maintenance Costs

This indicator is useful for monitoring contractor costs as a percentage of total maintenance costs. If the costs remain stable, then the contractor usage is stable. If an increase or decrease is indicated, then the efficiency and effectiveness indicators should highlight the reason for the change.

EFFICIENCY AND EFFECTIVENESS PERFORMANCE INDICATORS

Effectiveness emphasizes how well a department or function meets its goals or company needs. Effectiveness is often discussed in terms of the quality of the service provided, viewed from the customer's perspective. In the case of maintenance, effectiveness can represent the overall company satisfaction with the capacity and condition of its assets.

Efficiency is acting or producing with a minimum of waste, expense, or unnecessary effort. Efficiency compares the quantity of service provided to the resources expended: is the service provided at a reasonable cost? Efficiency measures concentrate on how well a task is being performed, not whether the task itself is correct. Effectiveness concentrates on the correctness of the process and whether the process produces the required result.

A common problem in efficiency and effectiveness performance measurement is the reporting of process or input measures (e.g., workload) instead of output measures. Indicators such as maintenance personnel per dollar of asset value, maintenance personnel as a percentage of total plant personnel, and number of work orders completed, may be useful in understanding how busy a maintenance department is, but they do not measure results. This data is easily gathered and, without clear definitions or communication, are often reported as performance measures for organization efficiency and effectiveness.

These indicators should examine the efficiency and effectiveness of the tactical functions within maintenance. They can then insure that the tactical performance indicators stay in line to support the annual financial performance indicators.

The following is a list of the efficiency and effectiveness indicators from the previous chapters of the book. These indicators all highlight an

impact on the efficiency and effectiveness of maintenance. No organization will use all of these indicators, but will choose the ones that support the selected financial indicators. All indicators are expressed as a percentage, unless noted otherwise.

Preventive Maintenance

$$\frac{\text{Downtime Caused By Breakdowns}^{*}}{\text{Total Downtime}}$$

$$\frac{\text{Manhours Spent on Emergency Jobs}^{*}}{\text{Total Manhours Worked}}$$

$$\frac{\text{Direct Cost of Breakdown Repairs}^{*}}{\text{Total Direct Cost of Maintenance}}$$

$$\frac{\text{Desired Equipment Uptime-Downtime}^{*}}{\text{Desired Equipment Uptime}}$$

$$\frac{\text{Hours Worked as Overtime}^{*}}{\text{Total Hours Worked}}$$

$$\frac{\text{Maintenance Work Orders Awaiting Parts}^{*}}{\text{Total Number of Maintenance Work Orders}}$$

Work Order Systems

$$\frac{\text{Emergency Orders}}{\text{Total Work Orders}} \qquad \frac{\text{Preventive Orders}}{\text{Total Work Orders}} \qquad \frac{\text{Corrective Orders}}{\text{Total Work Orders}}$$

Technical and Interpersonal Training

$$\frac{\text{Total Downtime Attributed to Operational Errors}}{\text{Total Downtime}}$$

$$\frac{\text{Total Downtime Attributed to Maintenance Errors}}{\text{Total Downtime}}$$

$$\frac{\text{Estimated Lost Time Due to Lack of Knowledge or Skills}}{\text{Total Time Worked}}$$

Maintenance Rework Due to Lack of Knowledge or Skills / Total Maintenance Work

Operational Involvement

Maintenance-Related Equipment Downtime (current period) / Maintenance-Related Equipment Downtime (previous year same period)

Actual Equipment Throughput (current year) / Actual Equipment Throughput (previous year same period)

Predictive Maintenance

Current Maintenance Costs / Maintenance Costs Prior to Predictive Program

Reliability-Centered Maintenance

Equipment Uptime
Equipment Capacity
Maintenance Labor

OSHA Citations: Notices Per Inspection (Current Year)
OSHA Citations: Notices Per Inspection (Previous Year)

EPA Citations: Notices Per Inspection (Current Year)
EPA Citations: Notices Per Inspection (Previous Year)

ISO-9000: Notices of Nonconformance Per Inspection (Current Year)
ISO-9000: Notices of Nonconformance Per Inspection (Previous Year)

Total Productive Maintenance: Overall Equipment Effectiveness

$$\text{Availability} = \frac{\text{All Downtime}}{\text{Scheduled Time}}$$ (should be at least 90%)

$$\text{Performance Efficiency} = \frac{\text{Actual Output for Scheduled Time}}{\text{Design Output for Scheduled Time}}$$ (should be at least 95%)

$$\text{Quality Rate} = \frac{\text{Total Production minus Defects or Rework}}{\text{Total Production}}$$ (should be at least 99%)

Goal for Overall Equipment Effectivess: 90% x 95% x 99% = 85%

TACTICAL PERFORMANCE INDICATORS

The tactical performance indicators monitor the function indicators in a longer-term window of a quarterly or ninety day timeframe. This window allows time for trends to develop. Monitoring the tactical indicators identifies required changes highlighted by the functional indicators working their way up the pyramid. Changes can then be made to the maintenance processes before the efficiency and effectiveness of the maintenance organization is impacted to the degree that the annual financial performance indicator targets are missed.

Tactical indicators focus on the individual processes within the maintenance function. However, optimizing that one process may have a negative impact on other processes. This potential effect shows the reason for the efficiency and effectiveness indicators. They evaluate the overall maintenance function; the tactical indicators evaluate only one of the eleven maintenance specific processes.

The following list of tactical indicators, previously mentioned in the book, focus on the evaluation of the specific maintenance function. No organization will use all of these indicators, but will choose the ones that support the selected efficiency and effectiveness indicators.

Preventive Maintenance

Preventive Maintenance Tasks Completed / Preventive Maintenance Tasks Scheduled

Number of Breakdowns Should Have Been Prevented / Total Number of Breakdowns

Inventory and Procurement

Total Annual Dollar Amount of Stores Usage / Total Inventory Valuation

Total Number of Orders Filled on Demand / Total Number of Orders Requested

Total Number of Items Filled on Demand / Total Number of Items Requested

$$\frac{\text{Total Number of Rush Purchase Orders}}{\text{Total Number of Purchase Orders}}$$

Work Order Systems (Planning and Scheduling)

$$\frac{\text{Maintenance Work Orders Planned}}{\text{Total Work Orders Received}}$$

$$\frac{\text{Maintenance Hours Scheduled}}{\text{Total Maintenance Hours Worked}}$$

$$\frac{\text{Total Hours Estimated on Scheduled Work Orders}}{\text{Total Hours Charged to Scheduled Work Orders}}$$

$$\frac{\text{Number of Work Orders Completed Greater than 20\% of Estimated Labor}}{\text{Total Number of Maintenance Work Orders}}$$

$$\frac{\text{Number of Work Orders Completed Greater than 20\% of Estimated Labor}}{\text{Total Number of Maintenance Work Orders}}$$

$$\frac{\text{Work Orders Overdue}}{\text{Total Work Orders}}$$

Computerized Maintenance Management Systems

$$\frac{\text{Total Maintenance Labor Costs in CMMS}}{\text{Total Maintenance Labor Costs from Accounting}}$$

$$\frac{\text{Total Maintenance Material Costs in CMMS}}{\text{Total Maintenance Material Costs from Accounting}}$$

$$\frac{\text{Total Maintenance Contracting Costs in CMMS}}{\text{Total Maintenance Contracting Costs from Accounting}}$$

$$\frac{\text{Total Maintenance Costs Charged to Individual Equipment Items}}{\text{Total Maintenance Costs from Accounting}}$$

Operational Involvement

$$\frac{\text{Hours of Preventive Maintenance performed by Operators}}{\text{Total Preventive Maintenance Hours}}$$

$$\frac{\text{Hours of Maintenance Activites Performed by Operators - Current Period}}{\text{Hours of Maintenance Activities Performed by Operators - Previous Year Same Period}}$$

$$\frac{\text{Hours of Equipment Improvement Performed by Operators}}{\text{Total Hours Worked by Operators}}$$

Reliability-Centered Maintenance

$$\frac{\text{Number of Equipment Breakdowns **}}{\text{Total Hours in Time Period}}$$

$$\frac{\text{Number of Repetitive Equipment Failures *}}{\text{Total Number of Equipment Failures}}$$

FUNCTIONAL PERFORMANCE INDICATORS

Functional indicators derive their name from the word function. Simply put, the indicators show how one of the eleven maintenance-specific functions is performing. The following list shows the specific functions required of or expected of a maintenance organization in most companies.

- Preventive Maintenance
- Inventory and Procurement
- Work Order Systems
- Computerized Maintenance Management Systems (CMMS)
- Technical and Interpersonal Training
- Predictive Maintenance
- Operational Involvement
- Reliability-Centered Maintenance
- Total Productive Maintenance
- Statistical Financial Optimization
- Continuous Improvement

The following functional indicators, mentioned previously in the book, show how well the parts of the function are doing in supporting the tactical issues. No organization will use all of these indicators, but will choose the ones that support the selected tactical indicators.

Preventive Maintenance

$$\frac{\text{Number of PMs Overdue*}}{\text{Total Number of PMs Outstanding}}$$

$$\frac{\text{Estimated PM Task Cost*}}{\text{Actual PM Task Cost}}$$

$$\frac{\text{Total Number of Work Orders Generated from PM Inspections*}}{\text{Total Number of Work Orders Generated}}$$

Inventory and Procurement

$$\frac{\text{Inactive Stock Line Items*}}{\text{Total Stock Line Items}}$$

$$\frac{\text{Total Maintenance Spare Parts in Controlled Stores*}}{\text{Total Inventory on Hand (Controlled + Uncontrolled)}}$$

$$\frac{\text{Total Number of Single Line Item Purchase Orders*}}{\text{Total Number of Purchase Orders}}$$

$$\frac{\text{Maintenance Material Costs Charged to a Credit Card*}}{\text{Total Maintenance Materials Costs}}$$

Work Order Systems

$$\frac{\text{Maintenance Labor Costs on Work Orders}}{\text{Total Maintenance Labor Costs}}$$

$$\frac{\text{Maintenance Material Costs on Work Orders}}{\text{Total Maintenance Material Costs}}$$

$$\frac{\text{Maintenance Contract Costs on Work Orders}}{\text{Total Maintenance Contract Costs}}$$

$$\frac{\text{Maintenance Downtime on Work Orders*}}{\text{Total Maintenance Downtime Charged}}$$

$$\frac{\text{Maintenance Labor Cost Charged to Standing Work Orders*}}{\text{Total Maintenance Labor Costs}}$$

$$\frac{\text{Materials Costs Charged to a Standing Work Order*}}{\text{Total Maintenance Materials Costs}}$$

$$\frac{\text{Total Charges for a Specific Equipment Item Written to a Standing Work Order}}{\text{Total Charges for a Specific Equipment Item}}$$

Planning and Scheduling

$$\frac{\text{Maintenance Labor Costs Planned*}}{\text{Total Maintenance Labor Costs}}$$

$$\frac{\text{Maintenance Material Costs Planned*}}{\text{Total Maintenance Materials Costs}}$$

Computerized Maintenance Management Systems

$$\frac{\text{Total Number of Equipment Items in CMMS}}{\text{Total Number of Equipment Items in the Plant}}$$

$$\frac{\text{Total Number of Part Items in CMMS*}}{\text{Total Number of Part Items in the Plant}}$$

$$\frac{\text{Total Number of Preventive Maintenance Tasks*}}{\text{Total Number of Equipment Items in the Plant x 3}}$$

$$\frac{\text{Number of Maintenance Employees or Full-Time Equivalents}}{\text{Number of Supervisors or Coaches}}$$

$$\frac{\text{Number of Maintenance Employees or Full-Time Equivalents}}{\text{Number of Maintenance Planners}}$$

$$\frac{\text{Total Number of Maintenance Overhead Personnel**}}{\text{Total Hourly Maintenance Personnel}}$$

Technical and Interpersonal Training

$$\frac{\text{Total Training Dollars**}}{\text{Total Number of Employees}}$$

$$\frac{\text{Total Technical Training Hours**}}{\text{Total Number of Employees}}$$

$$\frac{\text{Total Interpersonal Training Hours**}}{\text{Total Number of Employees}}$$

$$\frac{\text{Total Number of Training Employees}^{**}}{\text{Total Number of Maintenance Employees}}$$

$$\frac{\text{Total Training Dollars}^{*}}{\text{Total Plant Payroll}}$$

Predictive Maintenance

$$\frac{\text{Hours of Predictive Maintenance Activities}^{*}}{\text{Total Maintenance}}$$

$$\frac{\text{Predictive Maintenance Costs}^{*}}{\text{Total Maintenance Costs}}$$

Reliability-Centered Maintenance

$$\frac{\text{Number of Failures Where Root Cause Analysis Was Performed}^{*}}{\text{Total Number of Equipment Failures}}$$

$$\frac{\text{Number of Preventive Maintenance Tasks Audited}^{*}}{\text{Total Number of Maintenance Tasks}}$$

$$\frac{\text{Number of Predictive Maintenance Tasks Audited}^{*}}{\text{Total Number of Predictive Maintenance Tasks}}$$

Total Productive Maintenance

$$\frac{\text{Critical Equipment Items Covered by Design Studies}^{*}}{\text{Total Number of Critical Equipment Items}}$$

$$\frac{\text{Critical Equipment Items Covered by 5 S Activities}^{*}}{\text{Total Number of Critical Equipment Items}}$$

Statistical Financial Optimization

$$\frac{\text{Number of Critical Equipment Maintenance Tasks Audited}^{*}}{\text{Total Number of Critical Equipment Maintenance Tasks}}$$

$$\frac{\text{Number of Critical Equipment Major Spare Parts Audited}^{*}}{\text{Total Number of Critical Equipment Major Spare Parts}}$$

$$\frac{\text{Number of Critical Equipment Routine Spare Parts Policies Audited}^{*}}{\text{Total Number of Critical Equipment Routine Spare Parts}}$$

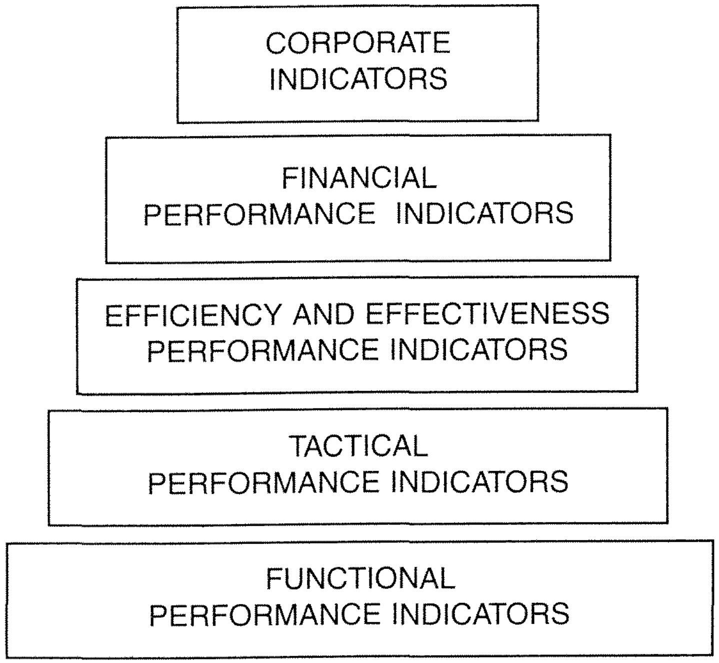
Example : ***A company striving to be the low-cost producer in its respective market.***

The corporate mandate is to keep costs low while insuring the long-term viability of the company assets. Each company function that contributes to production costs must be as efficient and effective as possible. The tactical focus is to insure optimization of the overall maintenance costs on a quarterly basis. The functional support focuses on the optimization of each component of the maintenance process. The scenario is as follows:

> The corporate cost-to-produce indicator begins to increase. The factors making up this indicator are examined. These include the individual financial indicators that in turn make up the cost-to-produce indicator. Upon examination, one particular financial indicator—Maintenance Costs per Total Manufacturing Costs—is checked and is found to have increased over the last quarter.
>
> The efficiency and effectiveness indicators for maintenance are examined next. Upon examination, the Desired Equipment Uptime indicator has declined and is below an acceptable level.
>
> The tactical indicators impacting the Desired Equipment Uptime indicator are now examined. As these indicators are checked, the Preventive Maintenance Compliance indicator is found to be lower than acceptable and heading downward.
>
> Next the functional indicators for the PM program are examined. The Overdue PM Tasks indicator is high and moving even higher. Upon reviewing the indicator factors, it is found that the equipment is not being released by production for preventive maintenance.
>
> Here is the task that is hindering the execution of the preventive maintenance services. This in turn is leading to increased equipment breakdowns, which lowers the uptime, which raises the maintenance costs, which impacts the cost-to-produce indicator.

This example shows how the performance indicators might be linked. If the indicators are not linked to performance at either a higher level or a lower level on the indicator pyramid, then the wrong indicators are being used.

Remember: No one uses all of the indicators. Use only the ones that connect to the corporate indicators. The use of nonconnected indicators will obscure the real problems and the solutions required. When this happens organizations flounder, never making the correct improvements or changes.



Chapter 15
The Future

Where is the future of maintenance headed and what will be the trends of the future? This chapter will examine three major areas in which many organizations are focusing their current improvement initiatives. These areas are:

Back to the Basics
Cost-Benefit Analysis
Enterprise Resource Planning (ERP)

Back to the Basics

Many organizations today are returning to the basics. As technology changed the focus of manufacturing and process efforts, it also distracted many maintenance organizations. Inspection and detection technology increased and the maintenance organizations focused on the new tools and how to use them. As they did, they either hurriedly handed off the basic tasks of maintenance to the operators or they didn't do them anymore. Thus, when vibration analysis would indicate there was a problem with a bearing, the bearing was changed. Upon examination, it might find that problem was caused by a lack of lubrication.

But do maintenance organizations need technology to tell them that they are ignoring basic maintenance procedures and requirements on their equipment? This approach seems to be an expensive way to be reminded. One survey showed that over 50% of equipment malfunctions and breakdowns are due to the neglect of the basics of maintenance. As discussed in the preventive maintenance chapter, if the basic issues are not addressed, then little, if any, sustainable improvements will ever be achieved in equipment reliability.

Back to the basics also ties in with training. Few maintenance management courses focus on what the basics of maintenance really are and how to meet those requirements. This area will need to be addressed for the new workforce. Many companies have aging workforces. When the current employees leave through retirement, who is prepared to take their place? Many companies today are facing serious situations in the next three to five years as they experience turnover of their older, higher-skilled employees. If the basics of maintenance are not getting the attention required now, how will they ever get the necessary emphasis in the future?

A 1989 survey of best maintenance companies, found the first enabler that made the companies successful:

The best do the basics very well. Even among the Best, there is still room for improvement.

Given this finding, companies would do well to ask themselves: Are we doing the basics well?

Cost-Benefit Analysis

Although it is improving in maintenance, cost-benefit analysis still is in its infancy. Cost-benefit analysis provides the ability to cost justify maintenance improvements. There are two main areas in which maintenance impacts a company financially: expenses (cost avoidance) and creating capacity (more throughput with same overhead costs).

In the expense area, anything that maintenance can save by being more efficient and effective is money that did not have to be spent. These savings can be applied to the bottom line as profit. Studies have shown that, depending on a company's cost structure, an expense dollar saved equals ten to twenty dollars in increased sales at the bottom line. Therefore, saving maintenance dollars by being efficient and effective is important.

In the creating capacity area, the production costs are stable and a fixed part of the cost-per-unit calculation. Most companies have focused on reducing expenses to impact that calculation. However, progressive companies are examining the other side of the indicator: the number of units produced. If the equipment ran closer to design speed without breakdowns, could more units be produced with the same fixed costs, thereby lowering the cost per unit?. Companies that are asking that question are finding that the answer is *Yes*.

In addition to increasing capacity, companies that are working in this area are finding secondary benefits. The need to purchase new equipment to keep pace with market demand is reduced, thereby saving capital dollars. This also has an impact on the Return on Fixed Assets and Return on Net Assets calculations.

Proper equipment maintenance also impacts energy costs. A well-maintained equipment unit requires from 5% to 11% less energy to operate than does a poorly maintained equipment unit. Reducing energy costs for a company saves expense dollars. The impact on profitability is undeniable.

The more that companies understand the impact maintenance has on their bottom-line profitability, the more they agree *equipment maintenance is the last of the million-dollar savings strategies.*

Enterprise Resource Planning (ERP)

As we head into the new millenium, Enterprise Resource Planning is skyrocketing n popularity. Its focus is to help streamline all systems in a company so that they communicate more closely, they more closely coordinate, and the information systems used to manage the separate functions in the organization are completely integrated.

There are two theories that address how to develop these ERP systems. One theory holds that a single vendor produces a massive software program with all of the functions needed to run the business; this vendor supplies the software system. The second theory holds that a system integrator finds the "best of breed" solutions for each of the functions in the company and integrates them into a seamless solution.

Both arguments have strengths and weaknesses. The single vendor has a fully integrated system with all modules required to run the business as a part of the system. The strength is usually the completeness of the integration. The weakness is the lack of functionality of some of the system's modules. For example, most of the integrated systems do not have a strong maintenance module. The exception occurs where a vendor purchases a CMMS and then integrates it in its package. This solution provides maximum functionality and full integration.

The "best of breed" solution allows the customers to select from a group of stand-alone packages. Once the best of each is found, the integrator puts them all together. The strength is that the customers get a solution made up of the modules that best suit their needs from a functionality standpoint. The weakness is that many of the systems are difficult to integrate. In many cases, they don't work as well as promised when they are finished.

Which solution a company selects really doesn't matter. One issue will always be raised: How do we reengineer the organization to take advantage of the new tool? This issue is the one that most companies have a problem addressing. Many companies think they can implement an ERP system, yet keep doing business the way they always have. This is not the case. Organizations will have to change some of their business processes to meet the requirements of the system. If they are not willing to change, then the implementation ends in frustration for everyone.

A second major issue is the commitment to use all of the ERP system. This commitment takes time and resources. The ERP system requires each department to input all of its data so accurately that the system can match and verify the data put in by other departments. Unless everyone who uses the system commits to this effort, the data accuracy suffers and the system is never utilized. Without full utilization, the return on investment for the system is never realized and its implementation is deemed a failure. Time and resources must be planned accurately if the ERP system is to be successful.

But what about the maintenance function in organizations? They will, in the future, be more fully integrated within an organization. In the same way that companies are turning to a fully-integrated ERP solution, with maintenance as part of the solution, most companies will integrate maintenance and operations even more closely. Even now, many companies don't have maintenance departments; they have capacity assurance departments. Some companies, employing a process team concept, don't have Total Productive Maintenance, but rather Total Process Reliability. Their focus is on maximizing the equipment assets, not on managing maintenance. While highly-skilled and talented maintenance technicians will always be required, how their work is integrated into operations, and how focused they are on data collection and analysis, will change.

Glossary

5 S - organization, tidiness, purity, cleanliness, and discipline. Focused on the work place and derived from five Japanese words that begin with the letter "s"

A

absenteeism - the act of missing work; being absent from a scheduled work shift

accounting - a functional department within a company with the task of compiling and analyzing all of the financial records for the company

asset management - the oversight of the life of an asset to achieve lowest life cycle cost with the maximum availability, performance efficiency, and highest quality

B

benchmarking - a continuous improvement process of examining companies that are more effective in a specific process, learning how they became more effective, and then adapting their methods to your company's process with a goal of being better at the process than the company that was benchmarked

best practice - a practice that leads to superior performance in a specific process

breakdown - an unexpected interruption to the service of a particular asset

breakdown maintenance - maintenance performed in response to a breakdown; typically costs two to four times as much compared to the same maintenance performed in a planned mode

C

cleaning - the act of removing contamination or other materials from an asset

CMMS (Computerized Maintenance Management System) - a software package designed to assist in managing the maintenance function

CMMS usage - the utilization of a CMMS; many companies only achieve a 50% utilization rate, preventing a realization of the full return on the investment in the software

competitive analysis - a comparison of a company's process with that of a specific competitor or group of competitors

continuous improvement - the process of constantly making a company's business processes better

contractor - an individual or company that has a legal agreement to provide a specific service or task

corporate indicators - measures that are used to determine how successful a company is in its particular business

critical spares - spare parts that have especially high value and long lead times; usually carried in stock to prevent excessive downtime in case of a breakdown; they average about 10% of inventory items, but may comprise up to 50% of the inventory value

D

data collection -the gathering of information to develop & support a performance indicator

downsizing - the reduction of a company's workforce; may be due to a department closure or market share reduction, but is commonly used incorrectly as a quick method for reducing company expenses

downtime - the time period during which a particular asset is not performing to design specification; asset may be actually in a breakdown condition or may be not be capable of producing at design specification

E

early equipment management - a management philosophy that examines how equipment or assets will be required to perform during their life cycle to insure that design specifications are adequate

early equipment management and design - a management philosophy that gathers data from existing equipment performance and provides the data to the design process for the next generation of equipment being developed

emergency - a type of equipment problem where a breakdown has occurred and immediate attention is required; usually involves safety, health, or process integrity

EPA - Environmental Protection Agency; a United States Government agency charged with enforcing governmental environmental regulations

equipment capacity - the ability of equipment to produce a product or provide a service at a given rate over a specified time period.

equipment uptime - the time period during which an equipment item is performing at design specification; the inverse of downtime.

ERP (Enterprise Resource Planning) - the planning of all resources of a corporation to insure that products and services are produced and provided at lowest total cost

F

FEMA (Failure and Effects Mode Analysis) - analysis that examines failures and the resulting effects; makes possible implementing changes to prevent or monitor any future failures

financial indicators - measures that connect the business process with the overall corporate goals; the structure of the indicators allows analysis for continuous improvement

financial optimization - an analysis technique that compares the total cost of an activity to a company; includes factors such as profit generated, cost of maintenance, cost of production, quality costs, and energy costs; goal is to achieve the optimum financial balance for the company

functional maintenance indicators - measures that examine the individual functions of the maintenance processes; these indicators then support the tactical indicators

I

idling and minor stoppage - a type of equipment loss that is caused by small interruptions of the equipment; causes are usually small and require little effort to repair or reset; however, losses can be significant when accumulated over time.

inventory - spare parts or equipment components kept in case of an equipment breakdown or for replacement when the original part or equipment component wear out.

inventory and procurement - a function within an organization that is responsible for obtaining and storing spare parts, equipment and, in some cases, raw materials; required to support the maintenance function if maintenance activities are to be carried out effectively and efficiently

ISO-9000 - Standards for quality systems insuring consistency in quality production

J

Just-In-Time - an operating philosophy that focuses on reducing lead times and work in process in manufacturing operations

L

lean manufacturing - a system of manufacturing that focuses on minimizing the resources necessary to produce a product or provide a service

Life Cycle Costing - a technique that examines the total cost of ownership of an asset; costs are calculated from the design phase to the disposal stage; this technique usually produces dramatic savings for companies used to buying from "low bid" vendors

M

MTBF (Mean Time Between Failure) - the average length of time from one failure to another failure for an asset or component

MTTR (Mean Time To Repair) - the average time needed to restore an asset to full operation after a failure

maintenance management implementation decision tree - a methodology for improving maintenance

maintenance performance - comparing the results of the maintenance function to the goals and objectives set for it

maintenance prevention - a design change or activity focusing on reducing or eliminating the maintenance needs of an asset

mechanical fastening - some form of a device that joins or fastens two components together; includes bolts, studs, screws, and locking devices

minor maintenance - small maintenance activities that are low cost and of short duration

N

NASCAR - a racing circuit in the United States that focuses on maximizing equipment utilization through structured teamwork and discipline.

O

OEE (Overall Equipment Effectiveness) - a measurement that compares the availability, performance efficiency and the quality rate of an asset

oil analysis — two techniques; one is the analysis of the actual lubricant for its condition; second is the analysis of the wear particles in the oil to determine what part of an asset is wearing

operational involvement - the use of operations personnel in some aspect of maintain ing their equipment or assets

operations personnel - employees who work in the operations department

operator involvement - the extent to which employees who run equipment are also engaged in some aspect of maintaining their equipment (or other asset)

OSHA - Occupational Safety and Health Administration; a United States agency that focuses on providing a safe and healthy workplace for all employees.

Overall Equipment Effectiveness (see OEE)

P

Pareto - an analysis performed to show which 20% of the equipment or assets creates or contributes to 80% of the problems the company is experiencing

PDM (see predictive maintenance)

performance indicators - measures to determine the performance of a function within a company.

performance measurement - the act of measuring performance

planning and scheduling - maintenance activities for which resources are determined in advance and time is estimated to carry out the work; estimates are then built into a weekly schedule for the maintenance staff

planner - a designated individual who plans maintenance activities

PLC (Programmable Logic Controller) - electronic system used in facilities and plants to control assets

Predictive Maintenance (PDM) - an advanced preventive maintenance technique that focuses on using technology to determine the condition of equipment or assets

preventive maintenance - activities designed to eliminate or reduce wear on assets or equipment systems

PSM (Process Safety Management) - special regulation designed to increase the safety and environmental control of process system

purchase orders - forms produced by the purchasing department to obtain materials for the company

purchasing - the functional department responsible for securing the material necessary for the company to produce its product or provide its service; often called procurement

Q

QS-9000 - quality standards for the United States automotive industry; similar to the ISO-9000 standards.

quality defects or rework - products that are not usable or need additional work to be usable

R

RCM (see Reliability-Centered Maintenance)

reactive - maintenance activities that occur with little or no notice; these activities interrupt the weekly maintenance schedule and will cost two to four times as much as when they can be planned and scheduled

reduced speed or capacity losses - losses incurred when equipment or assets are allowed to perform at less than design speed or capacity

reliability - the probability that equipment or an asset will perform its designed function without a failure for a period of time under specific conditions

Reliability-Centered Maintenance (RCM) - a technique designed to enhance and improve the preventive and predictive maintenance programs

return on fixed assets (ROFA) - the profit a company generates factored by the value of the fixed assets that produced the profit

return on investment (ROI) - the financial performance on any investment that is made

return on net assets (RONA) - the profit a company generates factored by the net value of the assets that produced the profit

root cause analysis - a technique used to discover the true reason for an equipment or asset problem, malfunction or breakdown

routine lubrication - the act of carrying out lubrication on an equipment or asset on a regular schedule

routine spares - spare parts that are used on a regular basis to maintain equipment or assets

S

service level - the percentage of time spare parts are in stock in the storeroom when they are required

set up and adjustment - the process of changing from running one product to running another

sonics - the use of ultrasound to detect thickness of materials and other techniques such as leak detection

start up and shutdown losses - equipment losses occurring when equipment is shut down and started up; losses occur when the process is destabilized and then is stabilized

start up inspections - inspections that are typically carried out by operational personnel while starting up the equipment

statistical financial optimization - a technique that blends the financial controls and the reliability statistics to forecast the lowest total cost for various maintenance decisions

stock out - an event that occurs when a part is required but is not available

stores - also referred to as inventory; the function within a company responsible for maintaining the supply of spare parts

stores and Procurement - also called inventory and purchasing; the function in a company responsible for ordering, purchasing, and maintaining spare parts for a company.

supervisor - a first-line manager usually responsible for a group of eight to twelve employees in a traditional organization

T

tactical ondicators - measures that highlight weaknesses in an organization that require the merging of functional processes within the maintenance function to improve

technical and interpersonal training - training programs that address the specific skills needed to operate the equipment and "soft skills" such as team building and diversity training; both types of training are required to produce a workforce capable of performing at world class levels

technical training - training in the technical trades areas, such as electrical, mechanical, and fluid power.

thermography - the use of infrared technologies to measure temperature differentials

total productive maintenance (TPM) - an operational strategy focusing on maximizing overall equipment effectiveness;.requires full organizational participation to be successful

U

ultrasonic - the use of sonics technology to discover equipment and asset problems

uptime - the time equipment or assets are available to perform their designed function

V

vibration analysis - a predictive maintenance technology focusing on vibration of rotating equipment to discover and then monitor wear of mechanical components, allowing maintenance activities to occur before a breakdown

visual systems - a technique utilized to highlight operating conditions, such as pressure, flow, and fluid levels; makes inspection and tracking equipment conditions easier and lessen the risk of a mistaken reading

W

wear particles - a type of lubricant analysis that examines the wear particles suspended in the lubricant; allows wear to be identified and corrected before a failure occurs

work order - a document used to request, plan, schedule, track, and report on all maintenance activities

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