Maintenance Work Management—Best Practices Guidelines

Maintenance Assessment and Improvement

TR-109968

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REPORT SUMMARY

This report on maintenance work management best practices is part of EPRI's Plant Maintenance Optimization (PMO) development efforts. Based on a series of assessment and improvement projects, the report describes the process and typical results.

Background

Deregulation has prompted a drive to better manage operation and maintenance (O&M) of fossil power plants. To help its member utilities make the transition and become more competitive in the new era of deregulation, EPRI has initiated PMO development efforts. In 1997, those efforts came under Target 43: Turbine, Generator, and Balance of Plant O&M Cost Reduction. For 1998, they fall under Target 54: Plant Maintenance Optimization. These efforts are intended to help utilities reduce production costs by developing and demonstrating cost-effective maintenance methods. This report is part of that program.

Objectives

To identify and describe a process of customization and adaptation to achieve maintenance work management best practices.

Approach

EPRI has identified three main areas in which to focus on maintenance best practices: (1) Technology, (2) People (or Work Culture), and (3) Work Processes. In addition to each area having its own best practices, there also are best practices in the synergy among these areas. For example, the best technologies integrate with good work culture and good work processes. To identify best practices, EPRI began a series of assessment and improvement projects in power plants based on methods used in manufacturing and process industries. This report is based on the results of this EPRI project.

Results

The report identifies three basic steps to achieve maintenance best practices. (1) A Maintenance Assessment that results in an (2) Improvement Plan whose completed projects are kept viable through brief progress reviews, or (3) Reinforcement. While the basic process is similar from plant to plant, results are highly individualized. Organizations that achieve the best practices do so through a process of customization and adaptation during each of the three basic steps.

EPRI Perspective

Every plant has its own unique set of work management best practices. The process by which utilities identify and achieve their own best practices takes effort, time, and money. Experience has shown that outside, expert facilitation is an important key to success; internal programs take longer and do not generally achieve the same level of success. For more information on maintenance work management best practices, refer to these EPRI reports: *Plant Maintenance Optimization* (TB-108949-R1) summarizes the assessment and improvement process; *Maintenance Work Management Practices Assessment* (TR-106430) outlines results from the first six assessments; *Maintenance Work Management Improvement: Improving Culture and Work Process* (TR-109734) describes the improvement process based on plant projects; and, *Value-Based Maintenance Grid* (TR-108937) details the assessment grid.

TR-109968

Interest Categories

Fossil steam plant performance optimization
Fossil steam plant O&M cost reduction
State-of-the-art power plants
Fossil assets management

Keywords

Maintenance management
Work culture
Work process
Best practices
Reliability

ABSTRACT

This report is part of EPRI's Plant Maintenance Optimization (PMO) development efforts. In 1997 it was in Target 43: Turbine, Generator and BOP O&M Cost Reduction. In 1998 it is in Target 54: Plant Maintenance Optimization. The PMO mission is to lead the industry by developing and demonstrating products and services for improved utilization of power plant maintenance resources and increased profitability for generation business units/companies. This report on maintenance work management best practices is based on a series of work management assessment and improvement projects. Nine assessment projects and four improvement projects have been completed in the utility industry to date.

Work management best practices are not a fixed set of activities that is the same at every power plant. Best practices are determined and achieved through a process that takes work, time and money. The process itself is very similar in each case, but the results are highly individualized. This report describes the process and typical results. The process has tremendous benefits if it is completed entirely. The key to success is outside expert facilitation. Internal programs to improve work management take longer and do not reach the same level of success.

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1

THE ELEMENTS OF BEST PRACTICES

Technology, People & Work Processes

The three elements of maintenance best practices are: ***Technology***, ***People*** (or *Work Culture*), and ***Work Processes*,** as shown below. *Technology* elements are the tools and systems that support the work processes. The *People* element, or *Work Culture*, is the way people work together. The *Work Processes* element is the sequence of steps or procedure that people followed to maintain equipment.

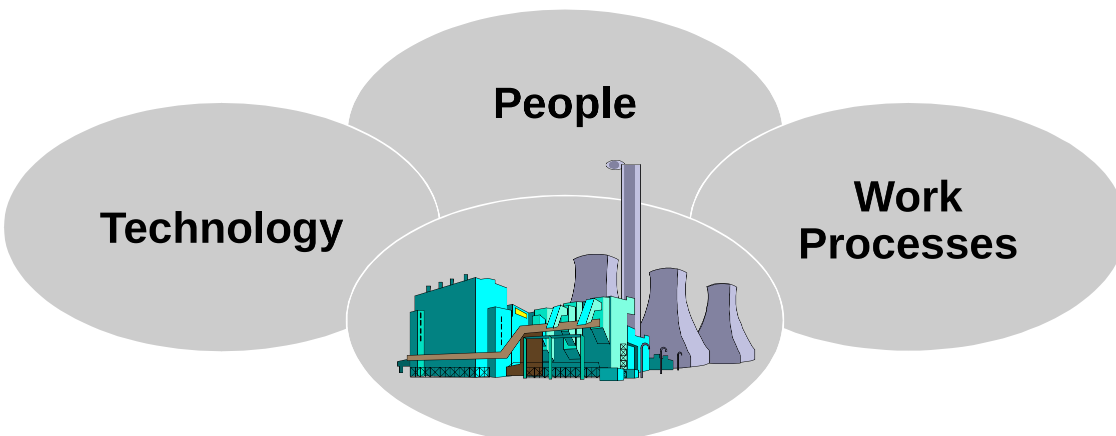

Figure 1-1
Three Elements of Maintenance Best Practices

Best practices are achieved with particular content in each element, and synergy between these three elements. In other words, there are best practices in *Technology*, *Work Culture* and *Work Processes*. There are also best practices in the synergy between these elements. For example, the best technologies are those that integrate with good work processes and good work culture. To find out *what are the best practices*, EPRI looked for examples and consultants in the utility industry and other process industries.

Traditionally EPRI has concentrated on the technology element, by developing tools and systems to address specific engineering issues. The Plant Maintenance Optimization Target at EPRI is taking a broader perspective, considering work culture and work process elements. It seems there is no single best practice for every power plant, nor is there one consultant who can address all three elements of best practices. That's why this report describes a process of customization and adaptation to achieve best practices. The process is similar from plant to plant, but the results are highly individualized.

Example from the Automotive Industry

The following example from the automotive industry illustrates the value of improvements that include *Work Culture* and *Work Process* elements. Figure 1-2 shows the investment level for five different automobile assembly plants, broken down into two categories: technology, and process & culture. Then Figure 1-3 shows the return amount for the five assembly plants broken down into quality and productivity, two important measures for the automotive industry. Best results were achieved when more was invested in *Work Process* and *Work Culture* than technology (NUMI-California and Honda-Ohio). In addition, a moderate investment in all elements (Nissan-Tennessee) is better than a large investment in *Technology* alone (GM-Michigan). This data came from *Corporation of the 1990's* by Michael Morton (1991).

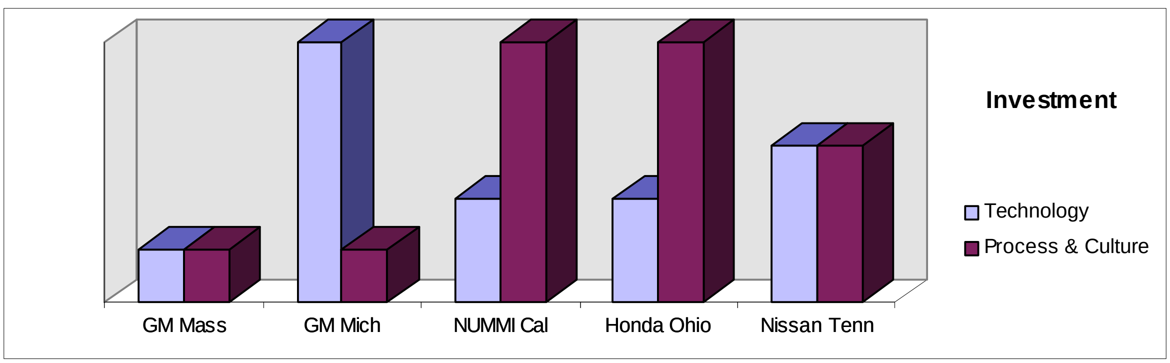

Figure 1-2
Relative Investment in Technology and Process & Culture

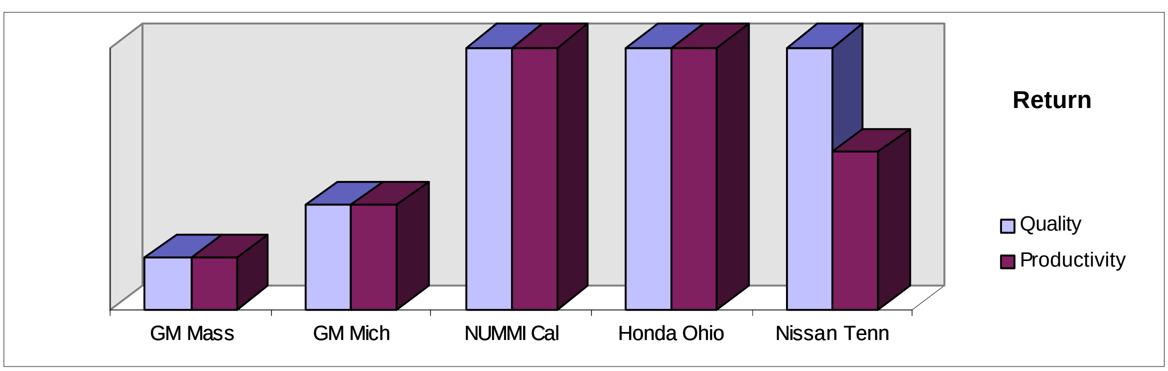

Figure 1-3
Subsequent Return in Quality and Productivity

Process to Achieve Best Practices

The process to achieve maintenance best practices starts with a *Maintenance Assessment*, as shown in the figure below. Then an *Improvement Project*, and finally there is *Reinforcement* to prevent backsliding.

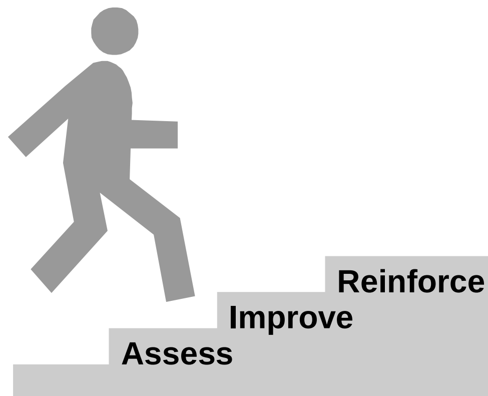

Figure 1-4
Steps in the Process to Achieve Best Practices

The next figure illustrates the sequence and deliverables in this process. An *Assessment* takes about 2 months and results in two reports: *Findings and Opportunities*, and an *Improvement Plan.* An *Improvement* takes about 18 months and results in several documents that include a plant's *Mission, Vision & Values* and *Roles, Relationships & Responsibilities.* Another deliverable is a *Work Practices Book* that describes new work processes in the plant. Often as a result of an *Assessment*, certain *Technology* improvements will be recommended such as Streamlined Reliability-Centered Maintenance (SRCM), Predictive Maintenance (PDM), Heat Rate Analysis and Training or a Computerized Maintenance Management System (CMMS). These *Technology* elements tend to be implemented near the end of an *Improvement Project*. Then finally, *Reinforcement* is achieved through brief progress reviews for some time after the improvement is completed.

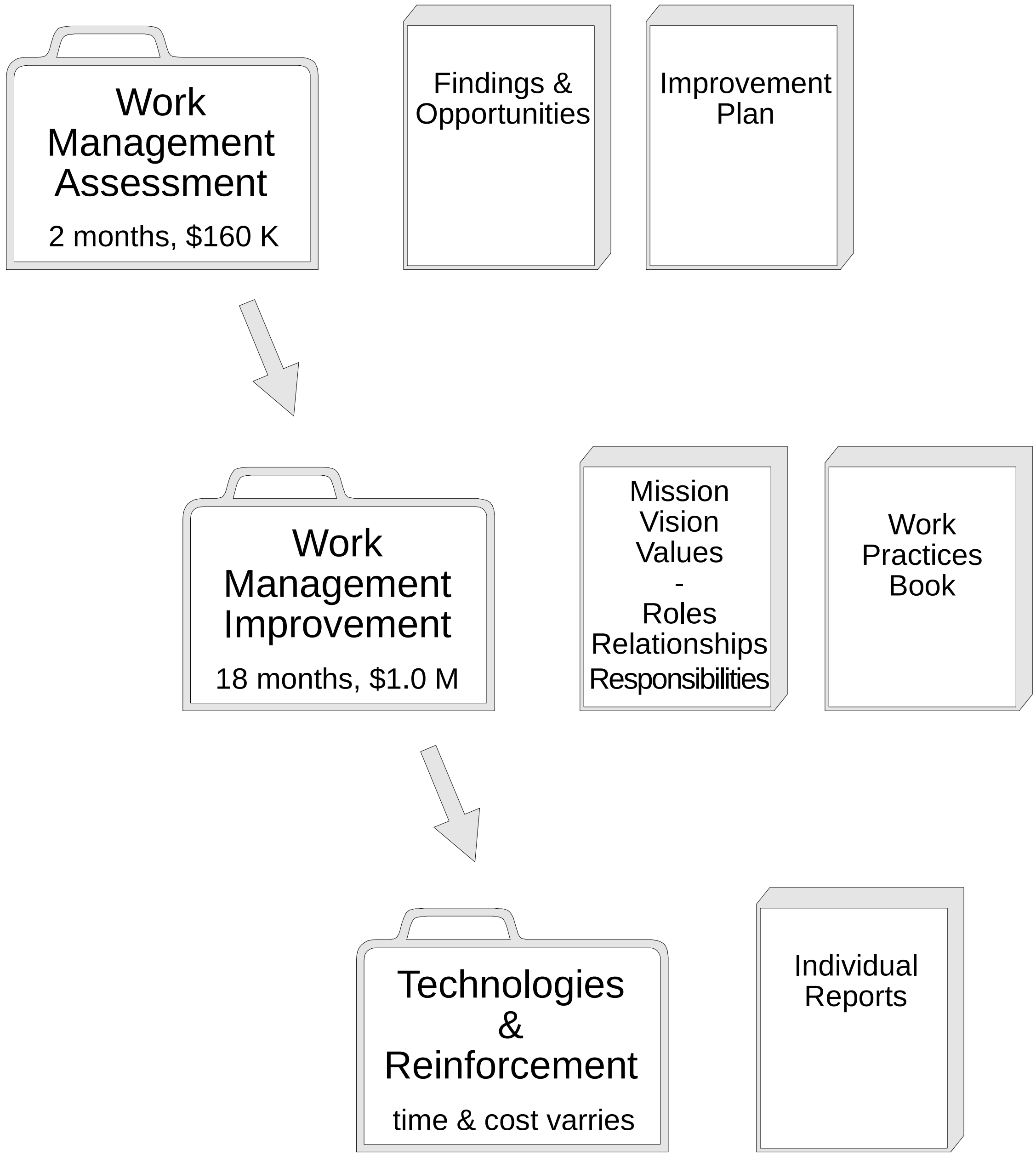

Figure 1-5
Process Sequence & Deliverables

References

The assessment and improvement process is summarized in the EPRI Tech Brief:

Plant Maintenance Optimization, TB-108949.

Results from the first six assessments are summarized in the EPRI Report:

Maintenance Work Management Practices Assessment, TR-106430.

The assessment grid is described in detail in the EPRI Report:

Value-Based Maintenance Grid, TR-108937.

The maintenance improvement process is described in detail in the EPRI Report:

Maintenance Work Management Improvement, TR-109964.

2

COMMON OPPORTUNITIES AND BENEFITS

One aspect of an *Improvement Project* is to introduce new terminology. For example, the term *opportunity* is used instead of *problem* to encourage a positive perspective. In addition, the word *benefit* has a more positive connotation than *metric* or *measure*. The following are some of the common opportunities and benefits observed in past *Assessment* and *Improvement Projects*.

Common Opportunities

- The staff miss a sense of unity, common purpose and pride in achievement. This often showing up as distrust and poor communication between union and non-union employees. People say things like: *this isn't my job*.
- There is a lack of accountability, lack of understanding how individual goals relate to corporate goals, and lack of measurement of individual or group performance.
- The Plant is falling behind in preventive maintenance, spending too much time fixing emergencies.
- The maintenance backlog is excessive, inaccurate, growing and not trusted.
- There are no effective programs in predictive maintenance or reliability centered maintenance.
- The inventory level is too high and much of it is obsolete.
- Few jobs are planned (field scoped) and schedule compliance is poor or not measured.
- There is no computerized maintenance management system, or the existing system is hard to use and not used effectively.
- There is an excessively long purchase order cycle time and time is wasted waiting for parts.

- Outages are planned poorly, a majority of the work is submitted just before an outage and outages are not completed on time or within budget.
- The plant does not reach, and often does not know its best achievable heat rate. On-line heat rate measurements are not sufficient for control.
- The control system is old (typically bench-boards and hard-panels); and is poorly maintained and calibrated. Most information is stored in hard copy form and is not widely accessible.
- Meetings are handled inefficiently, managers lack leadership skills, there is poor communication between maintenance and operations and there is little contact between management and labor.
- Interestingly, the plants that seek improvement efforts tend to be good performers to start with. They are usually base loaded plants with high dispatch level, and low cost in the region. They seem to want to insure their leading status and broaden their area of dominance.

Common Benefits

Qualitative Improvements

- Improved confidence, pride of accomplishment and interest in work.
- Improved skill level, better job mobility and more effective communication.
- Better expression of corporate goals, and better understanding of how a person's job relates to those goals.
- Quicker meetings, less conflict, and better documentation of commitments.
- An awareness of customer-supplier relationships and accepting responsibility for work.

Quantitative Improvements

- More business income resulting from higher availability, capacity and more sales of electricity.
- Lower costs resulting from improved heat rate, lower inventory level and lower annual budget.

- Higher work effectiveness as measured by: schedule compliance, amount of planned work, reduced backlog, shorter outages, and higher job completion rate.
- Improved work processes such as: shorter purchase order cycle time, quicker completion of routine maintenance work, faster work order cycle and more accurate planning.
- Increased accountability with frequent measurement of performance indicators and detailed indicators assigned to individuals and groups that role up into overall goals.
- So far there have been no lay-offs based on an *Improvement Project*. The level of staffing stays within normal attrition levels. However there always is a realignment of responsibilities, usually there is a change in the organization, and some individuals change assignments.

3

WORK MANAGEMENT ASSESSMENT

Value-Based Maintenance Grid

The *Value-Based Maintenance Grid* is a centerpiece that describes maintenance work management best practices. That's why an *Assessment* is oriented around the grid. The grid itself is organized in three levels of detail. The highest level of detail is a row. There are 10 rows; these are the categories of best practices. They build from a simple foundation of Row 1: *Work Orders* to a complex row 10: *Work Culture*. The second level of detail are the cells in each row; these describe the components of best practice. The third level of detail are the definitions and criteria for each cell; these describe the details of best practices. Row names and cell names are shown in the figure below. Row and cell definitions are summarized in Appendix A.

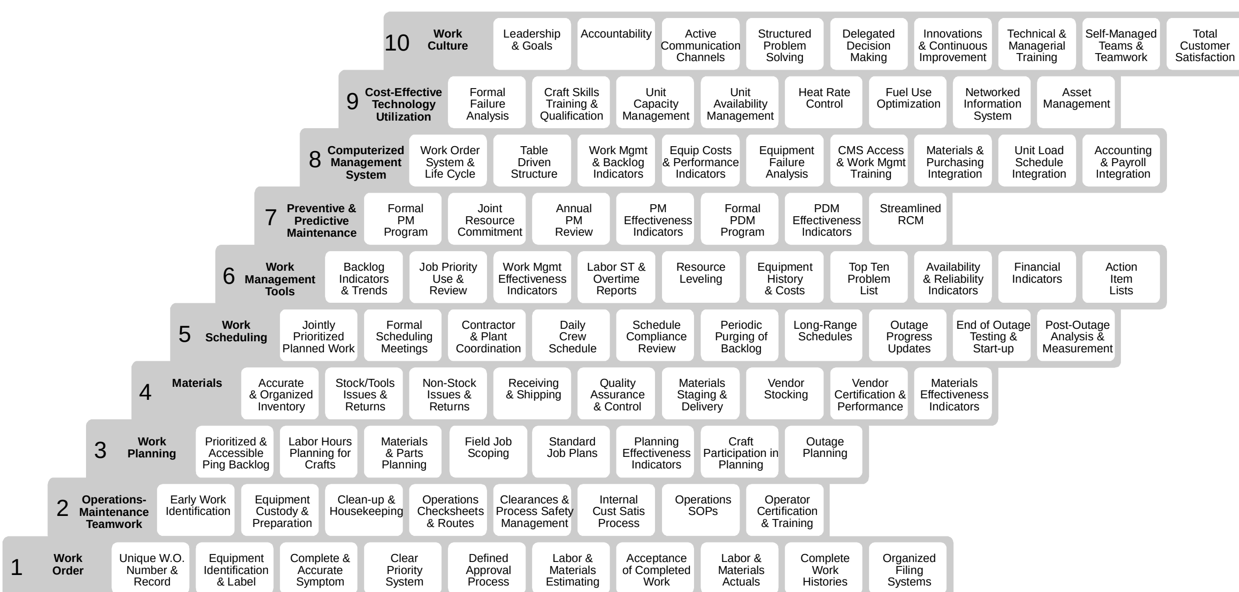

Figure 3-1
Value-Based Maintenance Grid

In the process of an assessment each cell is scored on a scale of 0 to 5 according to objective criteria. 0 to 1 means *absent with no use*, 1 to 2.5 means *available with minimal use*, 2.5 to 4 means *available with routine use*, and 4 to 5 means *fully implemented.* Individual cells with low scores point to opportunities to be addressed in an improvement effort. Typical average scores before and after an improvement are in the mid-2 range before and mid-3 range after.

Benchmark Data

Another element of an assessment is the gathering of benchmark data. While not as effective at identifying improvement opportunities, this data does indicate general areas of opportunities. They are compared to averages in the utility industry and in the general process industry. Several measures are better in the general process industry as a result of their longer history in competition. The following benchmark data is requested at the beginning of an assessment:

- Per Unit: $/MWhr, heat rate, availability, EFOR (Equivalent Forced Outage Rate), and replacement power cost
- Plant: replacement power expense per year, O&M (Operations & Maintenance), fuel, capital, total costs, FTEs (Full Time Equivalent)/MWhr (company & contractor)
- Maintenance: % emergency work, % PM, PDM, CM (Corrective Maintenance); % maintenance OT (Overtime), total outage days/yr
- Maintenance employee: % schedule compliance, lost time injuries, absenteeism, $ emergency shipment of parts, estimated vs. actual labor hours, backlog size, backlog input/output, outage duration compliance (last 6 outages), outage budget compliance (last 6 outages)
- Inventory: % inventory accuracy, inventory value, inventory turns
- #, $ parts delivered to job site, # management levels

Other data collected during an assessment are:

- # Crafts
- Maintenance turnover
- # Maintenance hourly
- # Total plant hourly

- # Storeroom employees
- # Planners
- # Engineers
- # Supervisors
- # Salaried employees

Then the following values and ratios are calculated and compared to industry averages:

- # Crafts
- Maintenance absenteeism
- Maintenance hourly turnover
- Maintenance hourly/total plant hourly
- # Hourly employees/storeroom employee
- # Hourly employees/planner
- # Hourly employees/engineer
- # Hourly employees/supervisor
- # Hourly employees/salaried employee
- Overtime hours/total hours total backlog/total available hours
- PM compliance (%), daily schedule compliance (% schedule hrs. completed/total avail. hrs.)
- Routine maintenance & repair/total labor hours (%)
- Preventive/predictive hours/total labor hours
- Emergency labor hours/total labor hours
- Direct purchase cycle time (days)
- Storeroom issue fill rate
- Storeroom accuracy, inventory value/maintenance hourly employee (>$10,000)

- # Storeroom annual inventory turns
- Inventory value/stores employee ($ million)
- Inventory value/replacement value (ratio)
- Total maintenance cost
- Maintenance personnel cost
- Contract labor/total labor

Survey

The third element of every assessment is an employee survey. This is a subjective measure of the level of consensus and communication in the plant. It is primarily used to indicate improvement opportunities in the area of Work Culture. The average survey score does not tend to change after an improvement effort. People seem to expect more, so the level of satisfaction doesn't change after an improvement.

The survey contains 45 questions as follows. Each question is graded by every employee on a scale of 1 through 7. One means *disagree strongly*, 4 means *neither agree nor disagree* , and 7 means *agree strongly*.

1. Safety rules are followed and enforced.
2. Everyone, including Operations, Maintenance and Engineering, writes work orders and tries to find equipment problems early.
3. Operators check maintenance work and sign off on completed work orders.
4. Operators conscientiously perform PM and minor maintenance (e.g., lubrication, adjustments, valve packing).
5. Operators conduct thorough rounds in which they inspect and adjust equipment and communicate equipment problems.
6. Work requests contain complete descriptions of equipment problems or symptoms.
7. Priorities assigned to work requests accurately reflect the urgency of the work.
8. Most work orders are planned.
9. Work order plans are reasonably good in terms of job steps, labor estimates and parts required.

10. Most work orders are scoped (i.e., future job sites are visited and evaluated in order to plan the job).
11. Crafts participate in planning some work orders.
12. Most parts and materials are available when needed.
13. Drawings and prints are up-to-date, organized and easily accessible to crafts.
14. Operations, Maintenance and Engineering work together to establish work priorities for the plant, area or unit.
15. Each crew has a full day's work scheduled prior to the start of their shift.
16. The Maintenance daily work schedule is communicated to Operations before the work is started.
17. The Maintenance daily work schedule is usually accurate; that is, the jobs that are scheduled actually get worked on.
18. A completed work order usually has written comments from crafts describing the actual work done.
19. Maintenance rework is infrequent.
20. Contractor work is closely supervised.
21. The PM program does a good job of preventing equipment failures.
22. Predictive Maintenance (PDM) technologies like Vibration Analysis, Thermography and Lubrication Analysis are used as much as possible.
23. PDM often alerts us to problems before they occur.
24. The plant analyzes all equipment failures to determine root cause.
25. Chronic equipment problems are routinely identified and addressed.
26. Maintenance resources are used where they are most needed in the plant; every area or unit gets its fair share.
27. Maintenance labor availability projections are compared with workload several months in advance so that imbalances can be adjusted.
28. Action item lists (who, what, when) are used in most meetings so that we don't lose track of tasks people are supposed to do.

29. Planned outages are completed on time and on budget.

30. Lessons learned from past outages are applied to current outages.

31. Information collected in the computer system (name of client CMMS) is used often and used well.

32. The computer system (name of client CMMS) is accessible to everyone, including crafts; and training is provided on how to use it.

33. Maintenance craft skills are kept up-to-date with effective training programs.

34. Operating and repair decisions are based on long-term economics.

35. The company gives its employees clear goals.

36. Performance, whether individual or group, is thoroughly measured and reviewed.

37. Poor performance is not tolerated.

38. Teamwork between Operations and Maintenance is good.

39. Teamwork between management and hourly employees is good.

40. Management gives me the authority I need to do my job well.

41. Management supports my decisions.

42. I receive the information I need to do my job well.

43. The company consistently looks for ways to improve all of its operations and procedures.

44. My opinions on how to improve are listened to.

45. In general, the plant is going in the right direction.

4

WORK MANAGEMENT IMPROVEMENT

A work management *Improvement Project* is made up of two distinct efforts, one addresses *Work Culture* and the other address *Work Process*. While it is possible to start with either activity, all the improvement projects to date have started with the work culture effort. Plants have chosen this sequence because they expect the most value from improving work culture, and the additional time during the work process effort helps solidify culture changes. In addition, the work culture effort is said to establish a *foundation for change*, making the work process effort go more smoothly. These efforts require allot of time from plant management staff, and it is not practical to do both efforts simultaneously.

Work Culture Efforts

Work culture efforts start by creating a governing body called the *Foundation Team*. The first job of this team is to generate the following three statements: *Mission*, *Vision* and *Values*. Then a list of *out-of-sync-conditions* is generated with input from everyone in the plant. These are conditions that are not consistent with the values defined in the previous step. Then *Action Teams* are formed to analyze and resolve those conditions. Then *Roles, Relationships & Responsibilities* are documented for exempt staff. These are analyzed for gaps and redundancies and the organization changes may occur. Then *Key Performance Indicators* are established and frequently monitored for progress toward plant goals. These indicators are broken down into levels of detail so they can be assigned to individuals and groups. Sometimes it is appropriate to establish *Operational Area Management Teams* which are accountable for certain indicators. This work culture improvement process is illustrated Figure 4-1.

Figure 4-1
Work Culture Improvement Process

Foundation Team & Mission, Vision, Values

The *Foundation Team* is a cross-functional, cross-departmental team. It must be lead by the Plant Manager. This team is designed through discussions regarding employee participation, different prevailing perspectives, buy-in, acceptance, and institutionalization. The result is typically a list of about 24 individuals who represented the diversity of the Plant. This includes representatives from Plant Management, Hourly Personnel and the Union. It is vital that a true cross-section of the organization has a voice so everyone feels ownership of the following statements. *Mission* is a short statement that describes why the Plant exists. *Vision* is a longer statement of what better looks like. *Values* are a lengthy list of important principles for people at the Plant.

Out-Of-Sync Conditions & Action Teams

After development of the *Mission*, *Vision* and *Values* the *Foundation Team* generates a list of conditions that existed at the Plant which are *Out-Of-Sync* with what is desired or valued. To communicate these initial results, the *Foundation Team* holds attendance voluntary meetings throughout the Plant. The information is presented by team members from Management and Non-Management personnel. Additional *Out-Of-Sync Conditions* are solicited from everyone in the Plant.

Out-Of-Sync Conditions are opportunities for improving specific areas of *the Work Culture*. There may be tens or hundreds of *Out-Of-Sync Conditions*. The *Foundation Team* prioritizes the list, perhaps separating some conditions that can be resolved easily.

Then *Action Teams* are then formed to resolve the *Out-Of-Sync Conditions*. Typically about 5 teams are formed to resolve the most important conditions. As they are resolved, new teams are formed to resolve lower conditions on the list. The process followed by Action Teams is shown in Figure 4-2.

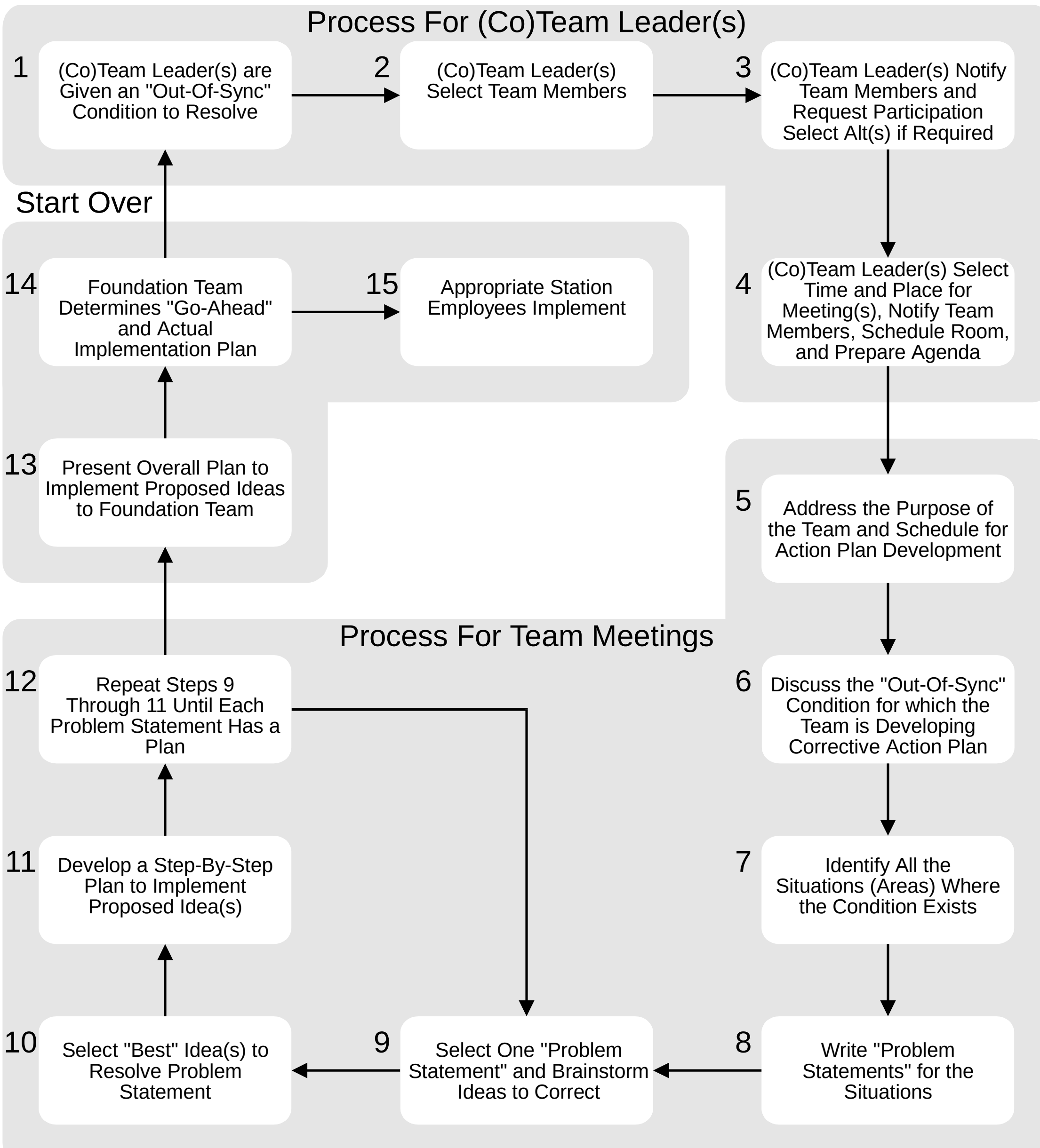

Figure 4-2
Action Team Process

Roles, Responsibilities & Relationships

A document is developed for each of the senior plant staff positions that defines their *Roles and Responsibilities & Relationships* (*RR&R*). This is a type of job description that follows a particular format in order to establish accountability and define measurable performance items. Relationships already exist in the reporting structure, however new customer-supplier Relationships are also defined to support new *Work Processes*. Typically, *RR&R* are developed for the Plant Manager, Superintendents, Supervisors and exempt direct reports.

A *RR&R* document contains the following information:

- Job Title, Division & Department
- Reports To & Direct Report list
- Job Function (described in a few sentences)
- Primary Roles (typically 10 to 20 separate measurable activities)
- Responsibilities (1 to 3 statements defining each role, including customer-supplier relationships)

This *RR&R* document is the basis for an individual's performance evaluation form. Each Role is measured on a scale of: above, at or below expectation. These may be in addition to a standard annual review form, and after time may replace the old form.

Key Performance Indicators & Operational Area Management Teams

The following list of *Key Performance Indicators* (*KPI*) includes items developed for several situations. Each Plant selects indicators that are appropriate to their situation. The indicators are divided into types: plant indicators, work indicators and budget indicators. Depending on the information systems available, they may be measured monthly, bi-weekly or weekly.

Plant Indicators:

- Net MWH Generated (1000's)
- Equivalent Availability (%) (By Unit)
- Equivalent Forced Outage Rate (%) (By Unit)
- Forced Outage Rate (%) (By Unit) or Lost Service Hours (By Unit)

- Net Capacity Factor (%) (By Unit)
- Net Heat Rate (BTU/NKWH) (By Unit)
- Environmental Events (Opacity, NOX, SO2, Water)
- Labor Incidents (Incident Rate, Lost Time Accidents, Outstanding Grievances)

Work Indicators:

- Work Orders (# Issued, # Completed, Total Hours Completed)
- Emergency Work (# WO's, # Hours)
- Work Performance (# WO's Completed, # PM's Completed, % Labor Utilization)
- Non-Outage Backlog (Size Hours, CM's, PM's, Total Work Requests, Crew Hours Available, BL Weeks, BL Weeks @ Util. %)
- Outage Backlog (Size Hours)
- Overtime (Operations Hours, Maintenance Hours)
- Contractor (Non-Specialty Hours)
- Statistics (% Productivity, Average Hours per Work Order, % PM's Completed to Total Completed, % Backlog to Total)

Budget Indicators:

- Budget $ (Payroll, Routine, Non-Routine, Total, Outage, Contractor)
- Budget Variance
- $/Net MWH (Total Operations, Total Maintenance, Total Fuels, Total Direct Expense)
- Materials (Inventory in $, Inventory $ Used, Turnover Rate)
- Purchase Process Time (Days, # Open Requisitions)

Once the *RR&R*'s and *KPI*'s are defined certain patterns emerge. Responsibilities may overlap or some indicators may not be anyone's responsibility. Overlap is reasonable for large responsibilities. Changes in the organization or changes in individual roles may be appropriate. Another possibility is that *Operational Area Management* (*OAM*) Teams should be established for certain responsibilities or indicators. This is a way to establish group accountability. In one *Improvement Project* the following *OAM* Teams were established:

- Water Treatment
- Coal Handling
- Scrubbers
- Continuous Emission Monitors
- One Team For Each Unit (1, 2 etc.)
- Ash Processing
- Mobile Equipment

Work Process Efforts

Work Practice Procedures are developed for about 10 maintenance activities. These include the 6 key activities shown in the next Figure as well as a Change Procedure.

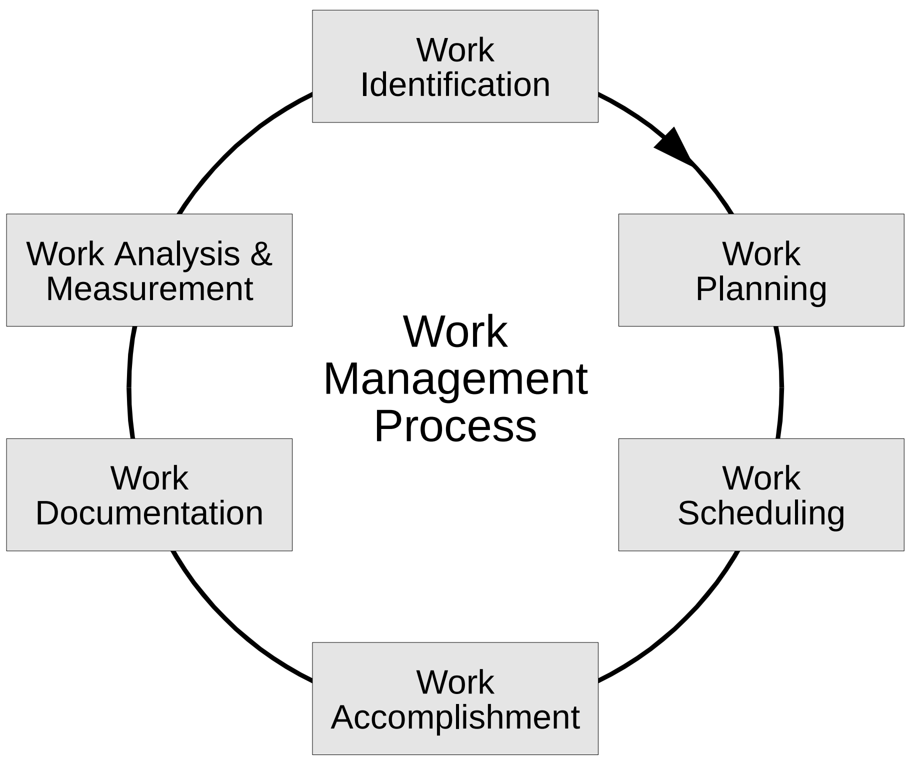

Figure 4-3
Six Key Maintenance Activities

The following list is a compilation of procedures developed in several *Improvement Projects*. Each Plant develops procedures appropriate to their work process.

- Change Procedure
- Work Identification & Approval
- Work Planning
- Backlog Review & Purge
- Long Range Scheduling
- Daily Scheduling
- Work Assignment, Execution & Completion (This optionally may be included in Daily Scheduling above)
- Work Order Closure (or Documentation)
- Operations Check Sheets & Routes
- Work Practice Measurements
- Failure Analysis Program (Optional)
- Stock & Direct Parts Purchasing (Optional)
- Trend Analysis (Optional)
- Drawing Changes (Optional)

Each *Work Practice Procedure* has the following contents:

- Purpose of the Procedure
- Definitions
- Responsibilities
- General Procedure (Detailed Description)
- Procedure Flow Chart
- Optional Material (References, Format, Forms or CMMS Instructions)

The process used to develop these procedures is illustrated in the following Figure. This shows an overseeing team called the *Work Practice Steering Committee* (*WPSC*) assigning procedure development to individual Process Teams. There have also been *Improvement*

Projects where the *WPSC* itself develops procedures, one after another, in order to accelerate the process.

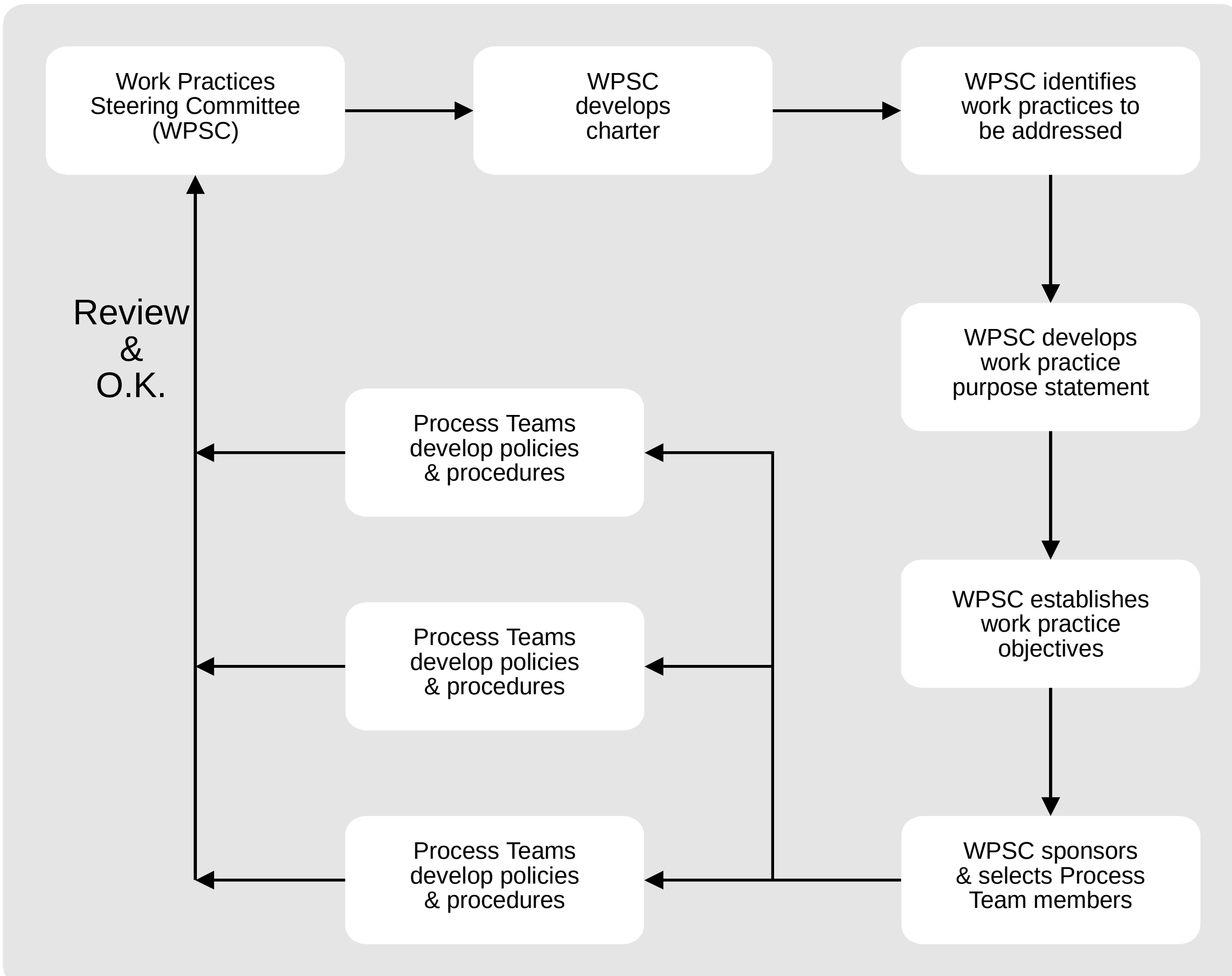

Figure 4-4
Work Practice Development Process

5

TECHNOLOGY AND REINFORCEMENT

Usually near the end of an *Improvement Project*, some of the following *Technology* projects will be undertaken. These complete the balance between the three elements of best practices: *Work Culture, Work Process* and *Technology*.

- Predictive Maintenance Program (PDM)
- Heat Rate Analysis and Training
- Streamlined Reliability-Centered Maintenance Analysis (SRCM)
- Computerized Maintenance Management System Selection or Implementation (CMMS)

In addition, after an improvement effort is completed, there is a periodic *Reinforcement* to keep progress on track and prevent backsliding.

Predictive Maintenance Program (PDM)

This establishes an effective program for determining equipment condition and subsequent timing of maintenance tasks. Ingredients of a good PDM program are that it has: a coordinator, a standard equipment condition report and a standard benefit calculation form. This activity may not increase the number of condition measuring techniques used in a Plant, but it will make better use of existing techniques.

Heat Rate Analysis and Training

This determines the *best achievable* heat rate for each unit and generates recommendations for achieving that heat rate. Analysis includes generation of a theoretical model of the turbines and boilers. Training is given to several groups at the plant which is tailored to their background and responsibility.

Streamlined Reliability-Centered Maintenance Analysis (SRCM)

This analysis technique determines whether it is most cost effective to perform preventive, predictive or corrective maintenance on equipment. In this process, a Plant is typically divided into about 12 systems. SRCM analysis can be performed on a couple of those systems, or all of them.

Computerized Maintenance Management System (CMMS)

This establishes an effective computerized system for documenting maintenance work, thus allowing analysis of equipment and work history. Existing systems may be inadequate, manual, obsolete, hard to use, or perform poorly. This activity can document system needs, evaluate commercial products, implement a system, test the system, and train personnel on the system. Most importantly, the CMMS will be integrated with new *Work Processes* and *Work Culture*.

A

VALUE-BASED MAINTENANCE GRID

Row 1, Work Order

This row is about the basic elements associated with a good work order. It is primarily about the work order itself, that is, what items should be allowed for and entered on the paper copy or automated screens of a work order.

Unique Work Order Number & Record

The work order, beginning with the work request, must have a unique number. A work order is the basis for communicating and recording everything about a maintenance job. It is tracked through the system, paper or computer, by a work order number. The number must be unique so that costs and work history can be associated with a particular job.

Equipment Identification & Label

The work order must have a space for an equipment number. Important equipment should have a unique identifying number assigned to it. The equipment should be labeled with its number and the number should be visible without extraordinary effort. The number is important for associating costs and work history to particular pieces of equipment (it is a complement to the unique work order number).

Complete & Accurate Symptom Description

The work order must have a space for a problem description. The problem description should communicate the symptoms observed. The problem description should be like a visit to the doctor, where the symptoms are carefully described while diagnosis and treatment are left to the professional, which, in this case, is Maintenance.

Clear Priority System

A work order must have a space for a priority designation. A priority indicates the relative urgency of a problem. A clear priority system contains four to five priority designations indicating the response time expected by the order writer.

Defined Approval Process

There should be a space on the work order for approval. An approval process helps to screen out duplicate or unnecessary work orders and serves to inform supervisors of equipment problems. Frequently, the approval process includes both review of work requests and assignment of priority. The approval process brings a broader view to the necessity and prioritization of work. There may also be a regulatory requirement for exempt position review of work requests. Work approvers generally look for: 1) good description of problem symptoms, 2) completeness of the work request, 3) overall necessity of work and, 4) overall priority of work.

Labor & Materials Estimating

The work order should have a space for labor hours and materials required. Labor estimates should be separated into crafts for those work orders that require multiple crafts. Labor and materials estimates are made by the persons responsible for job planning. They may be supervisors or full-time planners.

Acceptance Of Completed Work

Acceptance means the equipment has been released back to Operations. It involves an agreement within the organization as to what constitutes *completed* work. Acceptance should include a pre-run or walkdown of the equipment by Operations, plus job site clean-up by Maintenance.

Labor And Materials Actuals

The work order should have a space for recording the actual labor hours and materials used on the job. Actual labor hours and materials used are the basis of later cost analysis and history. They provide a foundation for problem solving and formal failure analysis at higher levels of the grid.

Complete Work Histories

The work order should have a space for recording what work was done and any special conditions that were encountered. Closure is to work history what acceptance and sign-off are to work completion; both must be timely. Work history is another vital component of maintenance analysis. Work history enables an analyst to review the reasons for failure and the type of repair work done. The analyst may find, for example, that the same seal, valve or bearing is failing regularly, prompting an investigation of the cause of this recurring failure. Most work orders should have work history written on them by crafts.

Organized Filing Systems

All work orders should be filed in a usable, retrievable system for future reference. Filing systems should be organized for all stages of the work order life-cycle, be accessible at all stages (i.e., preliminary, to plan, planned, scheduled, hold, in progress, completed, closed), and be accessible to all personnel. In addition, there should be organized filing systems for equipment drawings and specifications. Filing systems should be found in Operations, Maintenance and Engineering for planned work orders, open work orders and closed work orders for paper systems with multiple forms.

Row 2, Operations-Maintenance Teamwork

Operations is the primary customer of every department, but Operations also has responsibilities to those who supply it with information and services. When such mutual dependency is executed with speed and competence it is called teamwork. This row discusses the basic tasks Operations must do well to be a good team member.

Early Work Identification

There must be an emphasis throughout the organization on identifying work early. Early Work Identification is an aggressive program whose goal is to prevent significant failures. It is proactive, not reactive. It is designed to understand the performance of equipment, to recognize the most subtle indicators of equipment condition and to be attuned to the smallest, significant change in condition. Early identification means problems are caught when they are small and, consequently, equipment downtime and costs are reduced.

Equipment Custody & Preparation

Operations has to make equipment available (i.e., grant custody) for maintenance work. Custody includes time for both corrective and preventive maintenance and the time must be sufficient. It isn’t enough to make a window of opportunity for maintenance available, the window must be large enough to accomplish the necessary work. The equipment must also be clean enough to make the working environment safe and effective. Oil spills and leaks, for example, are commonly the responsibility of Operations.

Clean-Up And Housekeeping

Housekeeping can be the responsibility of Operators, Maintenance crafts or a crew specifically assigned to such duties. In utilities the work is often contracted out and there is a housekeeping supervisor who reports up through Administration, Maintenance or Operations. Housekeeping in that sense consists of floor maintenance more than anything else, where there is sweeping, mopping, vacuuming or use of floor cleaning machines.

Operations Equipment Checksheets & Routes

Operations should have and use routes that define the order and frequency of equipment checks, and checksheets that define the type of monitoring and work done on each piece of equipment. The checksheets should designate High-Low action limits that indicate explicitly what normal and abnormal conditions are and what should be done if abnormal conditions arise (e.g., a differential pressure that goes above the high action limit means the screen should be cleaned). Checksheets and routes are the formal program Operations uses to check equipment operation, process flow and to identify work early.

Clearances & Process Safety Management

A safe work environment requires formal training, written procedures, discipline and measurement. The safety program as a whole must command a great deal of attention from every level in the organization. For maintenance job safety in particular, Operations and Maintenance must work together closely on clearances and lockout/tagout programs.

Internal Customer Satisfaction Process

All departments have internal customers. Internal Customer Satisfaction is a process of identifying, understanding, measuring and meeting the needs of other work groups within the organization, in order to best meet the needs of ultimate customers outside the organization.

Operations Standard Operating Procedures

Standard Operating Procedures (SOPs) institutionalize the way equipment should be run by specifying conditions such as flow rate, temperature, pressure and start-up. SOPs should be derived from a policy of long-term, lowest-cost maintenance consistent with meeting operational goals (e.g., availability and performance). That is, equipment should be run within its sustainable capability and in ways that take into account the cost of corrective maintenance and the value of preventive maintenance. It should be started up and shut down in ways that promote long equipment life.

Operator Certification & Training

Operators have a great deal of responsibility. To fulfill their responsibility they must be trained in a program that leads to certification of their ability to meet the challenges of everything from equipment monitoring to crisis operations. A training and certification program should include conceptual understanding of system operations, practical understanding of equipment operation and the relationship between problem prevention and equipment reliability. Certification and training should be ongoing, that is, re-certification should be part of the process.

Row 3, Work Planning

The work management process has stages consisting of work identification, review and approval, planning, scheduling, execution, sign-off and closure to history. The cells in this row describe the characteristics of a good work planning system, the third stage of this process.

Prioritized & Accessible Planning Backlog

Non-emergency work requests go through the approval (and sometimes, planning) process to become work orders. Emergency work should not be formally planned. All work orders cannot be planned immediately any more than all work orders can be worked immediately. Unplanned work orders are therefore the backlog for the planning function. They must be organized to make them easy to find. The planning backlog must be accessible not only to those responsible for planning, but to Operations and Maintenance personnel who may want to know where a particular work request is in the work order life-cycle.

Labor Hours Planning For Crafts

The most fundamental aspect of job planning is estimating the labor hours required of each craft that will be involved. The next step is to specify craft sequence in order to minimize time wasted by poor coordination or overmanning. Estimated hours by craft are also used to measure the size of the maintenance backlog and change in the size of the backlog. Estimated hours assist daily scheduling and assignment of jobs. Routine and PM/PDM work must have labor hour estimates also.

Materials & Parts Planning

A good job plan specifies parts and materials one could reasonably expect to use for the work described. A list of parts/materials should be on the work order. The planning function, whether planners or supervisors, have researched parts availability. Parts orders may have been initiated. The plan should also indicate whether the parts and materials were reserved through stores and whether they will be delivered to the job site.

Field Job Scoping

Most corrective maintenance jobs should be scoped in the field. That is, the job planner should actually go out to the job site so that job steps and job time estimates can be as precise as possible.

Standard Job Plans

Standard Job Plans are pre-plans for recurring (regardless of time interval) and PM/PDM jobs. Standard job plans contain a work description, step-by-step procedures, labor hour estimates, craft requirements, standard parts and materials, special tools and equipment, and requisite permits and clearances. They are used for quarterly inspections, annual rebuilds, cleanings, projects (e.g., a project to change the shut-off valves in 180 soot blowers, doing 20 blowers per week), routine corrective work and any repeat job where the same work is done each time.

Planning Effectiveness Indicators

Planning is an important part of overall maintenance productivity. It is one of the many areas that must have its own measurement system. A high Maintenance Value organization intensely and consistently measures its performance, especially within functions such as this where measures are not standardized or common.

Craft Participation In Planning

Crafts should assist with, or take sole responsibility for, planning of all or portions of work orders. This includes labor estimates, craft requirements, parts and materials, tools, equipment and permits. Craft involvement in planning makes the plans more accurate in addition to giving hourly workers a chance to buy in to the planning process as a whole.

Outage Planning

The goal of Outage Planning is the shortest possible outage duration consistent with the unit's mission (i.e., some units are so valuable that 24 hour shifts are justified). Any outage that is not forced should be planned, but the degree of planning depends on the scope and duration of the outage.

Row 4, Materials

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Accurate & Organized Inventory

What is thought to be in inventory, and what actually is in inventory, must match exactly. If they do not, time and money are lost. The inventory must also be organized to make items easy to find and to count.

Stock/Tools Issues & Returns

The way in which materials or tools are issued/returned directly impacts inventory accuracy. If procedures are loose or discipline is lax, items may be removed or replaced without a record being made. The accuracy of equipment and work order histories also depend upon good procedures for issues and returns. If work order numbers and/or equipment identification numbers are not always included on requisitions, then tool and material costs can be allocated haphazardly.

Non-Stock Issues & Returns

Material not kept in storeroom inventory (non-stock items) must also be tracked so that materials used are attributed to specific work orders and equipment where applicable.

Receiving & Shipping

Receiving is the first step in the entry of materials into inventory. Proper receiving is necessary for accurate inventory in terms of checking receipts against bills of lading and entering data into the system. Urgently needed material can disappear (i.e., stolen) if procedures are not followed or, receiving can expedite work accomplishment by watching for urgently needed items and immediately notifying the requester.

Quality Assurance/ Quality Control (QA/QC)

The Quality Assurance/Quality Control function (QA/QC) inspects selected, received materials for correspondence to the materials ordered. QA/QC may or may not be a separate group of people. Usually it is a program utilizing personnel from existing departments, especially Materials.

Materials Staging & Delivery

Staging is the collection of material needed for maintenance work prior to the start of work. Controlled access areas are needed for this purpose. There should be pre-staging areas in stores and staging areas in and around the plant. Each staging area gets the materials closer to the jobs site. The ultimate form of delivery is to the job site itself.

Vendor Stocking

Vendor stocking means vendors keep agreed-upon items and quantities on their shelves that they will deliver quickly when requested. In effect, the vendor becomes a remote warehouse. Vendor stocking is used for safety stock on fast moving items and for regular stock on slower moving items.

Vendor Certification & Performance

Vendor performance becomes more and more important to maintenance productivity as the entire materials process approaches Just In Time (JIT). Vendors should go through a certification process that determines they have the facilities, finances, franchises and management commitment to meet performance specifications.

Materials Effectiveness Indicators

A package of measures is important to understand whether and how well fundamental tasks are being performed and what contribution the Materials function is making to maintenance productivity. The measures should encompass customer satisfaction and basic inventory procedures and discipline.

Row 5, Work Scheduling

Work scheduling is the next stage in the work management process, following work planning. Like planning, scheduling includes labor, materials, tools, equipment and coordination. Unlike planning, scheduling includes equipment custody and priority review, so Operations must be intimately involved in many scheduling activities.

Jointly Prioritized Planned Work

Jointly Prioritized Planned Work refers to Maintenance, Operations, Engineering and other departments agreeing on plant maintenance priorities for the next 1-3 weeks. Planned work, i.e., work ready to be scheduled, is jointly prioritized by representatives of each department. Prioritization here refers not to the priority system (1-5) per se, but to the general sequencing of work orders. The original priority assigned by the work author and approver is not changed. Instead, various work orders with the same priority are rank ordered or sequenced since they all can't be done at the same time.

Formal Scheduling Meetings

Engineering and Materials, together to resolve conflicting demands for labor, equipment custody and production. The time frame under consideration is usually one or two days, but can be up to one week. At this meeting backlog work is combined with emergency and urgent work to create a list of immediate work needs (as opposed to the general work needs list developed in Jointly Prioritized Planned Work). Maintenance should bring a rough-cut schedule to the meeting. It is the finalized version of this schedule that is the proper output of the meeting.

Contractor & Plant Coordination

When the plant is resource constrained (e.g., labor, tools or specialized skills), contractors are used for a limited time to complete specific work. Oversight/supervision of contractor crews for safety, quality, housekeeping and productivity should be specifically assigned. Also, the plant population should be notified in advance of the presence of contractors and the nature of the work that will be completed. It is also appropriate to coordinate the work schedules of contractors with each other when multiple contractors are on site and with regular maintenance and operating crews to eliminate competition for space, time, tools and equipment.

Daily Crew Schedule

A daily crew schedule specifies which of today's (this shift's) jobs are assigned to which crew members. The schedule connects specific people with specific jobs, gives the estimated time those jobs should take, allocates a full day's work for each crew member, and states the amount of work that should be accomplished if the job will not be completed on that shift. The daily schedule is developed from the planned work backlog.

Schedule Compliance Review

A Schedule Compliance Review examines which scheduled jobs have been completed on-time and which have not. For those jobs not completed on-time, a cause for the non-compliance is assigned so that causes can be grouped for focused problem-solving.

Periodic Purging Of Backlog

The backlog is a storage place for approved jobs that have not yet been closed. Some jobs never get started, they just aren't important enough or the need for them is eliminated by time and circumstance. For example, a capital project may eliminate the need for repairs, a unit may be decommissioned or an acute condition may fade.

Long-Range Schedules (3 Week Scheduling)

Long-range maintenance scheduling means defining and agreeing to blocks of work that will be done in each of the next three weeks (that's the minimum to be considered best in class, though it can go as high as 10 weeks). The long-range schedule is set by representatives of Maintenance and all its customers. The three week schedule rolls, that is, each week the schedule represents the three weeks following the current week so the three week time frame never shrinks.

Outage Progress Updates

Outage Progress Updates are conducted to assess progress on all work, especially along the outage critical path. Events that affected, or may affect, the critical path are reviewed. Corrective actions are agreed upon, recorded, reported and followed up. Participants should include Operators. The format of the meetings should include daily updates by crew and shift, plus contractors. Job duration changes and the reason for the changes should be reported. The format should also specify reporting periodic job cost estimates, including "committed" costs.

End-Of-Outage Testing & Start-Up

Maintenance, Operations and requisite support groups establish an agreed-upon schedule and responsibilities for pre-op equipment testing and start-up. Support groups agree to activities that need to happen, the specifics of which depend on the content of the outage. These activities are included as part of the original outage planning process.

Post-Outage Analysis & Measurement

A completed outage is thoroughly reviewed and dissected to determine overall degree of compliance with the outage schedule. Maintenance information and data should be recorded and made available for all future maintenance work (i.e., corrective maintenance, PM, next overhaul). Non-compliance and successes are both documented, loose ends are assigned for follow-up and completion. Recommendations are made for future outages. There should be a standard report in a standard format issued from such a meeting.

Row 6, Work Management Tools

The fundamentals of managing any process are Planning, Implementing, Measuring and taking Corrective Action. This row represents the last stage of the work management process in which work has been accomplished, work and equipment history have been recorded, and data is available for analysis and review by management. Seven of the ten cells in this row have to do with measurement.

Backlog Indicators & Trends

The backlog is a valuable source of information about work management. The flow of work into and out of the backlog indicates whether maintenance resources are equivalent to demand. The backlog is also an organizer indicating types and amounts of craft work. It is important to have a package of measures (indicator package) that collects and utilizes the information available from the backlog.

Job Priority Use & Review

Priorities are reviewed in order to minimize priority inflation. When units or areas compete for a centralized maintenance resource they tend to increase (inflate) the priorities of the work orders for their area in order to get their work done sooner. Priority inflation is an example of the squeaky wheel having a better chance of getting greased.

Work Management Effective Indicators

The entire work order life-cycle should be represented in this indicator package. The previous indicator cells were related to specific functions such as Planning, Materials, QA/QC or Outage Management. This cell states that the process as a whole should be measured and monitored. This package will therefore contain both unique indicators and selected overlapping indicators.

Labor Straight Time & Overtime Reports

Labor is a primary, controllable component of maintenance expense. Measuring and monitoring the use of labor is critical to budget control, but it is also important for problem solving. Labor Straight Time and Overtime Reports should be used not only to indicate the rate of consumption of resources, but the reasons for the rate of consumption. Labor consumption is generally divided into categories such as “expense” and “capital.”

Resource Leveling

Resource Leveling means to match the flow of work to the availability of maintenance resources. Plants experience peak resource demand during outages. Plants also experience low work force availability in the form of vacations, disability/sick leave and even hunting season. The idea then, is to anticipate planned workload/work force imbalances and to have contingency plans for unplanned imbalances.

Equipment History & Costs

Equipment history and cost databases are required for: 1) equipment replacement, modification or overhaul decisions; 2) identifying cost reduction opportunities; and, 3) verifying cost reduction successes. The information is critical to the effectiveness of PM, PDM, SRCM, Top Ten Problem List and Structured Problem Solving. The quality and extent of the information depends upon the discipline with which work history is recorded for individual pieces of equipment.

Top Ten Problem List

There should be a list of chronic maintenance problems. Top Ten should not be taken literally, it's fine to have a Top Five List or any other number. Top Ten Problem lists are compiled from downtime reports, equipment history and cost reports, and anecdotal feedback from operators and craftsmen about bad actors.

Availability & Reliability Indicators

Availability is the percentage of total time the equipment could run when demanded. Reliability is the percentage of time demanded the equipment actually does run. Both availability and reliability assume a specified performance level (i.e., quality and quantity).

Financial & General Indicators

Financial indicators tell the price being paid for a given level of availability and reliability (EFOR), plus the overall health of the business. Availability and reliability are two legs of a three legged stool. The third leg is cost. Together, these three indicators tell how well the reliability function is being managed. Just as there are tradeoffs between availability and reliability, there are tradeoffs between these and cost. Reliability and availability can be achieved by capital spending for redundant or replacement equipment and by expense spending for labor and materials. This is reliability at any cost rather than reliability at the lowest cost.

Action Item Lists

Action Item Lists contain assignments, person(s) responsible and due dates. They are fundamental management tools for keeping track of things people are asked to do. In most cases an action list is the only minutes needed for a meeting. An action list should be kept for every regularly scheduled meeting. Due dates should not be allowed to fall back regularly (indicating poor initial choice of due date and/or insufficient effort to complete the assignment). For complex tasks an action item will have sub-tasks called milestones, each with its own due date. Review of action item lists should be a standing agenda item in all meetings.

Row 7, Preventive & Predictive Maintenance

This row represents stepping beyond unplanned, breakdown or corrective maintenance to time-based and condition-based maintenance. This row is about using PM, PDM and SRCM to significantly reduce the cost of production by eliminating some corrective maintenance.

Formal Preventive Maintenance Program

Preventive Maintenance (PM) programs include inspections, calibrations, lubrication, filter changes and other minor/routine maintenance that are time directed, i.e., they are scheduled periodically (e.g., weekly, monthly, annually). This cell could almost be renamed *Time-Directed Maintenance Program*.

Joint Resource Commitment To Preventive Maintenance

Maintenance and its customers must jointly commit to providing the labor hours required to accomplish agreed-upon PM tasks. They must also agree upon equipment custody for the PM's that require equipment shutdown. A successful PM program relies on joint scheduling of PM jobs.

Annual Preventive Maintenance Review

An annual review of Preventive Maintenance is needed to keep the program from becoming irrelevant. PM programs suffer from bloat and ineffectiveness because tasks are often set up on self-serving recommendations from vendors or best guesses from experienced hands. Application of SRCM will improve the effectiveness of PM task selection. PM review, using SRCM, deletes or modifies tasks, and/or their frequencies, that have not proven their effectiveness, and sets up new tasks to anticipate problems found recently. Without review the program becomes stale, real PM task accomplishment drops off due to perceived lack of effectiveness of the program on the part of operators and craftsmen.

Preventive Maintenance Effectiveness Indicators

Preventive Maintenance (PM) Effectiveness Indicators tell us how well the PM program is being run and what results it is achieving. The primary indicators for evaluating effectiveness are Mean Time Between Failure (MTBF), decreasing overall cost of maintenance, and the trend of emergency/urgent work.

Formal Predictive Maintenance Program

Predictive Maintenance (PDM) is also known as Condition Based Maintenance (CBM). PDM uses non-invasive technology to monitor equipment condition. Non-invasive means the equipment doesn't need to be torn down to check its condition. The most common PDM techniques are vibration analysis, lubricant analysis and thermographic analysis.

Predictive Maintenance Effectiveness Indicators

Predictive Maintenance (PDM) Effectiveness Indicators tell us how well the PDM program is being implemented and how effective it is.

Streamlined Reliability-Centered Maintenance

Streamlined Reliability-Centered Maintenance (SRCM) is a cost-effective version of classical RCM that captures most (80%) of RCM's value while saving time and labor.

Row 8, Computerized Management System

The cells in row eight are the characteristics of a good Computerized Management System (CMS). A CMS is a necessary tool for optimizing maintenance for minimum production cost. A CMS centralizes and organizes records storage which are key to the institutionalization of maintenance information. This is invaluable in the maintenance journey from experience-based to information-based maintenance management.

Work Order System & Life Cycle

The Work Order provides the primary data entry into the CMS and consequently contains the majority of the data requirements for maintenance management. The Work Order captures work and equipment history data that is used in decision making associated with virtually all aspects of maintenance management. As such, accurate data on the Work Order combined with an efficient means of data storage and retrieval is vital to an effective maintenance management program.

Flexible Equipment/Org Structure (Table-Driven)

The CMS should provide a flexible means of associating and grouping resources (both equipment and personnel) within the maintenance organization and plant layout without the need of complicated reconfiguration or reprogramming.

Work Management & Backlog Indicators

The work management and backlog indicators are provided by the CMS from work orders entered into the system. The primary indicators are Backlog Input/Output Trends, which indicate the rate at which work is added to the backlog and the rate at which work is completed. For trend analysis, only estimated hours are used for planned and completed work. Actual hours are compared with estimated hours to measure planning accuracy and/or work execution effectiveness.

Equipment Costs & Performance Indicators

Equipment maintenance cost and performance indicators provide a measure of the performance of individual equipment items (Equipment IDs) relative to like equipment (Equipment Types). By comparing Equipment IDs to Equipment Types individual equipment with chronic maintenance problems can be identified for further analysis and corrective actions. Equipment should also be ranked by absolute number of dollars spent to maintain it so that high cost equipment can be reported and analyzed in order to identify R&D and capital replacement opportunities.

Equipment Failure Analysis Structure

Failures are analyzed to reduce costs. The CMS should provide the data necessary for the analysis.

CMS Access & Work Management Training

Access to the CMS by the maintenance department is crucial to CMS utilization. Computer access necessitates the availability of computer terminals connected to the CMS by not only Maintenance management but also by maintenance supervisors, foreman and hourly personnel. In addition, some form of access is required by all employees.

Materials & Purchasing Integration

The materials and purchasing tie-in with the CMS provides coordination between the work order planning and scheduling processes and stores. By providing an on-line storeroom catalog and current inventory, material availability is easily integrated into order planning and scheduling. The planning tie-in allows for material reservation, ordering/order status (through the purchasing tie-in) in addition to use of parts lists in the generation of the work order. The inventory link allows scheduling of the work order in concert with material availability. In addition, the storeroom tie-in allows the generation of pick tickets for material preparation and/or delivery to the work site or staging area.

Unit Loading Schedule Integration

Integration of the CMS with the dispatcher’s loading schedule and plan for the unit.

Accounting & Payroll Integration

The integration of the CMS with the accounting and payroll systems provides labor and equipment cost data to the CMS for cost analysis. More importantly, this interface provides work records to payroll that allows it to initiate payroll action (write checks) for work that has been done. In many cases, this can be a combination of paper and electronic systems.

Row 9, Cost-Effective Technology Utilization

These are advanced techniques that are applied to key equipment and systems to minimize power production costs. The techniques are based on management using advanced technology to support decision making.

Formal Failure Analysis

Failure analysis must be done consistently and rigorously. Failure analysis should encompass the five types of failure: design, normal wear and tear, improper repair, running beyond limits and early-life failures.

Craft Skills Training And Qualifications

Equipment, personnel, technology, products and services all change. There are regulatory, safety and licensing requirements for which crafts must be certified, either on equipment or their skills. Examples include welding, truck driving, emergency response and asbestos removal. As change accelerates so must the training effort.

Unit Capacity Management

Managing unit capacity means investing maintenance resources and capital to sustain a unit's capability in accordance with its mission. Resources are expended to control unit derates and maximize ROI.

Unit Availability Management

Unit availability is a function of both the frequency and duration of equipment outages. The unit mission will determine appropriate levels of availability and corresponding O&M expense levels. High levels of availability at any cost are usually detrimental to attaining ROI goals.

Heat Rate Control

The largest single expense in operating a fossil-fueled power plant is the cost of fuel. It can amount to 80% or more of production cost. Differences between actual fuel consumption and design or upgraded values are expressed and measured as deviations in heat rate, i.e. the amount of chemical energy in the fuel it takes to generate a unit of electrical energy.

Fuel Use Optimization

Relationships among fuel selection and cost, environmental performance, operation, and maintenance are well understood. Key fuel parameters, such as heating value and sulfur and ash content, are linked to plant performance and production cost. Implications of firing alternative fuels are understood.

Networked Information Systems

Open-Architecture means that various computer workstations and data sources talk to each other, regardless of hardware and software differences. Without such integration, new and rapidly changing information systems become *islands of automation* (e.g. computer user workstations isolated from data sources). Open-Architecture eliminates *island hopping* by operations, engineering and maintenance personnel to obtain, analyze and report data, and make decisions on solutions and actions. Ideally, plant staff members should have a single-entry point of access to information necessary to perform their job tasks.

Asset Management

Equipment is evaluated for criticality, with SRCM and data trends, and an asset replacement plan is developed to avoid keeping equipment beyond it's cost effective life span. Similar equipment models and makes are evaluated for performance, compatibility, maintaining costs, and purchasing cost for best organizational spending of the capital expenditures. Data from a computerized maintenance management system is utilized for capital replacement decisions.

Row 10, Work Culture

The objective of the activities in this row is to develop a work environment in which a cost effective combination of people, work processes and technology is used to achieve least-cost power production. Rows one through nine dealt with effective work processes and technology utilization and this row deals with the potential embedded in the human mind and spirit.

Leadership & Goals

Leadership, including clear goals, is required to cost effectively combine people, work processes and technology. Leadership is very complex and difficult to define. Many different styles of leadership can be successful. To narrow this down, a practical definition of leadership that allows objective evaluation is:

Accountability

Accountability is based on performance measurement. Appropriate consequences must follow from objective performance measures. The consequences may be perceived as positive or negative, or even as helpful advice, but they must be consistent and fair. Consistent, fair consequences are the result of easily identified expectations, which, in turn, are the result of clear performance measurement.

Active Communication Channels

The quality of work culture is hugely dependent upon the quality of communication. Communication mechanisms are called channels; they may be meetings, bulletin boards, goals, measures or performance reviews. Active channels are those that are consistently utilized and that flow more than one direction.

Structured Problem Solving

Problem solving should be formal and periodic. Problems addressed should be both technical and managerial. Problem solving should occur across the breadth and depth of the organization. A problem solving methodology should be standardized across the organization and people trained in its application.

Delegated Decision Making Authority

Decisions should be made as close as possible to the situation and the people most affected. Decisions should be supported by upper level management and only over-ridden in the most dire and unusual circumstances. Management by exception should be the general rule where lower level decisions that are not agreed with are overturned with great reluctance (e.g., if they pose some threat to health or safety), but instead lead to some form of coaching so that the decision makers better understand the kind of decisions desired by upper management.

Innovations & Continuous Improvement

Innovations are great leaps forward. Continuous improvement is many incremental changes. The best organizations embrace innovative and continuous improvement. That is, it isn't enough to get better, the organization must get better fast, and it must continue to improve even when it is very good already because the competition is always gaining.

Technical & Managerial Training

All levels, all departments should be involved in continuing education. Both technical and managerial topics should be addressed. Training should be based upon clear need. Training should be a mutual selection of those most affected and management.

Self-Managed Teams & Teamwork

Teams should be accommodated by the organizational structure. Teams should form around the work to be accomplished. Self-managed teams make decisions such as hiring & firing, work hours and goals without a supervisor. Management and the team agree on criteria for success and are rewarded as a team.

Total Customer Satisfaction

Row two dealt with the need for an internal customer satisfaction process among the departments of a power plant. This cell deals with a similar process that should exist for customers and sister organizations of the plant. For example, the plant's primary customer is the power grid. The power dispatcher and others who may represent that customer should have their needs specifically identified. In turn, the dispatcher should understand the plant's operating needs. The plant also interacts with sister plants, corporate functions like central purchasing, accounting, legal, Human Resources and design engineering, and with plant stakeholders such as the community in which it is located. All of these entities are plant customers.