EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Developing and Implementing an Asset Health Management Program

1023067

Division	Unit	USI	EQUIP TAG	EQUIPMENT DESCRIPTION	Overall Condition Status	THERMOGRAPHY	LUBE OIL	VIBRATION	MOTOR TESTING OFF-LINE	MOTOR TESTING ON-LINE	PARAMETER MONITORING (SMART SIGNAL)	OPERATOR ROUNDS	ENGINEER WALKDOWN
BA	Unit 3	33120A	3-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	06/16/10	04/27/10	06/16/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	06/17/10	04/27/10	06/17/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	07/09/10	04/27/10	07/09/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	07/09/10	04/27/10	07/09/10	06/25/09					
BA	Unit 4	33120A	4-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	05/11/10	07/08/10	05/11/10	02/18/10					
BB	Unit 5	33120B	5-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 6	33120B	6-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	05/25/10	08/17/10	06/01/10	08/11/10	05/25/10	07/21/04			
BB	Unit 6	33120B	6-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	08/17/10	08/17/10	06/01/10	08/11/10		07/21/04			
BB	Unit 6	33120B	6-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	08/17/10	08/17/10	06/01/10	08/11/10		07/21/04			
BB	Unit 6	33120B	6-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	08/17/10	08/17/10	06/01/10	08/11/10	05/20/10	07/21/04			
BB	Unit 7	33120B	7-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 8	33120B	8-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	08/19/10	08/19/10	07/16/10	07/21/10	05/25/09				
BB	Unit 8	33120B	8-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	08/19/10	08/19/10	07/16/10	07/21/10	05/25/09				
BB	Unit 8	33120B	8-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	07/22/10	07/22/10	07/16/10	07/21/10	05/06/09				
BB	Unit 8	33120B	8-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	01/14/10	01/14/10	07/16/10	07/21/10	05/25/09				

Legend:
- A - Acceptable
- N - Not Running/Inadequate Load
- P - Pending
- W - Watch List
- M - Marginal
- U - Unacceptable
- N/A - Not Applied
- Baseline Data (First time taken)

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1023067

Technical Update, December 2011

EPRI Project Manager

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This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

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ABSTRACT

In 2009, the Electric Power Research Institute's (EPRI's) Maintenance Management and Technology program worked with its member companies to develop an overview that described the functionality of a system health management program. Since that time, EPRI and its members have also worked on initiatives that focus on component health management and performance monitoring. To encompass these similar and integrated initiatives, EPRI has more recently focused on the broader concept of asset health management.

Asset health management (AHM) programs are a growing trend within the electric power generation industry. The concept of AHM builds on the component and system engineering programs that have been prevalent throughout the industry, particularly at nuclear power stations. An AHM program provides the means to assess and compare the current health status of numerous dissimilar assets across a system, unit, plant, or fleet. This includes operational trends, material conditions, performance and efficiency, maintenance strategies and actions, and many other elements that contribute to an asset's overall health. An AHM program provides the structure and processes to integrate data and information from a variety of sources, uniformly assess these data and information, and—ultimately—produce an objective comparison of the health of multiple assets.

The objective of this report is to identify best practices for organizations that would like to build an AHM program, given the limited resources afforded to fossil-fueled power generation organizations.

Keywords

Asset health management
Component health monitoring
Maintenance basis optimization
Material condition assessment
System and equipment ranking and prioritization
System health monitoring

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INTRODUCTION TO ASSET HEALTH MANAGEMENT

Background

In 2009, EPRI's *Maintenance Management & Technology* program worked with its member companies on developing an overview describing the functionality of a system health management program [1]. Since that time, EPRI and its members have also worked on initiatives that focus on component health management and performance monitoring. To encompass these similar and integrated initiatives, EPRI has since focused on the broader concept of asset health management.

Asset health management (AHM) programs are becoming a growing trend within the electric power generation industry. This concept of AHM looks to build upon the component and system engineering programs that have been more prevalent throughout the industry, particularly at nuclear power stations. An AHM program provides the means to assess and compare the current health status of numerous, dissimilar assets across a system, unit, plant, or fleet. This includes operational trends, material conditions, performance and efficiency, maintenance strategies and actions, and many other elements contributing to an asset's overall health. An AHM program provides the structure and processes to integrate data and information from a variety of sources, uniformly assess this data and information, and – ultimately – produce an objective comparison of the health of multiple assets.

AHM programs can be a key element to sustaining high levels of equipment and plant reliability in today's environment of plant operations and maintenance, where resources have been minimized. The integrated information can be used for decision making to most effectively prioritize and apply resources where most appropriately needed. This can help promote sustained plant material condition and, thereby, help optimize plant reliability and performance.

Objective

The purpose of this report is to provide guidance and assistance to organizations interested in establishing an AHM program. Due to the nature of these programs, building an AHM program from scratch can be an overwhelming task. Numerous steps must be made from the outset, including:

- defining the program and its objectives
- establishing the organizational structure and responsibilities to support the program
- scoping of the implementation project
- identifying critical assets to include in the program
- determining AHM metrics and assessment parameters
- developing processes, guidelines, and/or algorithms for aggregating data and metrics
- selecting technology and software to facilitate the program

The objective of this report is to identify best practices for organizations looking to build an AHM program with the limited resources afforded to fossil-fueled power generation organizations.

Asset Health Management in a Plant Reliability Program Structure

An AHM program should be viewed as a subset of a comprehensive plant reliability program. To gain a better understanding of the purpose of AHM in the context of a plant reliability program, it is helpful to view a plant reliability program as a whole. There are many processes and program elements that must be accounted for in a plant reliability program. It is important to understand these processes and elements, as well as the role each plays in supporting a comprehensive plant reliability program. A comprehensive plant reliability program includes five major categories and sixteen significant elements. These categories and elements are outlined below and can also be illustrated in a "Plant Reliability Excellence Matrix" (Figure 1-1).

- Plant Reliability Processes (Category 1)
  - Equipment Reliability (Element 1)
  - Work Control/Work Management(Element 2)
  - Work Execution (Element 3)
- Management and Business Planning Practices (Category 2)
  - Setting Goals & Business Planning (Element 4)
  - Organization (Element 5)
  - Leadership & Accountability (Element 6)
  - ER & AHM Program Communication (Element 7)
- Workforce Performance and Continuous Improvement Culture (Category 3)
  - Benchmarking (Element 8)
  - Measuring Performance/Metrics (Element 9)
  - Human Performance (Element 10)
  - Continuous Improvement (Element 11)
- People Skills and Knowledge (Category 4)
  - AHM Program Training (Element 12)
  - Qualifications (Element 13)
  - Knowledge Capture & Management (Element 14)
- Asset Management and Equipment Reliability Technology Application (Category 5)
  - Work Management & Diagnostic Technologies (Element 15)
  - Information Integration Technologies (Element 16)

Plant Reliability Excellence Matrix

1.0 Processes	ER Processes	Scoping/ID Criticality	Equip Cond. & Perf. Monitoring	PM Implementation	Reliability Analysis & PM Basis	Corrective Action/Proactive M&E	Long Term Asset Mgmt. & Planning
	Work Control	On-line/Outage Work Control Process	Work Prioritization & Risk Assessment	Stores & Inventory Management	Planning	Scheduling	Contract Management
	Work Execution	Work Execution Procedures	Equipment Clear/Tagging	Tools/Material Control/Staging	Pre-Job Briefs	Perform Maintenance & Work Quality	Safety
2.0 Management & Business Culture	Goals/Business Plan	Business Planning & Plant Health	Business Goals	N/A	N/A	N/A	N/A
	Organization	Roles & Responsibilities	Organizational Design	Core Competencies	Contracted Support	Facilities	N/A
	Leadership/ Accountability	Direction	Discipline/ Accountability	Process & Program Ownership	System Ownership / System Health	Component Ownership / Component Health	Empowerment & Motivation
	Communication	Operations, Maintenance, and Engineering	Management to Workforce	Workforce to Management	Peer Groups	N/A	N/A
3.0 Performance & Work Culture	Benchmarking	Within Industry	Outside Industry	N/A	N/A	N/A	N/A
	Metrics	Departmental Goals	Plant Goals - ER Index & ER Event Clock	Personal Goals	Customer Satisfaction	N/A	N/A
	Human Performance	ER/MC Fundamental Behaviors	Human Error Prevention Program	Teamwork	N/A	N/A	N/A
	Continuous Improvement	Self-Assessment	Change Management	Process Improvement	Research & Development	Use of Industry OE	N/A
4.0 Skills & Knowledge	Training	Processes & Policies	Personnel Skills Development	System & Equipment Training	Management & Supervisor Development	AHM & ER Process	Training Facilities
	Qualifications	Personnel Selection	Qualification Process	Succession Planning	N/A	N/A	N/A
	Knowledge	Knowledge Capture	Knowledge Management	N/A	N/A	N/A	N/A
5.0 Technologies	Work Mgmt & Diagnostics	CMMS	CAP	Cond. Monitoring Technologies	Performance Monitoring & Diagnostics	N/A	N/A
	Information Integration	Scoping / ID Criticality	Equipment Condition & Performance Monitoring	PM Implementation	Reliability Analysis & PM Basis	Proactive Maintenance	Long Term Asset Mgmt. & Planning

Figure 1-1
Plant Reliability Excellence Matrix

Plant Reliability Processes, 1.0

The processes (Processes 1.0) in the Plant Reliability Excellence Matrix are categorized as **Equipment Reliability** (ER), **Work Control/Management**, and **Work Execution**. The sub-processes related to **Equipment Reliability** are the most important elements of implementing an effective AHM program. These **s**ub-processes and related attributes of industry good practices are described as follows:

<u>Scoping and Criticality Determination:</u> Development and management of a high quality Master Equipment List (MEL) to identify assets and the application of criteria to establish the relative criticality or importance of each major plant asset.

<u>Equipment Condition & Performance Monitoring:</u> Monitoring and reporting systems for component performance to identify anomalies early and provide information to most effectively maintain equipment.

<u>PM Program Implementation:</u> Once a preventive maintenance (PM) program is established, PM tasks are prepared, identified in the computerized maintenance management system (CMMS), scheduled in a work management process, and accomplished within specified grace periods.

Reliability Analysis and PM Basis: System and component failure modes are identified. Time-directed and condition monitoring tasks for monitoring and preventing these failure modes are also identified, as well as the technical basis for performing these tasks. This PM basis is to be effectively maintained and continually improved.

Corrective Action & Proactive Maintenance: Documenting and utilizing maintenance feedback, traditionally through a corrective action process (CAP), and performing appropriate root cause and apparent cause evaluations when warranted.

Long Term Asset Management / Planning: Identifying long term equipment degradation mechanisms, determining remaining useful life of major components, and planning large-scale projects to optimize long term plant performance and reliability.

The **Work Control/Management** and **Work Execution** sub-processes include various elements pertaining to prioritizing, planning, scheduling, and effectively executing work that is identified by the ER sub-processes:

Management and Business Elements, 2.0

Many elements of management and business culture influence the ability of an organization to successfully implement an AHM program. An organization must establish the policies and strategy of the program, set goals and objectives, create an organizational structure to support AHM processes, and communicate a significant amount of information throughout the organization.

Workforce Performance & Work Culture, 3.0

The performance and culture of the workforce can significantly influence an organization's ability to implement an AHM Program. Behaviors associated with low tolerance for equipment failure are required to be successful, as well as a culture that is proactive, uses metrics to understand performance, and then strives to continuously improve upon these metrics. This is required due to the proactive nature needed to anticipate and/or react appropriately to equipment anomalies and failures.

People Skills & Knowledge, 4.0

Sustaining the level of skills among the workforce has recently become one of the most significant risks to fossil power generating companies. Workforce turnover is resulting in the loss of expertise and knowledge, and new staff often lack the training and competencies to fill these voids. Training and qualifications for these new ER and AHM processes and technologies must be well managed. Top tier organizations have also recognized worker knowledge as an asset that must be appropriately captured and managed to sustain high levels of equipment reliability.

Plant Reliability Technologies, 5.0

To effectively implement new plant reliability processes, new applications and technologies will be required to manage and automate the flow of information between processes. Because of this, new roles and responsibilities will be required to address these new technologies. If the appropriate technologies are not strategically applied, organizations struggle with accomplishing the required functions of a highly proficient work environment. Software technology to support the automation of the various equipment reliability processes should be applied to allow the limited resources to accomplish these processes effectively.

There are various work management and equipment-related technologies available. Some examples include computerized maintenance management systems (CMMS), condition monitoring tools, corrective action systems, on-line monitoring (OLM) systems, and advanced pattern recognition (APR) tools.

Implementation of an Asset Health Management Program

Each of the categories, elements, and sub-elements included in the Plant Reliability Excellence Matrix contribute to optimizing the reliability and performance of plant assets. Every organization has varying levels of proficiency relating to each element and sub-element and is uniquely challenged to determine where to focus improvement efforts to optimize plant reliability. The objective of an AHM program is to assist an organization in achieving and sustaining high levels of proficiency with respect to relevant categories, elements, and sub-elements.

With respect to AHM programs, there are several key tasks that must be addressed in order to achieve successful implementation of a program. These implementation steps represent the structural theme of this report and will each be addressed in greater detail in subsequent sections. These steps include:

- Identifying the scope and key AHM processes
- Developing the appropriate process and policy guidance to provide AHM program direction
- Organizational considerations for optimizing the AHM program
- Establishing plant health and equipment reliability meetings
- Measuring the performance and results of the AHM program
- Establishing training and communications for implementing and improving an AHM program
- Selecting tools (software) to automate key AHM process elements

2
SCOPING AN ASSET HEALTH MANAGEMENT PROGRAM

In order to successfully implement an asset health management (AHM) program, there are several requirements that must be addressed. These requirements can be organized into a series of steps that provide a sequential structure for AHM program implementation. One of the first steps involves establishing a program scope. In this step, objectives and goals must be identified, as well as key processes and procedures. This section of the report provides guidance for defining the scope of an AHM program and includes the following:

- Master Equipment List
- System and Equipment Ranking and Prioritization Process
- Maintenance Basis
- Material Condition Assessment Process
- Component Health Monitoring Process
- System Health Monitoring Process
- Equipment Reliability Meetings

Establishing a Master Equipment List

An important foundation to any AHM program is a comprehensive list of all the physical systems and equipment that are to be managed and maintained by the organization. This list is often referred to as a Master Equipment List (MEL), Master Equipment Database, or some other equivalent naming convention. It should be noted that in addition to providing asset management, engineering, and technical specifications, an organization’s MEL also provides critical information such as the location, clearance points, age of equipment, in-service date, operational and maintenance history, efficiency of operation, applicable spare parts, etc. Other information included in the equipment records are parameters such as baseline performance data acquired in the commissioning phase, operational data (e.g., the number of operations performed by a switch or breaker), and average, minimum, and peak load carried by electrical components. Consequently, the MEL serves as the foundation of an economically sustainable operational basis. The suggested fields that should be completed for a comprehensive MEL are shown in Table 2-1.

Table 2-1
Examples of Suggested MEL Fields

• Plant Name
• Unit Number
• System Name
• Sub-system Name (if applicable)
• Component Name
• Component Description
• Unique Identification Number (UNID)
• Clearance Points
• Age of Equipment
• In-Service Date
• Operational History
• Maintenance History
• Efficiency of Operation
• Applicable Spare Parts (BOM)
• Baseline Performance Data
• Average, Minimum and Peak Loads (as applicable)
• Component Classification, e.g. Critical, Non-Critical, Run-To-Failure
• Associated Drawing Numbers, e.g. P&ID, Electrical Single Line Diagram
• Component Name Plate data
• Preventive Maintenance (PM) Tasks
• PM Task Descriptions
• PM Task Frequencies
• PM Task Duration
• PM Task Material Requirements
• PM Task Labor Requirements
• Notations and /or Comments

Not all suggested MEL fields are always available or captured by every utility. An example of a typical MEL is provided in Figure 2-1.

APS PLANT / UNIT: Four Corners / 4 & 5

Date: 9/7/11

System Name: Fuel System

Sub-System Name: Coal Handling (Partial)

COMPONENT - UNID - MASTER EQUIPMENT LIST

Drawing Details - P&ID or One Line E						Current MAXIMO Identification		New MAXIMO UNID		Notations
No.	Component Name	Description	APS DWG/Sheet	APS TAG NO.	VENDOR TAG NO.	Current Maximo Location	Current Maximo Long Description	UNID	Equipment Reliability Component Classification (CC, NC, or, RTF)	
		COMMON	COMMON	COMMON	COMMON	COMMON	COMMON	COMMON	COMMON	
1	Conveyor	Main coal supply	82117	5185 (South)	Utah 5185	BCHCB - 2B BELT	B - Coal Handling Belts (2B)	FC00-FS-CH-CNV-002B	CC	Owned and maintained by Utah International
2	Conveyor	Main coal supply	82117	5187 (North)	Utah 5187	BCHCB - 2A BELT	B - Coal Handling Belts (2A)	FC00-FS-CH-CNV-002A	CC	Owned and maintained by Utah International
3	Surge Bin	South Side	82117	A		CCHSB - SURGE BINS	C - Coal Handling Surge Bins	FC00-FS-CH-SGB-000A	CC	1500 Ton
4	Surge Bin	North Side	82117	B		CCHSB - SURGE BINS	C - Coal Handling Surge Bins	FC00-FS-CH-SGB-000B	CC	1500 Ton
5	Surge Bin Exhuaster Fan	1 for both surge bins	82117			CCHSB - SURGE BINS	C - Coal Handling Surge Bins	FC00-FS-CH-FAN-001	NC	Check on this, top of surge bin
6	Conveyor 6	42" conv to 3A/B or Conv 7	82117	CONV6		BCHCB - 6 BELT	B - Coal Handling Belts #6 (Parent = BCHCB - SYSTEM)	FC00-FS-CH-CNV-006	NC	1200 TPH max
7	Conveyor 7	42" conv to emerg. storage pile	82117	CONV7		BCHCB - 7 BELT	B - Coal Handling Belts #7 (Parent = BCHCB - SYSTEM)	FC00-FS-CH-CNV-007	NC	1200 TPH max
			UNIT 4	UNIT 4	UNIT 4	UNIT 4	UNIT 4	UNIT 4	UNIT 4	UNIT 4
8	Tripper 4A		82117	4A		BCHCB - 4A TRIPPER	B - Coal Handling Belts Tripper (4A)	FC04-FS-CH-TPR-004A	NC	
9	Tripper 4B		82117	4B		BCHCB - 4B TRIPPER	B - Coal Handling Belts Tripper (4B)	FC04-FS-CH-TPR-004B	NC	
10	Silo 4-1	to unit 4 coal feeders	82117	4LS 4-1		BCHCB - CHUTES & TOWERS	B - Coal Handling Belts Chutes, Tower, Silo	FC04-FS-CH-SLO-041	NC	
11	Silo 4-2	to unit 4 coal feeders	82117	4LS 4-2		BCHCB - CHUTES & TOWERS	B - Coal Handling Belts Chutes, Tower, Silo	FC04-FS-CH-SLO-042	NC	
12	Silo 4-3	to unit 4 coal feeders	82117	4LS 4-3		BCHCB - CHUTES & TOWERS	B - Coal Handling Belts Chutes, Tower, Silo	FC04-FS-CH-SLO-043	NC	
13	Silo 4-4	to unit 4 coal feeders	82117	4LS 4-4		BCHCB - CHUTES & TOWERS	B - Coal Handling Belts Chutes, Tower, Silo	FC04-FS-CH-SLO-044	NC	
			UNIT 5	UNIT 5	UNIT 5	UNIT 5	UNIT 5	UNIT 5	UNIT 5	UNIT 5
14	Silo 5-1	to unit 5 coal feeders	82117	5LS 5-1		BCHCB - CHUTES & TOWERS	B - Coal Handling Belts Chutes, Tower, Silo	FC05-FS-CH-SLO-051	NC	

Figure 2-1
Master Equipment List (MEL) Example

Identifying, Defining, and Standardizing Systems and Equipment

One of the primary benefits of establishing standards for a MEL is that it provides a baseline for consistency that can be applied across a fleet. Consequently, this process of establishing consistent standards can introduce significant challenges. When developing a MEL for the first time to standardize systems and equipment, it is important to ensure that representatives from all plants are part of the standardization team. This is especially important if the fleet is comprised of several different types of plants (i.e., coal-fired, simple cycle, combined cycle, etc.) in which each plant has defined different system names, system boundaries, equipment hierarchies, etc. The standardization team should also include a corporate representative and, if possible, representatives from information management and technology (IT). These representatives will be responsible for determining standard nomenclatures, classifications, boundaries, and definitions for all physical assets (e.g., systems, sub-systems, components, equipment, etc.). They will also be responsible for defining unique number identification (UNID) formats that will be used to classify all defined systems, subsystems, component types, and equipment identifiers. The magnitude of this task is sometime underestimated. Developing the MEL is dependent upon:

- The size of the utility
- The size and configuration of the plants owned and operated
- The current state of each plants drawings
- The current state of components existing in the each plant’s CMMS and their associated existing unique number identifications (UNID) (if applicable)

An outline of steps to take to standardize a MEL across a fleet is as follows:

1. Assemble the standardization team.
2. Gather all plants drawings (e.g., piping and instrumentation diagrams – P&IDs – and electrical single line drawings).
3. Review drawings and develop lists of existing drawings for each identified system and/or component. This list should be independent of any list generated from the computerized maintenance management system (CMMS), as all components may not be in the CMMS.
4. Generate a list of existing systems and components from the CMMS.
5. Develop a systems boundary description document for each system that identifies all system boundaries.
6. As a team, compare system lists, sub-systems list (if applicable), and system boundary lists and begin deliberations on developing a standard systems / sub-systems (if applicable) list for the entire fleet.
7. Once the new systems list is agreed upon, define the system boundaries that are applicable for all plants across the fleet.
8. Once systems and system boundaries are completed, define the unique number identification (UNID) hierarchy format that will used going forward (Figure 2-2).

PLANT	UNIT	SYSTEM	SUBSYSTEM	EQUIPMENT	LOCATION
CH - Cholla	00	BP – Balance of Plant	CA – Compressed Air	PMP - Pump	001A
FC - Four Corners	01	BH – Bag House	FH – Fly Ash Handling	PLV - Pulverizer/Mill	001B
OC - Ocotillo	02	BO - Boiler	BA – Boiler Air	MOV - Motor-operated valve	001C
RH - Redhawk	03	HC - Heat Cycle	CS - Condensate	AOV - Air-operated Valve	002
SA - Saguaro	04	TG - Turbine	FA – Fly Ash	RCV - Receiver	023Y
SU - Sundance	05	WW – Waste Processing	CE – Continuous Emissions	ACU - Accumulator	
WP - West Phoenix	06	DM - Dams	GE - Generator	FAN - Fan	
YU - Yucca	07	DC – Distributive Controls	NP – NPDES Sump Systems	FLT - Filter	
	08	CT – Combustion/Gas Turb	FP – Fire Protection System	TNK - Tank	
	09	FS – Fuel Supply	MV – 4160 Voltage		
	10				
	23				
	45				

NEW DEVELOPED UNID

UNID	Long Description (Currently in Maximo)
CH01_BP_CA_CMP_001A	Instrument Air Compressor 1A
FC05_HC_FW-PMP_001B	Boiler Feedwater Pump 1B

Figure 2-2
Unique Number Identification (UNID) Hierarchy Example

1. Develop a standard format and set of fields to be included in the MEL (Table 2-1).
2. Compare all CMMS equipment lists to lists generated from the drawing reviews for each system. Create an overall equipment list representing an integration of these two lists.
3. Document the MEL for assigned systems, including all required MEL fields UNID for each component. Separate UNIDs should be assigned for the driver and driven components (i.e., fan and motor combinations; compressor, gearbox, and motor combinations; pump, hydraulic coupling, and motor combinations, etc.).
4. Incorporate into the CMMS.

Selecting Systems and Equipment to be Included in the Asset Health Management Program

The typical methodology for selecting systems and components to be included in an AHM program is through the determination of the component classifications relating to equipment reliability (ER) and operations. The component ER classification is the process of determining if a component is *critical, non-critical,* or *run-to-failure (RTF)*. This process is typically performed by a determining a component's **Importance Level**, a numerical prioritization value assigned to a component that is driven by the effects or consequences of a component failure.

Critical Equipment: (Importance Levels 1 through 5). An equipment failure or degraded performance would create one of the following effects:

Importance 1 - Results in unit trip or full load loss.

Importance 2 - Results in a 40 percent power derate below normal full load.

Importance 3 - Results in a significant derate 20 percent below normal full load.

Importance 4 – Results in no derate, but possible generation loss due to extended asset failure.

Importance 5 – Results in potential loss of generation due to failure of redundant equipment.

Non-Critical Equipment: (Importance Levels 6 through 9). An equipment failure or degraded performance would create one of the following effects:

Importance 6 - Loss of asset causes loss of auto function to multiple equipment and or systems.

Importance 7 - Loss of asset causes significant operational inconvenience.

Importance 8 - Loss of asset precludes normal system or equipment operation.

Importance 9 - No effect.

Run-to-Failure Equipment: Equipment that does not affect safety, reliability, or environmental regulation and is more economical to run-to-failure than to perform preventive maintenance.

The operating classification is an assessment of three operating parameters in which a component performs its function. These three parameters include:

Critical/Non Critical Assessment: May be determined by the importance level assigned to the component failure – *critical*, *non-critical*, *RTF*, or undefined.

Service Condition: The two categories for the operating environment are *harsh* and *non-harsh*. Harsh environments could include one or more of the following conditions: temperature extremes, toxic or caustic medium, high pressure fluids, prevalent coal dust, salt water, high humidity, dirty or greasy environments, etc. Non-harsh environments may include heated or cooled enclosures, clean environments, or sheltered from external atmospheric conditions.

Duty Cycle: The two categories for the usage are *frequent* or *seldom*. Frequent usage includes numerous start and stop cycles or continuous duty service. Seldom usage involves infrequent use, such as only during plant startup or shutdown.

Establishing the System and Equipment Ranking and Prioritization Process

In most organizations, a formal backlog of work exists that is comprised of projects and jobs relating to maintenance. From this backlog, activities are selected, planned, and scheduled by the organization to be completed and removed from the backlog. While this method ensures that activities are completed, it does not ensure that work is completed in the order of its priority relative to the organization's strategy, goals and objectives. This is especially prevalent when resources are insufficient to complete assigned activities at the same rate as they are identified.

In order to effectively prioritize emerging work as well as backlog activities, the first step taken must be to establish a process for prioritizing work orders. Such a process typically begins by establishing a methodology to consistently rank and prioritize all critical systems and equipment with respect to the relative importance of each asset to the organization's mission, strategy, goals, and objectives. One such process of prioritizing and ranking of systems and equipment is referred to as the system and equipment ranking and prioritization (SERP) process. The process of ranking each individual system results in a system criticality ranking (SCR) value for each system. The process of ranking each individual piece of equipment results in an operational criticality ranking (OCR) value. The product of SCR and OCR results in an asset criticality ranking (ACR). The product of the ACR can then be combined with the asset failure probability factor (AFPF) to generate a corresponding maintenance priority index (MPI). A system's or equipment's MPI is essentially an absolute number that identifies the relative importance of one system or equipment to another. A high level outline of the prioritization process is provided in Figure 2-3:

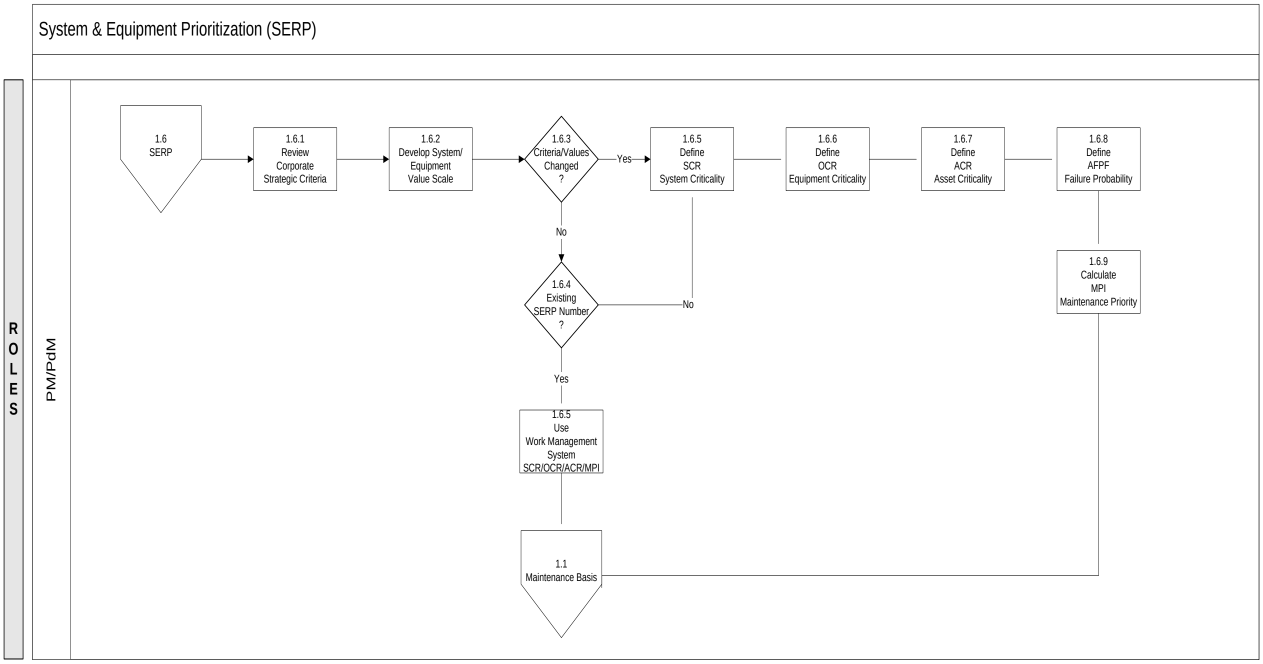

Figure 2-3
System and Equipment Reliability Prioritization (SERP) Process

The objective of the SERP process is to develop a comprehensive listing of an organization's critical assets relative to the strategic direction and criteria of the organization. Once the criticality of each system or component is consistently identified, the priority of a work order can assigned as a function of the asset's MPI.

As part of the process, the organization will periodically evaluate the importance and/or value of each system, sub-system, component, or group of components to ensure alignment with the organization's strategic criteria. In each case, the value or importance of a particular system will need to be ranked by all stakeholders in the organization in reference to the strategic values at the system level. The strategic criteria are generally defined amongst the leadership team prior to the actual ranking exercise. Similarly, the value or importance of a particular component will also be ranked by all stakeholders in reference to a different set of strategic values at the component level. Again, the strategic criteria are defined by the leadership team prior to the actual ranking of the components. As part of the process, the resulting ranking of all assets will also be reviewed regularly.

Once this effort has been completed, the resulting itemized list of systems and components, their respective ranking, and the criteria used in the ranking will be incorporated into the organization's CMMS.

The SERP ranking process constitutes a proven tool that is used extensively throughout the industry to identify and document the criticality of systems and components. Risks to successful completion of SERP include the lack of data that will permit the organization to define the criticality, the availability of resources to perform the ranking, and an incomplete or inaccurate MEL. Once the SERP ranking has been completed, the biggest challenge to the organization is to ensure that newly added system and equipment information is appropriately entered in the MEL, and that the responsibility of ranking each new system or component is consistently and effectively managed.

Establishing the Maintenance Basis

An organization's maintenance basis clearly defines the combination of preventive, predictive and proactive maintenance activities to be performed on specific systems and equipment. This combination of maintenance activities are those that are expected to maximize the expected service life while minimizing life cycle expenditures. The primary objective is to foster the development of system and equipment specific maintenance strategies that can be realistically resourced and implemented. It is imperative that an organization assign resource requirements (i.e., labor, materials, and directs) to each maintenance activity based on the frequency outlined in its maintenance basis and the respective number of assets to be maintained. Once defined, the resource requirements of all activities can be aggregated and summarized to evaluate if the current level of resources is sufficient, if additional resources are required, or if the basis needs to be adjusted to fit economic realities.

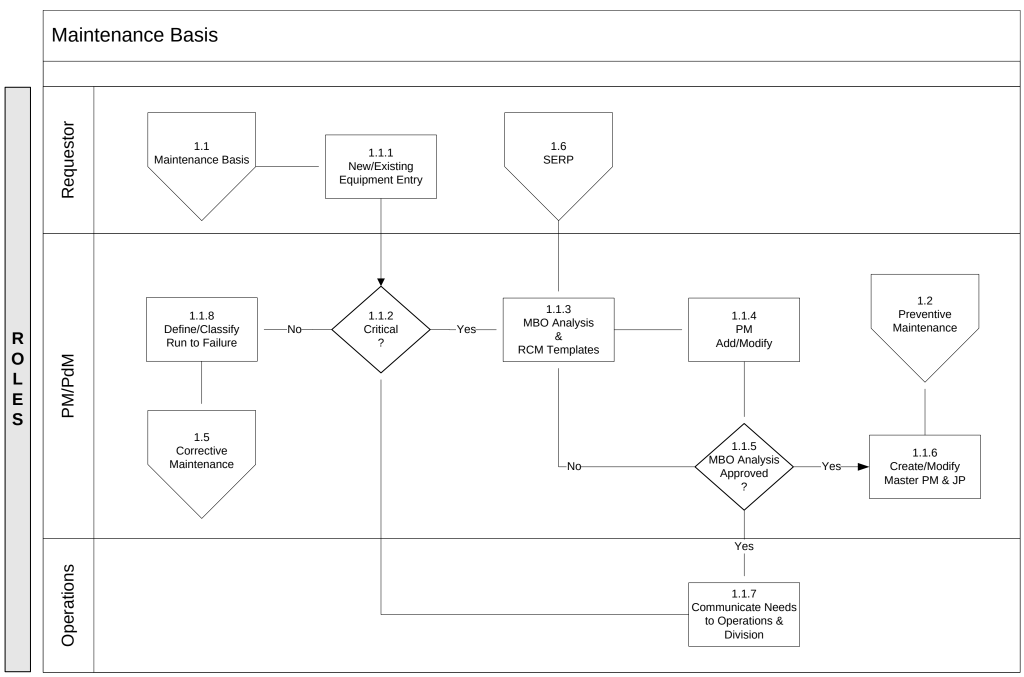

Figure 2-4
Maintenance Basis Process Example

Figure 2-4 provides a high level diagram of the process required to manage an organization's maintenance basis. It is recommended that appropriate policies, processes and procedures are developed to actively manage the maintenance basis of the organization. Specifically, it is recommended that a utility evaluate projected resource needs of each maintenance activity, the value associated with each maintenance activity, and also those systems or components that will be managed on a run-to-failure basis. Additionally, the utility should ensure that the corresponding activities in the organization's CMMS work order management system correlate with the goals and expectations of the organization. In essence, the utility needs to validate that its proposed maintenance basis is likely to achieve the organization's customer satisfaction, reliability, and financial goals and objectives.

Once the maintenance basis is developed, it should be actively maintained in the organization's CMMS work order management system. This will foster consistency in the management of capital replacement and maintenance related tasks within the organization. Parameters addressed in the development of the maintenance basis include, but are not limited to:

- Priority assigned to a particular system or component from SERP or an equivalent process
- Type of condition monitoring deployed (e.g., vibration analysis, lubricant analysis, infrared thermography, acoustic monitoring, dissolved gas analysis, etc.)
- Type of restore/replace maintenance deployed (e.g., breaker refurbishment, functional tests, and other minor and major preventive maintenance tasks)
- Frequency of application of each diagnostics, preventive maintenance activities, and proactive maintenance tasks
- System and equipment ownership which provides a clear indication of the appropriate single point of contact that own the maintenance basis for each component in the system
- Failure mode addressed by each condition directed and time directed maintenance task

Figure 2-5 shows an example of a maintenance template for a 4kV motor. The maintenance basis generally contains a maintenance template which summarizes the overall maintenance strategy of a specific type of system or component. It also contains information that provides the justification for the activities and frequencies identified in the template.

Component type:	Motor (Low Voltage <1KV, High Voltage ≥1KV)									
Component Classification Category:										
Critical YES	✓	✓	✓	✓						
NO					✓	✓	✓	✓		
Environment Harsh	✓	✓			✓	✓				
Non-Harsh			✓	✓			✓	✓		
Usage Frequently	✓		✓		✓		✓			
Seldom		✓		✓		✓		✓		
	Frequency								Failure Cause	COMMENTS
Condition Monitoring Tasks:										Tasks identified for Non-Critical components ONLY applies to expensive/large motors.
Perform FULL Spectrum vibration monitoring. Establish baseline and action levels. Trend results.	1M	1M	1M	1M	3M	6M	3M	6M	BS; LC; SC	NN for low voltage motors less than 200 HP.
Perform BASIC lube oil analysis. Establish action levels. Trend results.	3M	3M	3M	3M	3M	6M	3M	6M	BS; SC; MS; DL	Perform physical (sediment, dirt, viscosity) and chemical analysis (water content). Perform quantitative ferrography (wear particle count). Change oil only when determined
Perform FULL SPECTRUM lube oil analysis. Establish action levels. Trend results.	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	BS; SC; MS; DL	Perform physical (sediment, dirt, viscosity) and chemical analysis (water content). Perform qualitative ferrography to identify type / composition of wear particles.
Perform motor curcuit evaluation. Establish action levels. Trend results.	2Y	3Y	2Y	3Y	4Y	4Y	4Y	4Y	DA; MB; MS; SH; SC	NN for non-critical low voltage motors.
Perform polarization index test. Establish action levels. Trend results.	2Y	3Y	2Y	3Y	4Y	4Y	4Y	4Y	DA; MB; MS; SH; SC	NN for non-critical low voltage motors.
Perform winding / insulation resistance checks.	2Y	3Y	2Y	3Y	4Y	4Y	4Y	4Y	DA; MB; MS; SH; SC	NN for non-critical low voltage motors.
Perform thermographic inspection.	6M	6M	6M	6M	6M	6M	6M	6M	BS, LC, SC, MB	NN for low voltage motors less than 200 HP.
Perform ultrasonic monitoring.	1Y	1Y	1Y	1Y	2Y	3Y	2Y	3Y	BS, LC, SC, MB	NN for low voltage motors.
Perform motor current analysis / sample current wave form testing.	3Y	4Y	3Y	4Y	4Y	6Y	4Y	6Y	MB; MS; SC; SH	NN for non-critical low voltage motors.
Monitor motor heater current	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	AG, SH	
Time Directed Tasks:										
Perform changout of lubricant (oil lubricated bearings)	1Y	2Y	1Y	2Y	2Y	2Y	2Y	2Y	BS; DL; MS	Use these frequencies if not performing lube oil sampling.
Lubricate greased bearings.	See Lube Tabl	See Lube Tabl	See Lube Tabl	See Lube Tabl	See Lube Tabl	See Lube Tabl	See Lube Tabl	See Lube Tabl	BS; DL; MS	For specific lubrication frequencies, reference the vendor manuals where available. Where no other information is provided, reference Motor Lubrication Table.
Check lube oil level, add where necessary (oil lubricated bearings).	OR	OR	OR	OR	OR	OR	OR	OR	SC; DL; BS	Use the lube oil analysis to condiction direct the oil change on large sump motors.
Perform a visual inspection of the filters. Clean/replace as required.	OR	OR	OR	OR	OR	OR	OR	OR	BS; CB; DA; LC; MB; MS; SC; SH	
Perform external visual inspection.	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	BS; CB; DA; LC; MB; MS; SC; SH	NN for non-critical low voltage motors. Task includes inspection for damaged, loose, or missing parts, oil/water leaks, broken/loose cables, air filter/screen condition, and bearing slinger rings.
Perform an internal visual inspection of all accessible motor internals, air passages, and air gap. Disassemble and clean as needed.	2Y	4Y	2Y	4Y	5Y	5Y	5Y	NN	BS; CB; DA; LC; MB; MS; SC; SH	NN for non-critical low voltage motors. Use borescope to inspect all accessible motor internals, air passages, and air gap. Inspect slip ring and brushes for abnormal wear and alignment. Also inspect motor mountings.
Refurbishment	10Y	15Y	10Y	15Y	10Y	20Y	10Y	20Y	BS; CB; DA; LC; MB; MS; SC; SH	NN for non-critical low voltage motors.
Surveillance Tasks:										
Monitor bearing/winding temperatures and cooling water pressure/flow. Data log and trend weekly or monthly.	1D	1D	1D	1D	1D	1D	1D	1D	DA; LC; MB; SC; DL	NN for non-critical low voltage motors.
Verify proper operation.	OR	OR	OR	OR	OR	OR	OR	OR	DA; LC; MB; MS; SC; SH	The qualitative observation of a component's condition or performance. [Look, Listen, Touch]
Economic Considerations:										
Run until corrective maintenance is required.	NA	NA	NA	NA	✓	✓	✓	✓		

Task Groupings - These activities should be scheduled to be performed concurrently.

Group 1 Tasks.

Group 2 Tasks.

Operator Rounds Tasks

General Note: Critical category corresponds to Vital and Significant categories in AMOP process. Noncritical corresponds to Minor category in AMOP process. Run to Failure corresponds to Insignificant category in AMOP process.

Figure 2-5
Maintenance Template Example

The template shown in Figure 2-5 is only part of the maintenance basis of the component and is utilized as an overall summary. This template provides a depiction of the maintenance basis for each component type that is easy to reference and interpret. As part of the process of developing maintenance templates, the utility compares existing PM activities against templates that represent industry best practices. A customization process ensues resulting in a combination of current and best practices that represents an optimal level of PM activities. The maintenance basis optimization (MBO) process is usually performed on a system by system basis, starting with the top ten most troublesome systems at the plant. Typically this process is a 12 to 18 month process to capture most of the critical and non-critical systems.

Establishing the Material Condition Assessment Process

A material condition assessment (MCA) is a process that serves as a formal evaluation of the physical condition of plant systems, structures, and components (SSC). This involves conducting walk-downs of SSCs, collecting and reviewing data, and producing a single overall assessment of the SSC. The MCA walk-down is a focused, critical, and careful examination of a system, structure, or component and can be regarded as a vital part of a system engineer's responsibilities. The system engineer shall ensure that all desired measurable parameters of a walk-down are added to the appropriate operator rounds walk-down and should not be part of the MCA walk-down. A typical process flow of the MCA walk-down and assessment are outlined in Figure 2-6 below:

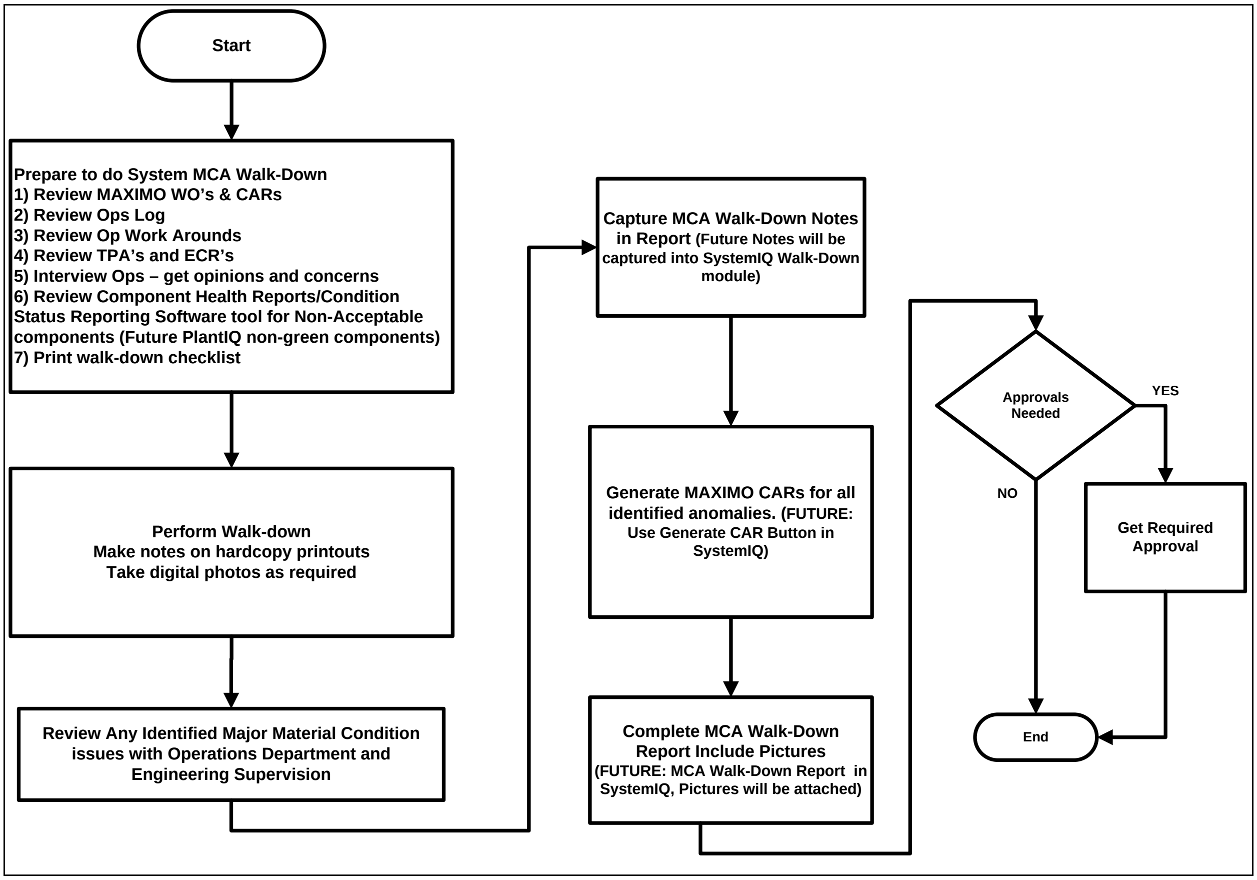

Figure 2-6
Typical MCA Walk-Down and Assessment Process

The purpose of a MCA walk-down is also to ensure that material deficiencies, safety hazards, and housekeeping issues are identified and resolved before they negatively affect the safety, operation, and integrity of the SSC. Frequent, quality MCA walk-downs will help ensure that small problems are identified and addressed before they expand into larger problems that could result in industrial safety hazards, environmental events, or costly plant shutdowns. This form of monitoring is important in maintaining current awareness of system and component health conditions and performance, as many degraded or degrading conditions may not be apparent via performance data review. MCA walk-downs are typically performed for one of three reasons:

1. **Routine** - routine system walk-downs are essential to all system engineers. The frequency for these walk-downs is highly dependent upon the system importance and history
2. **Specific -** A specific event, concern, or question dictates the need for walk-downs on an as-needed basis
3. **Opportunistic -** System engineers should perform walk-downs and inspections during maintenance activities and outage situations.

When performing MCA walk-downs, there are six areas to look for when assessing SSCs. These areas are condition, stressor, degradation mechanism, indicator, consequence, and mitigator. An example situation would be as follows:

- *Condition*: Reduced cooling air flow through motor
- *Stressor*: Higher temperature in motor
- *Degradation mechanism*: Thermal degradation of insulation, polymers, and lubricants
- *Indicator*: Signs of poor housekeeping, dusty environment, blocked air passages, burning odor, and/or hot surfaces
- *Consequence*: Reduced motor performance, shortened motor life, and/or bearing failure
- *Mitigator*: Maintenance of adequate cooling air flow and enforcement of housekeeping

Optimizing walk-down inspections is necessary to maximize the benefit. The focus of walk-down inspections should be based on several factors, such as:

- Presence and magnitude of stressors
- Susceptibility of material and component to stressors
- Consequence of component failure
- Plant experience
- Industry experience
- Anticipated subtlety of the degradation

Configuration control observations are an important part of MCA walk-downs. Typical configuration issues include tagging issues (i.e., tags not being hung on noted deficiencies, improper identification of components, improper “lock-out/tag-out” (LOTO) tagging, etc.), scaffolding problems, and ensuring that interim configuration for modification work in progress does not have a negative impact on system performance.

System performance monitoring is another critical MCA walk-down function. System performance monitoring can be accomplished by trending system performance indicators and initiating proactive actions before failure can occur. This performance monitoring can be achieved either quantitatively or qualitatively. Quantitative monitoring would include measuring and trending quantifiable parameters (e.g., valve positions, temperatures, flows, pressures, and material condition). Qualitative monitoring would involve changes that can be seen, heard, felt, or smelled without quantitative measurement. This type of monitoring is less quantitative, but is also important to trend. Examples of qualitative monitoring include:

- The “feel” of the ambient conditions in the vicinity of the system (temperature, humidity)
- Volume level and type of noise emitted by the system
- Introduction of new noise or loss of old noise
- Color and surface condition of protective coatings and other uncoated surfaces
- Odors
- Visual appearance
- Misalignment, sagging, or bending
- Incremental or vibratory movement
- Corrosion or other deterioration

Documenting MCA walk-down results is important to ensure identified issues are captured and tracked. MCA walk-down checklists provide a structured format for these results to be collected and assessed. These checklists should be generated to capture all quantifiable and qualitative walk-downs results. Typical items that should be documented include:

- Measurements such as size, location, and population of cracks, pits, blisters, and settlement and/or movement
- Color photographs or videotape of the general condition, observed degradation indications, and specific degradation
- Sketches that map the location of degradation and degradation indications
- Any identified operational concerns found during the walk-down
- Written notes or comments that describe the general condition, observed degradation indications, and specific degradation
- Determine the overall status of walk-down as *Acceptable*, *Watch List*, *Marginal*, or *Unacceptable*.
- Actions that should be taken once the MCA walk-down has been completed include:
- Inform supervisor of significant degradation found during walk-down
- Input significant findings into the CMMS as work order requests and discuss during plan-of-the-day meetings
- Document completion of walk-down via a standalone report or in asset health reporting software
- List significant observations requiring CMMS work order generation in each applicable asset health report
- An example MCA Walk-Down report and checklist can be seen in Appendix C.

Establishing the Component Health Monitoring Process

Component health monitoring (CHM) is defined as the process of gathering, evaluating, and analyzing data pertinent to component performance so that component health can be assessed. Data that is evaluated includes direct data (e.g., component output flow, pressure, component bearing or winding temperatures, vibration, visual inspections, etc.) and indirect data (e.g., number of unexpected corrective maintenance work orders, overdue preventive maintenance tasks, outstanding design modifications, number of re-work work orders, etc.) as depicted in Figure 2-7.

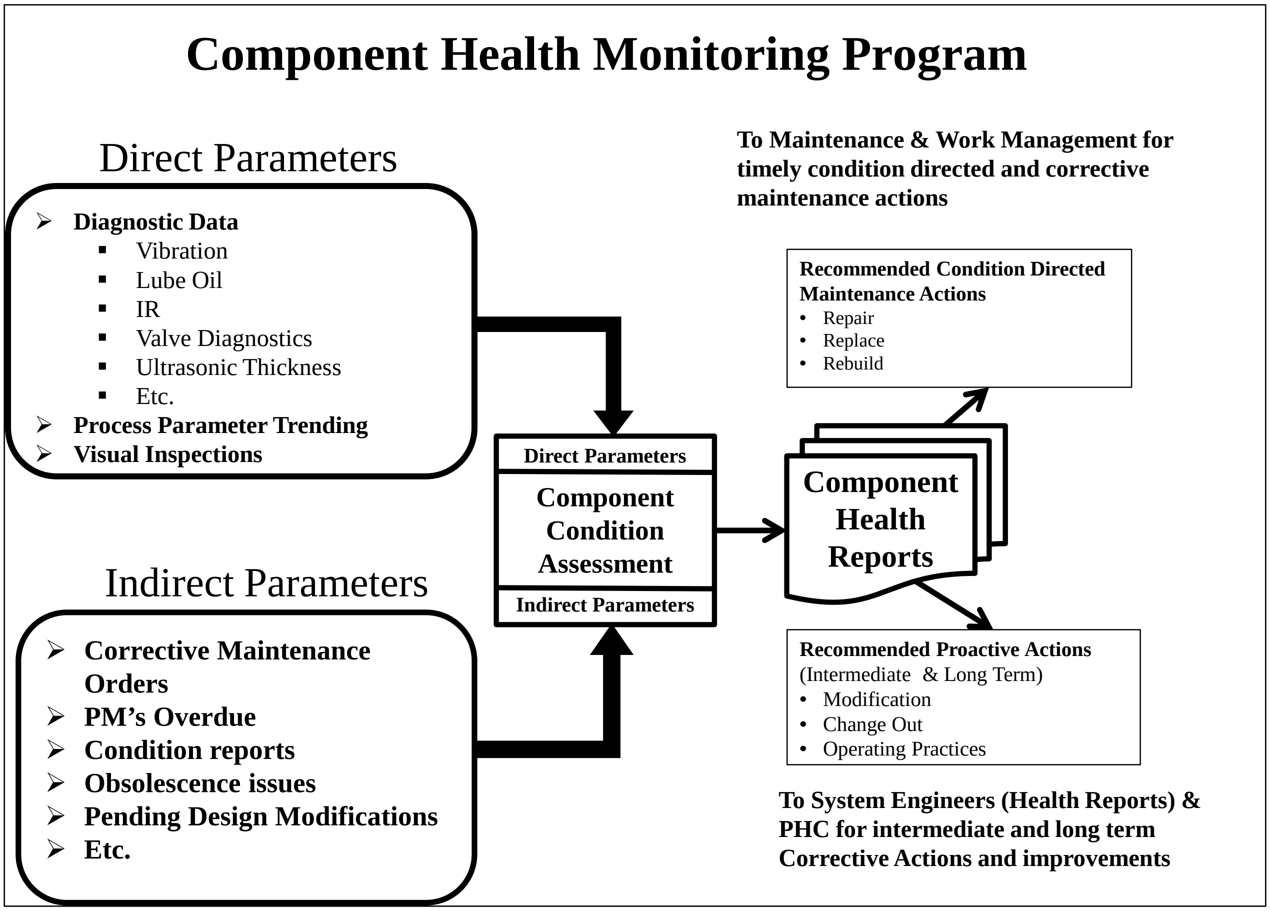

Figure 2-7
Component Health Monitoring Process

The first major step in the CHM process is assigning the component ownership responsibility and the responsibilities for collecting all available data to determine component health. This can be done is several ways and all organizations take a different approaches. One approach that is common is to establish a condition based monitoring (CBM) group that is responsible for gathering most of the direct parameters, typically the condition monitoring technology (e.g., vibration analyses, lubricant analyses, infrared thermography, motor testing, etc.) A graphic depiction of the CBM sub-process is shown in Figure 2-8.

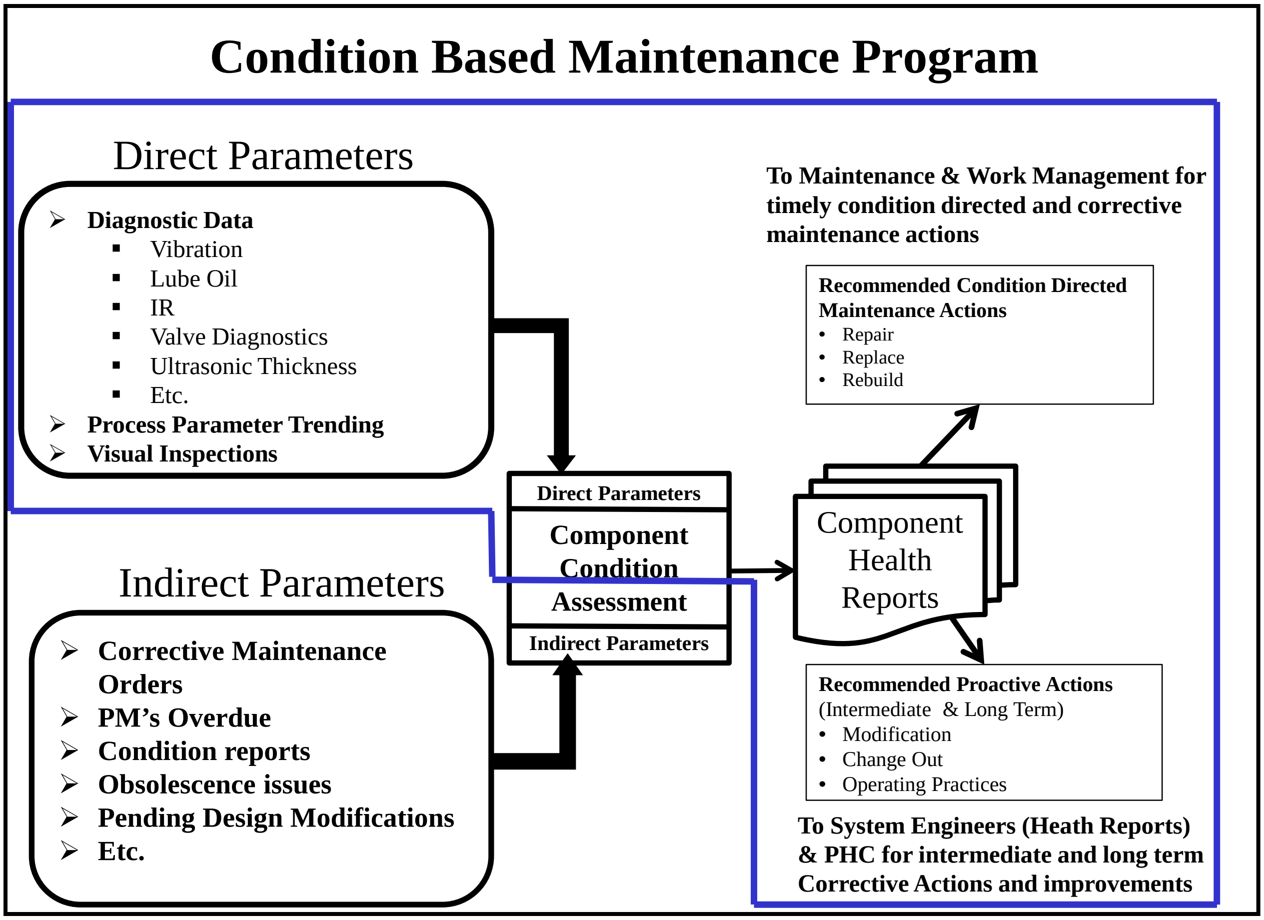

Figure 2-8
Condition Based Maintenance Program Outline

The details of establishing CBM processes and organizations are outlined in subsequent sections of this report, as well as other industry documentation [13]. An overview of some key aspects of CBM is outlined as follows:

Selection of Critical Components

Determination of what critical plant equipment will be included in the CHM should be identified through a maintenance basis optimization (MBO) project discussed previously.

Selection of Condition Monitoring Technologies and Indicators

A utility typically includes direct and indirect condition monitoring technologies and indicators to be the primary inputs for the CHM program. Some inputs can be automated, while others remain manual inputs.

- Indirect indicators include:
- Preventive maintenance tasks (PMs) overdue
- Corrective maintenance (CM) backlog (online and outage)
- Number CM-U work orders
- Outstanding engineering change request (ECR)

- Component equivalent forced outage rate (EFOR)
- Temporary plant alterations (TPA)
- Operator work-arounds (OWA)
- Obsolescence and critical spares
- Direct indicators include:
- Periodic vibration monitoring
- Online vibration monitoring
- Lube oil analysis
- Infrared thermography
- Online motor testing
- Offline motor testing
- Operator rounds results
- Insulating oil dissolved gas analysis (DGA)
- Process parameters
- Advanced pattern recognition (APR)
- Boiler monitoring
- MCA walk-down results and visual inspections
- Valve testing
- Performance testing
- Eddy-current testing
- Acoustic monitoring

Create an Equipment and Condition Indicator (E&CI) Matrix

An E&CI matrix is a listing of all the equipment included in the CHM program. Included in this matrix is a mapping of all condition monitoring technologies and indicators, including the data collection frequency. An example E&CI matrix is depicted in Figure 2-9.

The E&CI Matrix must be maintained and updated. It is part of the maintenance basis for all the applicable components and typically resides in the condition status reporting software tool.

As part of the maintenance basis program, an annual comparison must be made between current data collection frequencies and approved maintenance strategy data collection frequencies for all applied CHM technologies. Appropriate updates must be made to both the E&CI matrix and the associated PM activity within the organization's CMMS.

LEGEND: N = New Technology Monitoring; E = Existing Monitoring, the following number represents months between surveys; X = Condition Indicator Available; NA = Condition Indicator Not Available; FB = Failure Based Testing; N/A = Not Applicable			TECHNOLOGY & CONDITION INDICATOR OWNERS																								
			Periodic Monitoring						Process & Operations Indicators											Continuous Monitoring			NDE		Maintenance Data		
Component Descriptions	Component Identification Number	Equipment Owner	Vibration Analysis	Performance Testing	Infrared Thermography	Motor Testing	Oil Sampling & Analysis	Acoustics Monitoring	Temperature	Pressures (Transmitter or Gauge)	Control Signal / Position	Level	Flow	Running Amps / Line Voltage	Load	Starts	Running Hours	Visual Inspections	Ops Log Review	On-Line Performance Monitoring	On-Line Vibration Monitoring	Process Chemical Parameters	Borescope or Videoprobe Insp	UT MT VT Metal Density	PM Reviews	Maintenance Histories	Visual Inspect
MECHANICAL EQUIPMENT																											
Elevation 005																											
1 Service Water Pump	SH-UC-SW-SWP-1-PUMPS		E1		E3	N/A	N/A	N/A	N/A	N1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
1 Service Water Pump Motor	SH-UC-SW-SWP-1-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
2 Service Water Pump	SH-UC-SW-SWP-2-PUMPS		E1		E3	N/A	N/A	N/A	N/A	N1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
2 Service Water Pump Motor	SH-UC-SW-SWP-2-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
3 Service Water Pump	SH-UC-SW-SWP-3-PUMPS		E1		E3	N/A	N/A	N/A	N/A	N1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
3 Service Water Pump Motor	SH-UC-SW-SWP-3-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
4 Service Water Pump	SH-UC-SW-SWP-4-PUMPS		E1		E3	N/A	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
4 Service Water Pump Motor	SH-UC-SW-SWP-4-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
5 Service Water Pump	SH-UC-SW-SWP-5-PUMPS		E1		E3	N/A	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
5 Service Water Pump Motor	SH-UC-SW-SWP-5-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
Elevation 016																											
#1 Plant Air Compressor	SH-UC-SB-PAC-1-COMP		E1		E3	N/A	N3	N3	N/A	N1	N1	N1	N1	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
#1 Plant Air Compressor Motor	SH-UC-SB-PAC-1-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N1	N1	N1	N1	E1	N1	N1		N/A				X	X	X
#1 Silo Vent Fan	SH-UC-FA-SVF-1-FANS		E1		E3	N/A	N3	N3	N/A	N1	N/A	N1	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X
#1 Silo Vent Fan Motor	SH-UC-FA-SVF-1-MOTOR		E1		E3	N12	N3	N3	N/A	N/A	N/A	N1	N/A	N1	N/A	N/A	N1	N1	N1		N/A				X	X	X
#2 Silo Vent Fan	SH-UC-FA-SVF-2-FANS		E1		E3	N/A	N3	N3	N/A	N1	N/A	N1	N/A	N/A	N/A	N/A	N/A	N1	N1		N/A				X	X	X

Figure 2-9
Equipment and Condition Indicator (E&CI) Matrix

Component Health Monitoring Program Goals and Metrics

Goals and metrics should be established so that success can be measured. Typical CHM program goals include:

- 100% data collection on all critical equipment
- 80% to 90% CHM data collection on all non-critical equipment
- Defined financial metrics for cost benefit analysis (CBA)
- Number of condition indicators representing unacceptable or marginal conditions is always trending down
- Percentage of condition indicators that are within acceptable thresholds
- Tracking of Work Order Types
- Preventive maintenance, repair or replace activities (PM-RR)
- Preventive maintenance, condition monitoring tasks (PM-CMT)
- Corrective maintenance, unexpected failure (CM-U)
- Corrective maintenance, expected failures (CM-E); also referred to as run-to-failure (RTF)
- Condition directed maintenance (CDM)
- Proactive maintenance (PAM)

Component Health Report

A component health report is a comprehensive indicator of health status for specified components. The component health report can be displayed graphically to provide an overview of all components being monitored under the CHM program. Included in this overview are indicators relating to each of the condition monitoring activities for each designated component (Figure 2-10).

Division	Unit	USI	EQUIP TAG	EQUIPMENT DESCRIPTION	Overall Condition Status	THERMOGRAPHY	LUBE OIL	VIBRATION	MOTOR TESTING OFF-LINE	MOTOR TESTING ON-LINE	PARAMETER MONITORING (SMART SIGNAL)	OPERATOR ROUNDS	ENGINEER WALKDOWN
BA	Unit 3	33120A	3-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	06/16/10	04/27/10	06/16/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	06/17/10	04/27/10	06/17/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	07/09/10	04/27/10	07/09/10	06/25/09					
BA	Unit 3	33120A	3-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	07/09/10	04/27/10	07/09/10	06/25/09					
BA	Unit 4	33120A	4-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	05/11/10	07/08/10	05/11/10	02/18/10					
BA	Unit 4	33120A	4-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	05/11/10	07/08/10	05/11/10	02/18/10					
BB	Unit 5	33120B	5-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 5	33120B	5-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	03/30/10	03/30/10	07/30/10	08/03/10					
BB	Unit 6	33120B	6-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	05/25/10	08/17/10	06/01/10	08/11/10	05/25/10	07/21/04			
BB	Unit 6	33120B	6-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	08/17/10	08/17/10	06/01/10	08/11/10		07/21/04			
BB	Unit 6	33120B	6-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	08/17/10	08/17/10	06/01/10	08/11/10		07/21/04			
BB	Unit 6	33120B	6-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	08/17/10	08/17/10	06/01/10	08/11/10	05/20/10	07/21/04			
BB	Unit 7	33120B	7-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 7	33120B	7-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	04/13/10	04/13/10	07/22/10	07/21/10					
BB	Unit 8	33120B	8-33120-PM1	PRIMARY HEAT TRANSPORT PUMP MOTOR 1	08/19/10	08/19/10	07/16/10	07/21/10	05/25/09				
BB	Unit 8	33120B	8-33120-PM2	PRIMARY HEAT TRANSPORT PUMP MOTOR 2	08/19/10	08/19/10	07/16/10	07/21/10	05/25/09				
BB	Unit 8	33120B	8-33120-PM3	PRIMARY HEAT TRANSPORT PUMP MOTOR 3	07/22/10	07/22/10	07/16/10	07/21/10	05/06/09				
BB	Unit 8	33120B	8-33120-PM4	PRIMARY HEAT TRANSPORT PUMP MOTOR 4	01/14/10	01/14/10	07/16/10	07/21/10	05/25/09				

Legend:		
	A	- Acceptable
	N	- Not Running/Inadequate Load
	P	- Pending
	W	- Watch List
	M	- Marginal
	U	- Unacceptable
	N/A	- Not Applied
		- Baseline Data (First time taken)

Figure 2-10
Component Health Report

A Component Health Report can be configured in the form a spreadsheet, or can be developed and displayed in the form of a condition status reporting (CSR) software tool. A CSR software tool allows for the capture and display of technology exams and equipment assessments in a format that can be easily viewed by all utility personnel. A CSR tool also allows for the integration of technology exam data analysis reports, images, charts, graphs, and other relevant data relating to the equipment assessment process.

Establishing the System Health Monitoring Process

System health monitoring (SHM) is defined as the process of gathering, evaluating, and analyzing data pertinent to system performance so that system health can be assessed. Data that is evaluated includes direct data (e.g., system flow rates, pressures, component bearing or winding temperatures, vibrations, material condition assessments, visual inspections, etc.) and indirect data (e.g. number of unexpected corrective maintenance work orders for the system, the total number corrective maintenance work orders in the backlog, number of preventive maintenance tasks for the system that are overdue, outstanding design modifications, operator work-arounds, temporary plant alterations for the system, etc.).

The SHM process produces system health reports (SHR) that include a scoring methodology to identify current system conditions. This scoring methodology is depicted through the use of color schemes that are representative of system scores (e.g., green = excellent, white = meets Expectations, yellow = needs improvement, and red = unacceptable). SHRs provide comprehensive information pertaining to a specific system's ability to deliver its design functions in the near, intermediate, and long terms. A SHR should include:

- Coversheet
- SHR overview
- SHR indicator scorecard
- SHR action Plan (as necessary)

SHRs provide a periodic analysis and reporting of a defined amount of specific system assessment areas, including the associated indicators. It provides communication to appropriate site organizations to ensure corrective actions are implemented prior to further component degradation and/or system failure. SHRs also provide the capability for site management to prioritize and manage the allocation of resources to improve system performance.

The system health process consists of the steps outlined in detail below and seen in Figure 2-11:

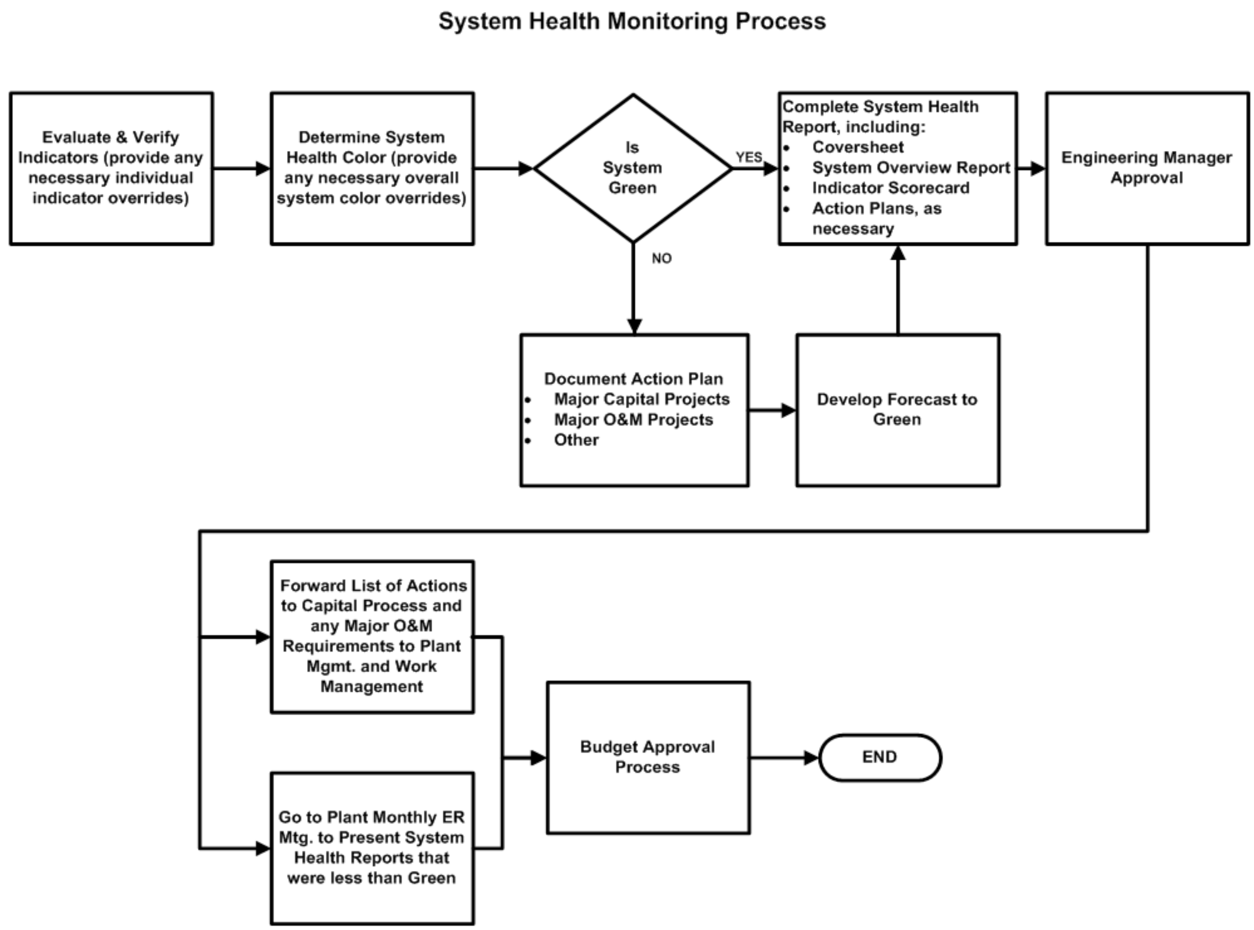

Figure 2-11
System Health Process Flow diagram

- Gather data
- Evaluate and verify gathered data
- Score the evaluated data to determine overall system health score. (An example of a manual system health scorecard can be seen in Appendix D.)
- Create action plans for systems with a SHR score resulting in “needs improvement” or “unacceptable” conditions. (An example of an outline for a system health action plan can be seen in Appendix E.)
- Complete a SHR overview. (An example outline of a SHR overview can be seen in Appendix F.)
- Conduct peer reviews of SHR should also be peer reviewed
- Approval of SHR by appropriate management

Establishing an Equipment Reliability Meeting

- When an organization implements an AHM Program, a significant amount of information regarding the current health of critical systems and components is generated. This new information will often lead to the identification of actions needed to ensure the reliable operation of these assets. To effectively prioritize, manage, and fund the required actions, it is an industry best practice to establish a site equipment reliability committee that meets to address these needs. This equipment reliability meeting (sometimes referred to as plant health committee meeting) is intended to discuss all issues and opportunities relating to impacts on plant performance and reliability and should include the following functions:
- Action items from previous month; identify resolved and unresolved issues
- Review new items
- Review of AHM program performance with respect to program goals
- System health status review
- Review action items to ensure they are prioritized, in progress, and on schedule
- SHR status updates for systems newly designated as “needs improvement” or “unacceptable”
- Recent performance testing results
- Changes to plant work-arounds list
- Recent or upcoming MCAs
- Recent maintenance template revisions (include lessons learned)
- Review all design change requests (both submitted and active)

3

ORGANIZATIONAL STRUCTURE TO SUPPORT AN ASSET HEALTH MANAGEMENT PROGRAM

Corporate Organizational Structure Considerations

It is important that an asset health management (AHM) program has well-documented process and procedural guidance to ensure that roles and responsibilities are clear. Once policy and guidance is developed, it is critical to organize and align an organization to implement the process and procedural guidance. A common cause for AHM program implementation failure is to develop new processes without ensuring that resources to implement and sustain a program are considered. Fossil power generation companies are challenged in today's competitive environment to effectively manage day-to-day operations while at the same time providing for continuous improvement in asset management. The organizational structure and roles and responsibilities must be aligned to implement these new asset health management processes. Good practice results across a fleet are best established when the corporate organization develops the standards for new AHM processes that are planned for implementation. The first step would be to organize a group within the corporate organization that would be responsible for implementing and maintaining the desired AHM processes. This typically is the responsibility of a corporate engineering department. The second step would be to develop AHM governance documents that identify all AHM processes that are to be implemented. This documentation outlines corporate sponsorship responsibilities, identifies program terminology, and outlines all program metrics that are to be used to measure success. The corporate support organization should consist of a section manager and subject matter experts (SME) in the key areas of AHM. The size of the corporate group would be dependent on the size of the utility and number of operating units to support. These SMEs would be experts within the areas of system and components and should include:

- Component experts (e.g., motors, valves, transformers, rotating equipment, etc.).
- Condition monitoring technology experts (e.g., vibration, lubrication, infrared thermography, electric motor testing, etc.).
- Non-destructive examination technology (e.g., ultrasonics, magnetic particle, partial discharge, eddy current, etc.).
- System specific experts

These resources should be responsible for developing the standard procedures or guidelines for the associated AHM processes. Additional responsibilities would include supporting plant staff at each site develop site-specific AHM processes. These individuals would act as the appropriate SME when assisting in troubleshooting site issues associated with their expertise.

After establishing the appropriate SMEs, the next step for the organization is to have the SME's establish and develop the standard procedures and/or guidelines for each AHM process to be implemented. Typical procedures and guidelines that would establish good practices with AHM include:

- Master equipment list (MEL)
- System and equipment ranking and prioritization (SERP)
- Maintenance basis optimization (MBO)
- Material condition assessment (MCA)
- Component health monitoring (CHM)
- System health monitoring (SHM)

Site Organizational Structure Considerations

The assignment of personnel responsible for assessing the condition of the systems and components at plant sites can vary from organization to organization. One approach is to create an organizational structure that assigns responsibility of the assets to component subject matter experts, sometimes referred to as component engineers or performance engineers. Another approach is to facilitate the assessment of the equipment and components to system engineers or system owners. Each of these methods typically provides the desired results of converting data to information to action. Outlined below in Figure 3-1 is a good practice example of how to best organize to effectively AHM processes associated with component health at the site.

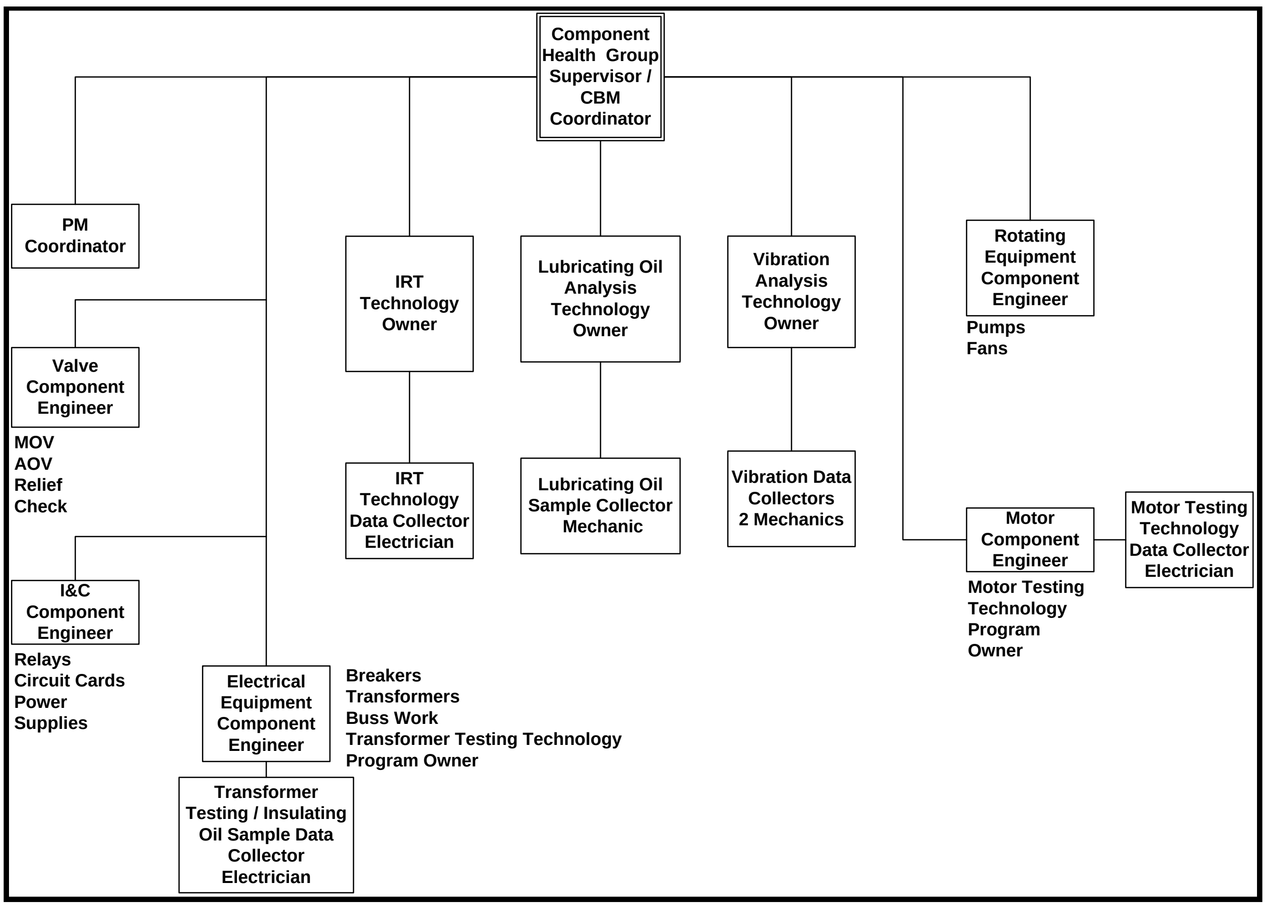

Figure 3-1
Component Health Monitoring Group Organization Chart

Site re-structuring for implementing AHM processes would include the following:

- Establish the system engineering concept, if not already in place. This would require assigning site engineers to specific systems in accordance with the MEL systems list.
- The System Engineers would be responsible for:
- Reviewing and maintaining the MEL for all components within their assigned systems
- Reviewing and maintaining the system and equipment ranking and prioritization (SERP) results for all components within their assigned systems
- Reviewing and maintaining the PM Basis for all components within their assigned systems
- Performance of material condition assessment (MCA) walk-downs for all critical components within their assigned systems in accordance with the predetermined timeframe
- Development of MCA walk-down reports for all assigned systems in accordance with the predetermined reporting timeframe
- Review of component health reports
- Development of system health reports for all assigned systems in accordance with the predetermined reporting timeframe
- Establish a condition based maintenance group that would be responsible for ensuring that all data gathering, data analysis, and reporting for all predictive maintenance technologies.

4
SELECTING SOFTWARE TOOLS AND TECHNOLOGY TO FACILITATE THE ASSET HEALTH MANAGEMENT PROGRAM

Integration of Data and Information Sources

In today's economic environment, it is extremely important for a utility to maximize its resource utilization due to the limited amount of resources available at each facility. To accomplish this, elimination of duplicate work efforts is critical. Therefore application and integration of software tools used by those resources on a daily basis will be required. The CHM and SHM software tools should be integrated with existing facility software tools, such as:

- The computerized maintenance management system (CMMS) used to control work being performed throughout the organization
- Any software scheduling tool used outside the CMMS
- Operator rounds and/or operator logbooks software tools
- Any existing predictive maintenance data analysis software tools

Identifying Sources of Data and Information

To identify the sources of data and information required to implement AHM program software tools, it is important to ensure that representatives that use the typical AHM program data sources be involved. This involvement should include kick-off meetings, as well as any follow-up meetings to develop software tool specifications. Typical personnel included would be:

- Corporate project management
- Corporate PdM technology SMEs
- Site engineering
- IT support
- Personnel familiar with the CMMS
- Site PdM personnel familiar with PdM software analysis tools,
- Operations personnel familiar with operator rounds and/or operator logbooks software tools
- Maintenance personnel familiar with work order types and work scheduling process

Once a team is comprised of all necessary personnel, the software specification development should commence using the standard supplier, inputs, process, outputs, and customers (SIPOC) methodology. Figure 4-1 outlines the SIPOC results developed for implementing a Component Health Monitoring process.

SUPPLIERS	INPUTS	PROCESS	OUTPUTS	CUSTOMERS
		Component Health Process		
MAXIMO	CARs		Overall Condition	System Engineers
MAXIMO	PMs overdue		(# of red, yellows, whites, & greens)	Ops (Biggest)
MAXIMO	Work Order Backlog (Online & Outage)		Recommendations	Sr. Mgmt
MAXIMO	# of CM-U Work Orders		Maintenance work orders	Work Week Coord.
MAXIMO	Eng. Change Request (ECR) Backlog		Corrective Actions	
??	Operating Mode		Operating Recommendations	
	Cycling, Base-loaded, etc…		Training Recommendations	
Reliability Data			Other Recommendations	
MAXIMO	Component EFOR		Mods / Capitol Improvements	
MAXIMO	Temporary Plant Alterations (TPA)		CBA reports	
MAXIMO	Operator Work Arounds			
Excel/NueCo	Thermal Performance			
Excel / MAXIMO	MCA Walk-Downs (WO Classifications)			
Operators	Operator Rounds Results (Manual)			
Condition Monitoring technologies				
AMS	Periodic Vibration Monitoring (Automatic)			
ABB / PI	On-Line Vibration Monitoring (Automatic)			
AMS	Lube Oil Analysis (Automatic)			
FLIR software	IRT (Manual)			
Baker Box software	Motor Testing (Manual)			
Excel spreadsheet	Valve Testing (Manual)			
PI	Process Parameters (Automatic)			
	Chem. Data Exceedances			
	Ops Round Exceedances			
	Smart Signal Exceedances			
NueCo/Smart Signal	APR (Automatic)			
Matricon software	Matricon Alarms (Automatic)			
T/S TOAN database	Insulating Oil DGA Testing (Automatic)			
Excel spreadsheet	Eddycurrent Testing (Manual)			
AWARE software	Boiler Monitoring (tube leaks/UT inspections) (Automatic)			
MLIS	Obsolesces and Critical Spares (Automatic)			
Excel / NueCo	Acoustic Monitoring			

Figure 4-1
Component Health Process SIPOC

Once the SIPOC is completed, the software specification development becomes much clearer as to what is needed to be integrated. Further discussions may be required with the applicable team members as to why and how the integration is necessary. This includes evaluating the benefit that integration provides to the process against the necessity of including the integration into the software specification.

This same SIPOC methodology can be applied to all other applicable AHM program software tools. This includes system health reports (SHR), component health reports (CHR), maintenance basis optimization (MBO), long-term asset management (LTAM), and other applicable applications.

Developing Integration Processes for Information Flow

When integrating AHM program software tools, it is important to understand which software tools need to be integrated and for what purpose. The fundamental objective of an AHM program is to create an information flow that starts with data collection and results in actionable information.

All AHM programs begin with data collection. Software tools provide information that is typically required to assess component and system health and generate component health reports (CHR) and system health reports (SHR). Because of this, it is necessary to integrate data into the CHR and/or SHR software tools. The SIPOC methodology described above helps delineate which information goes into which software tool. The CHR integration is typically done within the CSR software tool via creation of technology exams. Integration links are typically made to automate the transfer of analysis results into the CSR software. This type of integration eliminates a duplicate work effort of putting the results into both the analysis software tool and the CSR software tool.

The next step would be to automate the initiation of the corrective actions. This makes the integrations with a CMMS necessary. This is typically done by creating CMMS integration links (i.e., create work request within the CSR software that allows the creation of work order requests in the CMMS from the information retained in the CSR). This integration eliminates duplicate work efforts of entering results in the CSR and then re-entering the same results in the CMMS to create work order requests. Another useful integration is the ability to search work order history in the CSR software tool via the individual components configured in the CSR software tool.

Purpose of Data and Information

When developing an AHM program it is important to understand the purpose for needing component health reports (CHR) and system health reports (SHR). Ultimately, the fundamental purpose of these reports is communication. Communication is one of the most important aspects of AHM programs. Figure 4-2 depicts that communication is 70% of the issue when it comes to the fundamental rule of “Data-to-Information-to-Action”.

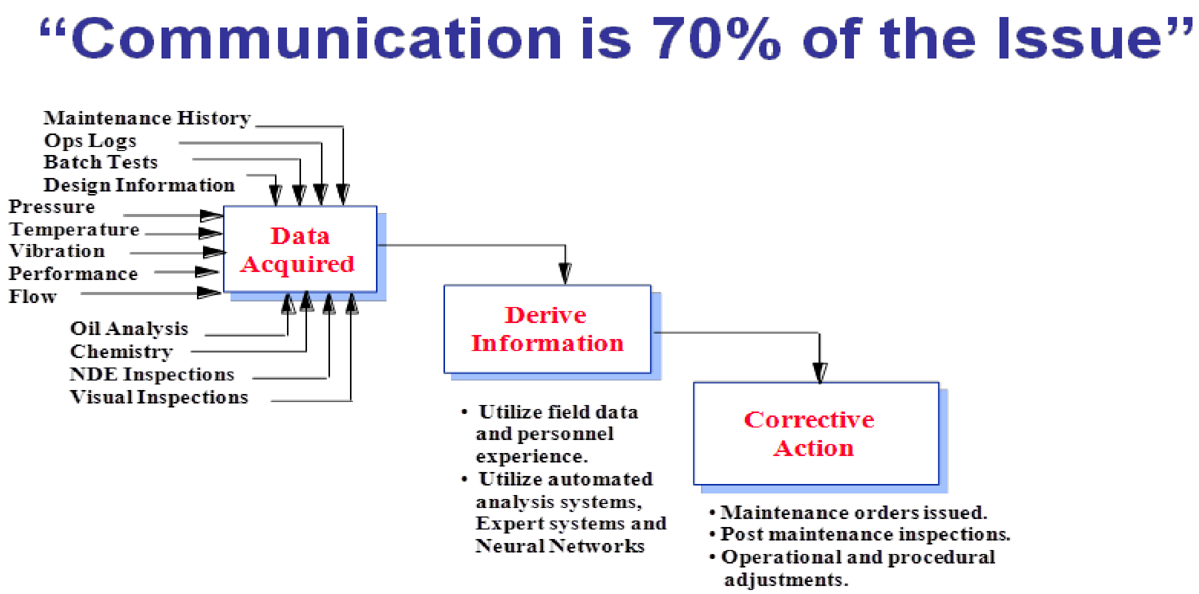

Figure 4-2
AHM Program Communication

How well the results of both CHR and SHR processes are communicated will dictate the success or failure of an AHM program. That success is based upon the proper selections of inputs and outputs of both CHR and SHR process. Described below are typical examples of inputs and outputs of CHR and SHR processes.

Inputs

The selection of inputs for CHR and SHR is based on the SIPOC methodology. Figure 4-3 defines inputs for a typical fossil utility SHR from a SIPOC analysis performed when developing the software specification.

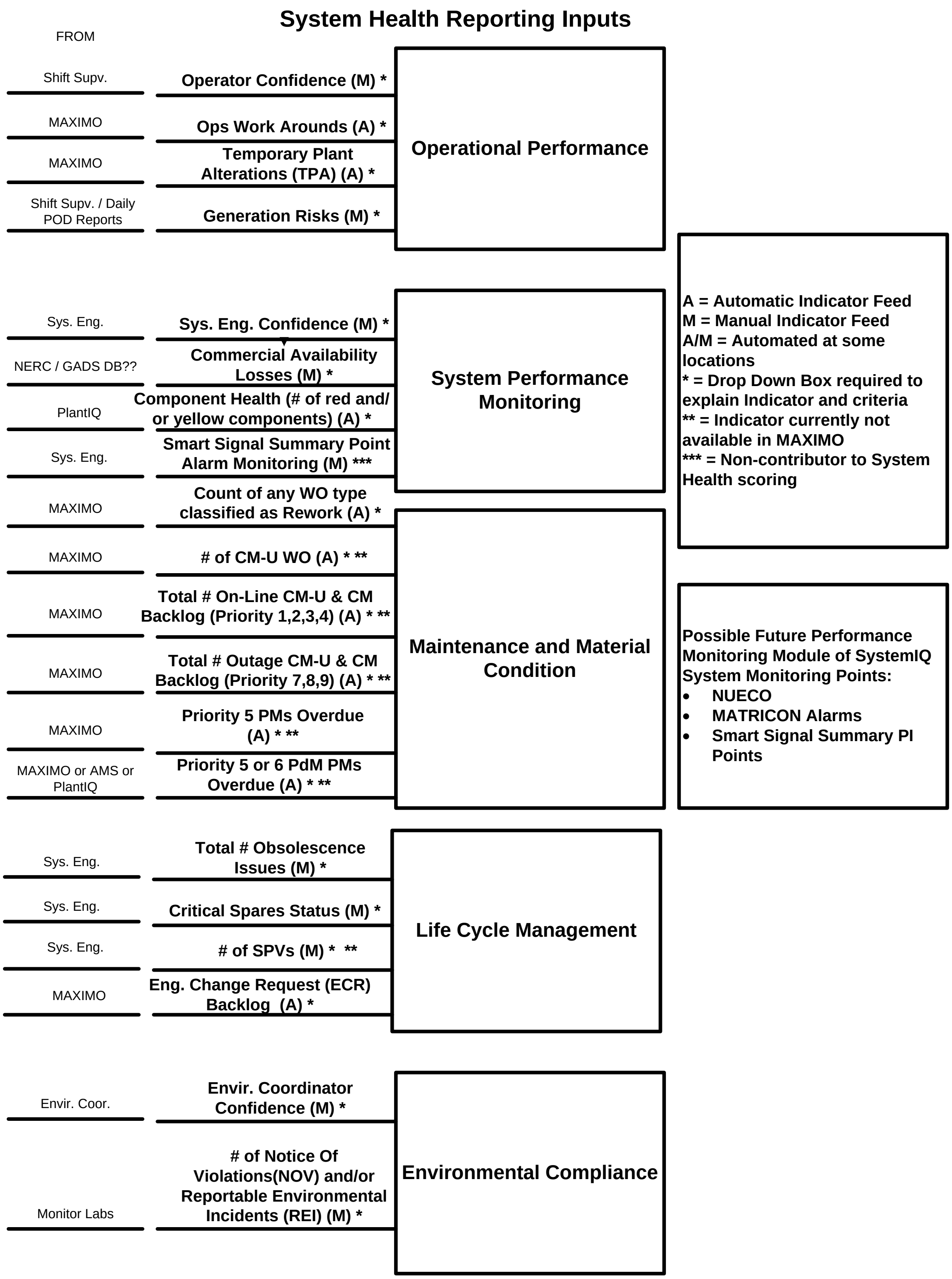

Figure 4-3
System Health Report Inputs

The inputs for a CHR process are usually determined by the condition monitoring technologies and indicators available at the plant. A list of typical condition monitoring technologies and indicators is identified below:

- Periodic vibration monitoring
- Online vibration monitoring
- Lube oil analysis
- Infrared thermography
- Online motor testing
- Offline motor testing
- Operator rounds results
- Insulating oil dissolved gas analysis (DGA)
- Process parameters
- Advanced pattern recognition (APR)
- Boiler monitoring
- MCA walk-down results and visual inspections
- Valve testing
- Performance testing
- Eddy-current testing
- Acoustic monitoring

Outputs

The selection of outputs for CHR and SHR is based on the SIPOC methodology. Typical outputs from CHR and SHR processes are as follows:

CHR outputs:

- CHR overview
- Overall condition of the systems or components (e.g., Acceptable, Watch List, Marginal, Unacceptable, etc.)
- Recommendations for identified anomalies including maintenance, operating, training, and design changes
- Initiation of corrective action work order requests for identified anomalies
- Cost benefit analysis development and support

SHR outputs:

- SHR coversheet
- System health indicator scorecard
- System health overview report
- System health action plan

5
DETERMINING ASSET HEALTH MANAGEMENT PROGRAM METRICS AND ASSESSMENT PARAMETERS

Development of Program Metrics

The means to measure a program's success is one of the most important aspects to implementing any new process. This provides the ability to determine any benefits received from the investment of time and money to implement the new process. Determining the program metrics and assessment parameters to be measured should be agreed upon by all parties involved. This includes corporate executive sponsors, management teams, program implementation managers, and all key role personnel involved in the new process being implemented. Also the means to measure those agreed upon metrics and parameters must also be available.

AHM program effectiveness can be measured using lagging industry metrics, such as equivalent forced outage rates (EFOR), commercial availability (CA), equivalent availability factors (EAF), and others. Coincidentally, there are also leading indicators that can be tracked and monitored to provide early indication and allow for corrective action before performance levels drop.

System Level Metrics

Leading system level metrics include:

- % completion rate of System Health Reports (SHR)
- System availability trending
- System health score trends

Component Level Metrics

Leading Component Level Metrics include:

- Unexpected corrective maintenance (CM-U) work orders
- # of "unacceptable" and "needs improvement" scores
- Condition monitoring task completion rate on critical components
- % of CHM components with "acceptable" scores
- Cost benefit analysis (CBA) results

6

EDUCATION AND COMMUNICATION FOR ASSET HEALTH MANAGEMENT PROGRAMS

Asset health management (AHM) programs are successful when they receive strong sponsorship, and when an organization is held accountable for its AHM program responsibilities. Dedicated sponsorship and accountability must begin at the highest level of corporate and plant management. Accountability must then be driven by corporate and plant management and expected throughout the organization. Obtaining the necessary buy-in, understanding, and sponsorship for effectively implementing new AHM processes requires an extensive amount of education and communication throughout the organization.

One very effective means to educate the workforce and communicate the new AHM roles and responsibilities is to perform “AHM program level-of-awareness (LOA) Training”. These LOA training sessions are typically conducted as interactive workshops. These sessions are used to capture the organization’s specific issues and/or barriers to implementation.

Level-of-Awareness for Senior Leadership and Management

The purpose of LOA training sessions for senior leadership and management is to provide a basic understanding of the comprehensive AHM Program processes, requirements, and potential benefits, as well as how success will be measured. This ensures that leadership and management will sponsor their respective organizations to perform the new roles and responsibilities and adhere to AHM Program policies and procedures. In addition to educating the leadership and management, the LOA training workshop also facilitates an interactive session to capture issues and/or barriers to successful AHM Program implementation.

Level-of-Awareness for Maintenance, Operations, and Work Management

The purpose of LOA training sessions for maintenance, operations, and work management is to provide a basic understanding of the comprehensive AHM Program processes, requirements. Specific roles and responsibilities to support the AHM program are represented to maintenance, operations, and work management, respectively. The specific benefits of AHM to the respective departments are also presented to increase the level of buy-in. In addition to educating maintenance, operations, and work management, the LOA training workshop also facilitates an interactive session to capture specific issues and/or barriers to successful AHM Program implementation.

Level-of-Awareness for Corporate Governance, Oversight and Support Organizations

The purpose of LOA training sessions for corporate governance, oversight, and support organizations is to provide a basic understanding of the comprehensive AHM program processes and requirements. Specific roles and responsibilities of the corporate organization to support the AHM program are presented. This LOA training workshop session provides information and experiences regarding issues that typical corporate support organizations incur when providing governance and oversight for AHM program implementation. The LOA training workshop also facilitates an interactive session to capture specific issues and/or barriers to successful AHM program implementation.

Level-of-Awareness for Engineering

The purpose of LOA training sessions for engineering is to provide a more detailed understanding of the comprehensive AHM Program processes, requirements and specific roles and responsibilities of the engineering department to support the AHM Program implementation. The specific benefits of AHM to the engineering department are also presented to increase the level of buy-in and ensure that roles and responsibilities will be supported. In addition to educating the engineering department, the LOA training workshop also facilitates an interactive session to capture specific issues and/or barriers to successful AHM program implementation.

A
APPENDIX – REFERENCES

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B
APPENDIX – ACRONYMS

ACR – Asset Criticality Ranking

AFPF – Asset Failure Probability Factor

AHM – Asset Health Management

AOV – Air Operated Valve

APR – Advanced Pattern Recognition

APS – Arizona Public Service

ASNT – American Society of Nondestructive Testing

BOM – Bill of Material

CA – Commercial Availability

CAP – Corrective Action Process

CAR – Corrective Action Request

CBA – Cost Benefit Analysis

CBM – Condition Based Maintenance

CC – Critical Component

CDM – Condition Directed Maintenance

CHM – Component Health Monitoring

CHR – Component Health Report

CM – Corrective Maintenance

CM-E – Corrective Maintenance - Expected

CMMS – Computerized Maintenance Management System

CM-U – Corrective Maintenance - Unexpected

CSR – Condition Status Reporting

DGA – Dissolved Gas Analysis

EA – Equipment Assessment

E&CI – Equipment and Condition Indicator

ECR – Engineering Change Request

EFOR – Equivalent Forced Outage Rate

EPRI – Electric Power Research Institute

ER – Equipment Reliability

ERM – Equipment Reliability Meeting

IRT – Infrared Thermography

IT – Information Technology

LOA – Level-of-Awareness

LOTO – Lock-Out-Tag-Out

LTAM – Long Term Asset Management

MBO – Maintenance Basis Optimization

MCA – Material Condition Assessment

MCIP – Material Condition Improvement Program

MEL – Master Equipment List

MOV – Motor Operated Valve

MPI – Maintenance Priority Index

NC – Non-Critical

NOV – Notice Of Violation

O&M – Operations & Maintenance

OCR – Operational Criticality Ranking

OLM – Online Monitoring

P&ID – Piping & Instrument Diagram

PAM – Proactive Maintenance

PdM – Predictive Maintenance

PI – Plant Information

PM – Preventive Maintenance

PM-CMT – Preventive Maintenance – Condition Monitoring Task

PM-RR – Preventive Maintenance – Restore/Replace

PMT – Post-Maintenance Test

ROI – Return on Investment

RTF – Run-to-Failure

SCR – System Criticality Ranking

SERP – System and Equipment Ranking & Prioritization

SHM – System Health Monitoring

SHR – System Health Report

SME – Subject Matter Expert

SPV – Single Point Vulnerability

SSC – System, Structure, Component

TE – Technology Examination (Tech. Exam.)

TPA – Temporary Plant Alteration

UNID – Unique Number Identification

WO – Work Order

C

APPENDIX – MATERIAL CONDITION ASSESSMENT REPORT EXAMPLE

System/Component Material Condition Assessment (MCA) Walkdown Report

2011

Plant Site: Four Corners Unit #: 4 System/Sub System: Baghouse/ NW BH Fly Ash Handling

Date: 9/1/2011 Time: 10:00am System Engineer: Russell Cloer

Overall Status of Walkdown: Excellent ☐ Acceptable ☐ Marginal ☐ Unacceptable ☒

Summary of Results:

Result #:	Description of Issue Found:	Action Taken (CAR#):	Recommended WO Priority:
1	Pin Hole leak in Fly Ash Handling pipe downstream of #12 Air Lock.	CAR # xxxx	2
2	Isolation valve to Air #10 leaking around gate packing.	CAR # xxxx	2
3	#12 Hopper equalizing valve solenoid leaking air from bleed off port.	CAR # xxxx	8
4	#9 Hopper equalizing valve solenoid and lower gate actuator cylinder leaking air.	CAR # xxxx	8
5	#6 Hopper lower gate actuator cylinder leaking air.	CAR # xxxx	8
6	#4 Air Lock lower gate actuator missing cotter pin.	CAR # xxxx	8
7	#3 and #1 Air Lock lower gate actuator missing cotter pin.	CAR # xxxx	8

Operations Comments / Concerns:

There were no operations comments during the walkdown.

Remarks:

Walkdown was conducted as a training exercise with System Engineer.

Note: **WO Priority Levels:** **1**-Start work immediately **2**-Start work within 24 hrs **3**-Start work within 2 weeks **4**-Start work within 5 weeks **5**-Non-deferrable work normal schedule **6**-Deferrable work normal schedule **7**-Outage work that created outage **8**-Outage work must be completed **9**-Outage work could be completed

1

Example MCA Walk-Down Checklist

System:	
Walk-Down Performed By:	**Date:**
Walk-Down Boundaries:	
Plant Status:	**System Status:**

Plant or System Parameters Monitored: ☐ Applicable Tracking or Trending Data Update Required

Temperatures			Pressures			Flows			Other		
Parameter	Expected	Actual	Parameter	Expected	Actual	Parameter	Expected	Actual	Parameter	Expected	Actual

Equipment Performance Problems; Deficiencies; Material Condition Issues Identified:

☐ **Eng. Supervision Notified** ☐ **Ops. Dept. Notified;** ☐ **Digital Images captured**

Applicable Temporary Plant Alterations (TPA) or Incomplete Engineering Change Request (ECR) and any Configuration Control Issues Identified:

Ops Log Issues or Operator Work Arounds Identified:

Non-Acceptable (Not Green) Component Health Issues Identified:

Corrective Actions – Existing, Required, or Taken:

Existing CARs & WOs	Required Corrective Actions	CARs or Work Orders Created

Additional Comments:

D

APPENDIX – MANUAL SYSTEM HEALTH SCORECARD

System Health Indicator Scorecard					
Facility: Power Plant	**System: Heat Cycle**				
Sub-System: Feedwater	**Reporting Period**		**3rd Quarter 2011**		
Assessment Areas & Indicators	**Data Input Type**	**Indicator Score**	**Evaluation Value**	**Weight**	**Score**
Operational Performance					**25.5**
1. Operator Confidence (See 6.2.4.3.1)	Manual	1	75	10%	7.50
2. Number of Operator Work Arounds (See 6.2.4.3.2)	Auto	0	100	4%	4.00
3. Number of TPAs (See 6.2.4.3.3)	Auto	0	100	4%	4.00
4. Number of Generation Risks (See 6.2.4.3.4)	Manual	0	100	10%	10.00
System Performance Monitoring					**30.0**
5. System Engineer Confidence (See 6.2.4.4.1)	Manual	0	100	10%	10.00
6. Commercial Availability Losses (See 6.2.4.4.2)	Manual	0	100	5%	5.00
7. Number of Red & Yellow Components from PlantIQ (See 6.2.4.4.3)	Auto	0	100	15%	15.00
Maintenance & Material Condition					**21.5**
8. Number of CM-U Work Orders (See 6.2.4.5.1)	Auto	0	100	6%	6.00
9. Total Online CM-U/CM-E Backlog (See 6.2.4.5.2)	Auto	1	75	1%	0.75
10. Total Outage CM-U/CM-E Backlog (See 6.2.4.5.3)	Auto	1	75	1%	0.75
11. Critical Component PMs Overdue (See 6.2.4.5.4)	Auto	0	100	6%	6.00
12. PdM PMs Overdue (See 6.2.4.5.5)	Auto	0	100	6%	6.00
13. Number of Rework Work Orders (6.2.4.5.6)	Auto	0	100	2%	2.00
Life Cycle Management					**7.5**
14. Obsolescence Issues (See 6.2.4.6.1)	Manual	0	100	2%	2.00
15. Critical Spare Status (See 6.2.4.6.2)	Manual	0	100	2%	2.00
16. Number of Single Point Vunerabilities (SPVs) (See 6.2.4.6.3)	Manual	0	100	2%	2.00
17. Engineering Change Request (ECRs) Backlog (See 6.2.4.6.4)	Auto	1	75	2%	1.50
Environmental Compliance					**12.0**
18. Environmental Coordinator Confidence (See 6.2.4.7.1)	Manual	0	100	10%	10.00
19. Number of Notice Of Violations (NOVs) and/or Reportable Environmental Incidents (REI) (See 6.2.4.7.2)	Manual	0	100	2%	2.00
SYSTEM HEALTH SCORE					
System Health is Green				**100%**	**96.50**

E

APPENDIX – SYSTEM HEALTH ACTION PLAN EXAMPLE

System Health Action Plan for YELLOW, & RED Systems

System ____________________ System Engineer ___________________Date _____________

Current Overall Color: ______________________ Total Points: _________________________

Scorecard Summary: Record the Color of each window input in the box:

Color	Assessment Area	Reason
	Operational Performance	
	System Performance Monitoring	
	Maintenance and Material Condition	
	Life Cycle Management	
	Environmental Compliance	

Improvement Action Summary: For each input that is RED or YELLOW, summarize plans to improve the system. Include any appropriate tracking numbers involved, projected completion date, and action owner.

	Action	Due Date	Owner	Tracking No.
1.				
2.				
3.				
4.				

Forecast: Based on plans above and projected completion dates, indicate when system will improve to an overall Yellow and/or White.

CURRENT OVERALL COLOR	Month PROJECTED YELLOW (if currently RED)	Month PROJECTED WHITE (if currently Yellow)

F

APPENDIX – SYSTEM HEALTH OVERVIEW REPORT EXAMPLE

System Health Overview Report

Plant:	Cholla Power	**Date:**	10/5/2011
System:	Feedwater	**Preparer:**	Tim Vachon

Assessment Area	Color Indicator	Reasons for Color Indicator
Operational Performance	Green	Acceptable Criteria
System Performance Monitoring	Green	Acceptable Criteria
Maintenance & Material Condition	Green	Acceptable Criteria
Life Cycle Management	Green	Acceptable Criteria
Environmental Compliance	Green	Acceptable Criteria

List of components with Marginal (Yellow) health reports: 1B Boiler Feed Pump, IRT indicated an increase temperature on the outboard pump bearing as compared to similar pump bearings. WO #CH554695 created, investigation on-going.

Operational Recommendations: None

Configuration Control Issues: None

List any O&M or Capital projects, ECR's that will resolve any long term issues or Condition Action Reports that are investigating any issues: ECR WO CH5077773 initiated to install Cuno filter platforms, this was initiated as a safety issue so that operations could safely access the filters. Unit 3 BFP rotating element O&M project to determine when and if which unit 3 BFP rotating element should be replaced is ongoing. This project was originally initiated as a capital project, but has sense been delineated as O&M, CAR 27081 is tracking progress.

List any Scheduled or Forced Outage jobs or any significant outage preparation issues: None
List System Team Accomplishments: Boiler Feed Pump Performance field testing completed on units 2, 3 & 4
Critical Spare Discussion/Information: None
Single Point Vulnerability Discussion/Information: None
System Material Condition
Completed Corrective Maintenance Activities: The FW controls issue was investigated and resolved through Root Cause Analysis report #XXXXXX.
Corrective Maintenance Work Order Review: 8 Outage CM Work Orders & 5 On-Line CM Workers
Other System Issues
Operator Confidence is only Acceptable due to a recent Operations Departement Clock Reset due to a possible controls issues within the Feedwater systems. The issue has been found and resolved however high confidence has not been restored yet.

G

APPENDIX – SERP CRITERIA EXAMPLE

A. Safety

10	High Safety Concern, possible fatality…injuries occur to personnel
8	High Safety Concern – possible injuries occur to personnel….lost time
5	Safety concerns - Possible doctor attended injuries
3	Low Safety Concern - Action taken to secure area
1	No Safety Concern

B. Environmental

10	Shut Down
8	Fine
5	Notice of Violation
3	Close Call (Non-Reportable)
1	No Effect

C. System Cost Criteria

10	Major O&M Cost > $100,000
6	Medium O&M Cost $100,000 > *X* >$50,000
4	Minor O&M Cost < $50,000
1	No Effect

C. Equipment Cost Criteria

10	Major O&M Cost > $1,000,000
9	$500,000 - $1,000,000
8	$250,000 - $500,000
7	$100,000 - $250,000
6	$75,000 - $100,000
5	$50,000 - $ 75,000
4	$25,000 - $50,000
3	$5,000 - $25,000
2	$1,000 - $5,000
1	No Effect - $1,000

D. Commercial Availability – Use the following ratings and document the loss of MW and the timing of that loss

10	Plant (all units) Shutdown
9	Long Term Unit Shutdown (> 1 week)
8	Short Term Unit Shutdown (< 1 week)
7	Long Term Boiler Shutdown (> 1week) for dual boiler units only
6	Short Term Boiler Shutdown (< 1week) for dual boiler units only
5	Long Term Unit Load Reduction (> 1 week)
4	Short Term Unit Load Reduction (< 1 week)

3 Future Potential Loss of MW’s
1 No Effect

E. Efficiency

10 > 100 BTU’s
5 < 100 BTU’s and > 25 BTU’s
1 < 25 BTU’s

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