Plant Maintenance Optimization (PMO) Program Development

Fleet Asset Management & Optimization Solutions Symposium

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PMO Presentation Topics/Objectives

INSERT KEY SOLUTIONS

1. Define PMO and Objectives
2. Gain a working understanding of the PMO Process and Maintenance Basis key elements:
   - 2.1 Component Classification
   - 2.2 PM Templates and Implementation
   - 2.3 Component-Based Maintenance Strategies
3. Recognize how PMO and the Maintenance Basis impacts other Equipment Reliability (ER) elements.
4. Briefly Discuss Continuous Improvement Processes
5. Demonstrate software and productivity tools that facilitate the PMO process and the “Living” Maintenance Basis

Plant Maintenance Optimization (PMO) – Definition

INSERT KEY SOLUTIONS

- Systematic process of developing an optimized **Maintenance Basis** that increases equipment reliability and plant capacity factor.
  - Priority on Critical and Non-Critical Components.
    - Run-To-Failure (RTF) Components must be identified.
  - Scope includes all Maintenance Tasks
    - PM Program – Time-based tasks
    - Condition Monitoring, PdM, Performance Monitoring
    - Surveillance and Performance Tests
    - Long Term Asset Management - Rebuild/Replace Strategies
  - Optimization must incorporate overall company objectives.

PMO – Objectives

- Perform the Right Work at the Right Time.
  - Within Resource/Cost Limitations
- Eliminate Corrective Maintenance – Unexpected (CM-U).
  - Maintenance Basis Failures
- Create a Living Maintenance Basis.
  - Visibility
  - Continuous Improvement

Corrective Maintenance Expected vs. Unexpected

- PMO does not eliminate all Corrective Maintenance (CM)
  - Expected and Unexpected is an important distinction

- Corrective Maintenance – Expected (CM-E)
  - CMs on Run-To-Failure (RTF) Components are Expected
  - CMs on Non-Critical Equipment are Expected
    - Not all Failure Modes are protected through PM/Condition Monitoring (PdM)
    - Some level of risk is acceptable based on company objectives
  - CM-E is not a Maintenance Basis Failure

CM Expected vs. Unexpected Con't

INSERT KEY SOLUTIONS

- Corrective Maintenance – Unexpected (CM-U)
  - CM-U is a Maintenance Basis Failure
  - Critical Component Failures are obvious examples of CM-U
  - Identification of CM-U is critical to success
  - When CM-U's occur, cause analysis and actions should be taken to eliminate future failures

- Identification of CM-U/CM-E requires a visible Maintenance Basis!
  - Electronic Format in Shared Environment

- CM-U is an important Performance Indicator
  - Effectiveness of the Maintenance Basis
  - Electronic Capture, Trending/Reporting Needed

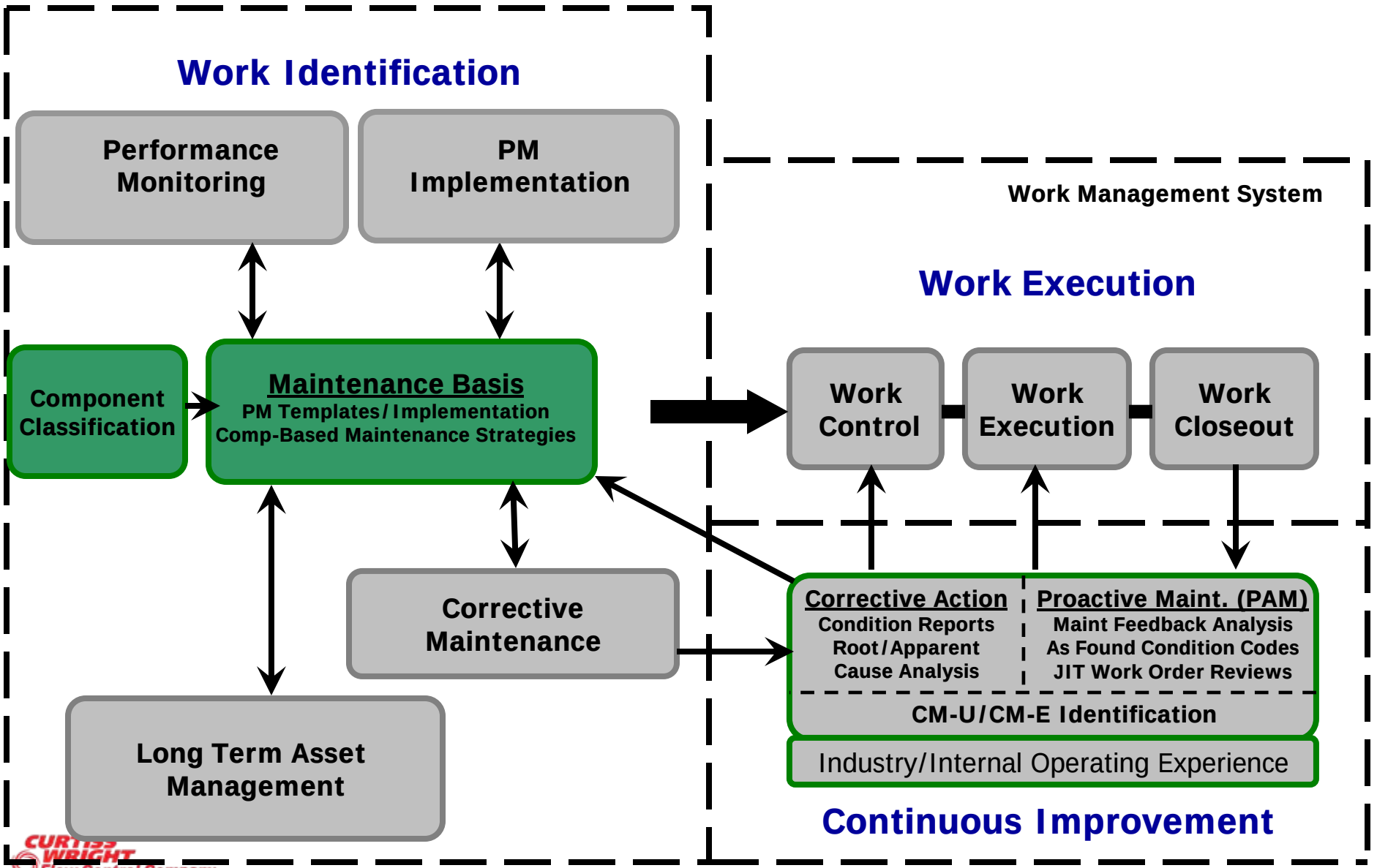
Management and Leadership need Education!

Maintenance Basis Elements

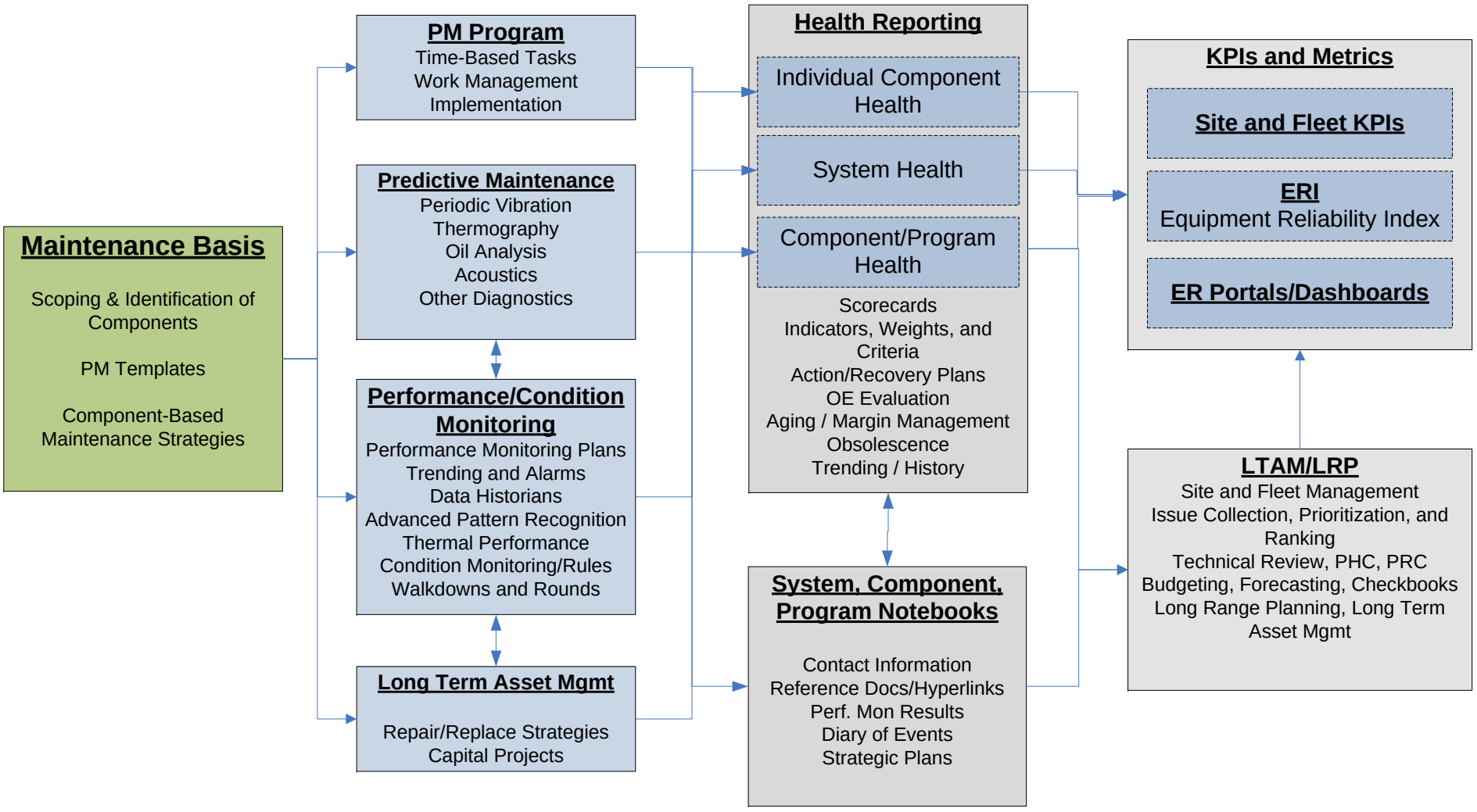
- **Component Classification**
  - Importance – Critical, Non-Critical, Run-To-Failure (RTF)
  - Duty Cycle – High/Low
  - Service Condition/Environment – Mild/Severe
- **PM Template Development**
  - Component Type Maintenance Strategy
  - Based on Company Objectives
  - Incorporate Condition Monitoring, PdM
- **PM Template Implementation**
  - Component-Based Maintenance Strategies
  - Reconcile with Current Practice
    - Add/Delete PM Tasks, Extend Frequencies
  - Identify and Execute Change

Fundamental Building Block to Equipment Reliability!

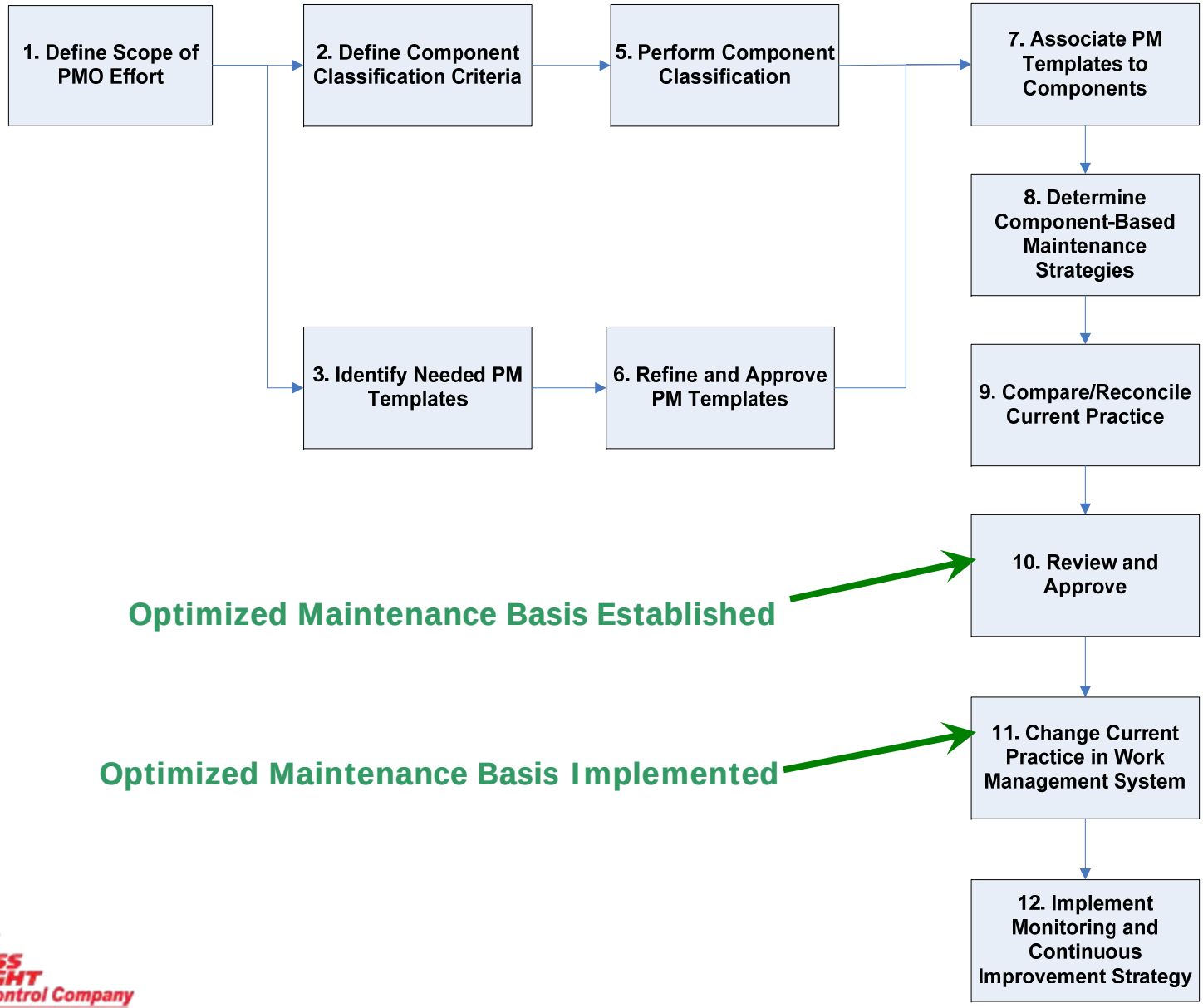
Equipment Reliability Process



Maintenance Basis and Performance Monitoring



PMO Implementation Approach



Comp Classification – Definition

- Component Classification Elements
  - Component Importance – Impact on System Functions
  - Duty Cycle – (High/Low)
  - Service Condition/Environment (Mild/Severe)

- 3 Character Abbreviation Used Often
  - Example
    - CHS = Critical Importance, High Duty Cycle, Severe Service Condition

- Component Importance Terms
  - Industry Standard Terms – Critical, Non-Critical, Run-To-Failure (RTF)
  - Company Example – Critical (C), Significant (S), Economic (E), RT
    - 1A, 1B, 2, 3 … others

Performing Component Classification

- Determined Primarily by System Engineers
- Input required from:
  - Operations, Instrument & Controls (I&C) SME, Others
- Focuses attention of Component Engineers/Experts to the right components
  - Component Experts are generally not System Experts!
- Provides first clue to Component Grouping
  - PMO Productivity
- Plenty of industry benchmark data available

Comp Classification Basis – Criteria Driven

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- Standard Criteria

  Can be implemented

  as wizard-like questions.

Answer all of the questions in sections 1-3 below to determine the component's ER classification. Note - Answers pertaining to the initial Component Classification process are not required.

1. ERC 1A criteria - Does the component's failure cause loss of a function that will result in any of the following?

No	Defeated or degraded Maintenance Rule risk significant function?
Yes	Reactor or turbine trip?
No	Power transient or derate >2%?
No	Entry into a TS shutdown or derate action statement of <= 72 Hours?
No	Actuation of engineered safeguards features (ESF), including; Auxiliary Feed Water, Safety Injection, Residual Heat Removal (RHR), Chemical and Volume Control (CVCS)?
Yes	Determined to be Critical (1A). Basis Unknown

2. ERC 1B criteria - Does the component's failure cause loss of a function that will result in any of the following?

No	Defeated or degraded Maintenance Rule non-risk significant function?
No	Entry into a shutdown or derate action statement > 72 hours?
No	Loss of automatic trip, interlock, or control to maintain a critical function or to protect critical equipment. This criteria pertains to supporting the operation and protection of critical equipment?
No	Loss of local or control room indication for performance monitoring of critical functions. For example, a performance or condition indicator used for decision input in an Annunciator Response procedure to reduce load or initiate a Unit trip.
No	Reduction in defense-in-depth that could lead to a reactor or turbine trip. This includes train redundancy such as standby parallel pumps, and built-in control logic redundancies such as 2/3 signal actuation. The extent of this criteria is that the reduction results in placing the Unit one step away from a plant trip or > 2% load reduction?
No	Determined to be Critical (1B). Basis unknown.

3. ERC 2 criteria - Are any of the following applicable to the component?

No	Failure has regulatory consequences, or maintenance is required to satisfy commitments. For example: Maintenance is required to satisfy commitments such as OSHA or NEIL, Failure results in a violation of an NPDES permit, Maintenance

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Component Classification – Key Points

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- Capturing Result of Classification (CHM) is not enough!
  - Common U.S. Mistake
  - Must capture the basis for the Classification
  - Question Answers make up the basis
- Evaluate all Criteria/Questions – Don't Stop!
  - Useful Data for Analysis

No	Defeated or degraded Maintenance Rule non-risk significant function?
No	Entry into a shutdown or derate action statement > 72 hours?
No	Loss of automatic trip, interlock, or control to maintain a critical function or to protect critical equipment. This criteria pertains to supporting the operation and protection of critical equipment?
No	Loss of local or control room indication for performance monitoring of critical functions. For example, a performance or condition indicator used for decision input in an Annunciator Response procedure to reduce load or initiate a Unit trip.
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No	Determined to be Critical (1B). Basis unknown.

PM Templates – Definition and Key Elements

INSERT KEY SOLUTIONS

- Industry Method to Group, Evaluate, Monitor Component Equipment Reliability.
  - Industry “Best Practice”
- Corporate Recommended Maintenance Strategy
  - Established for Component Types
  - Further Groupings
- Captures Expertise of
  - experienced workers before they retire / In-house “tribal knowledge”
  - industry events and experience
  - outside experts (Goodyear, ARGO)
  - numerous System Engineers
- Provides PM Basis
  - the what, when, how, & why
- Essential for Fleet Standardization – 1 Set for a Fleet!
  - Requires Site and Corporate Component Specialists Ownership to Create

PM Templates – Key Driver

INSERT KEY SOLUTIONS

- Component Classification – Key Driver
  - Component Importance – Critical, Significant, Economic
    - Does not cover RTF – No need
  - Duty Cycle – High, Low (e.g. How frequently does it stroke?)
  - Service Condition – Mild, Severe (Pressure, Temperature, Environment …)

Component Classification		CHS	CLS	CHM	CLM	SHS	SLS	SHM	SLM	EHS	ELS	EHM	ELM
Criticality	Critical	x	x	x	x								
	Significant					x	x	x	x				
	Economic									x	x	x	x
Duty Cycle	High	x		x		x		x		x		x	
	Low		x		x		x		x		x		x
Service Condition	Severe	x	x			x	x			x	x		
	Mild			x	x			x	x			x	x

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PM Template – Example Task View

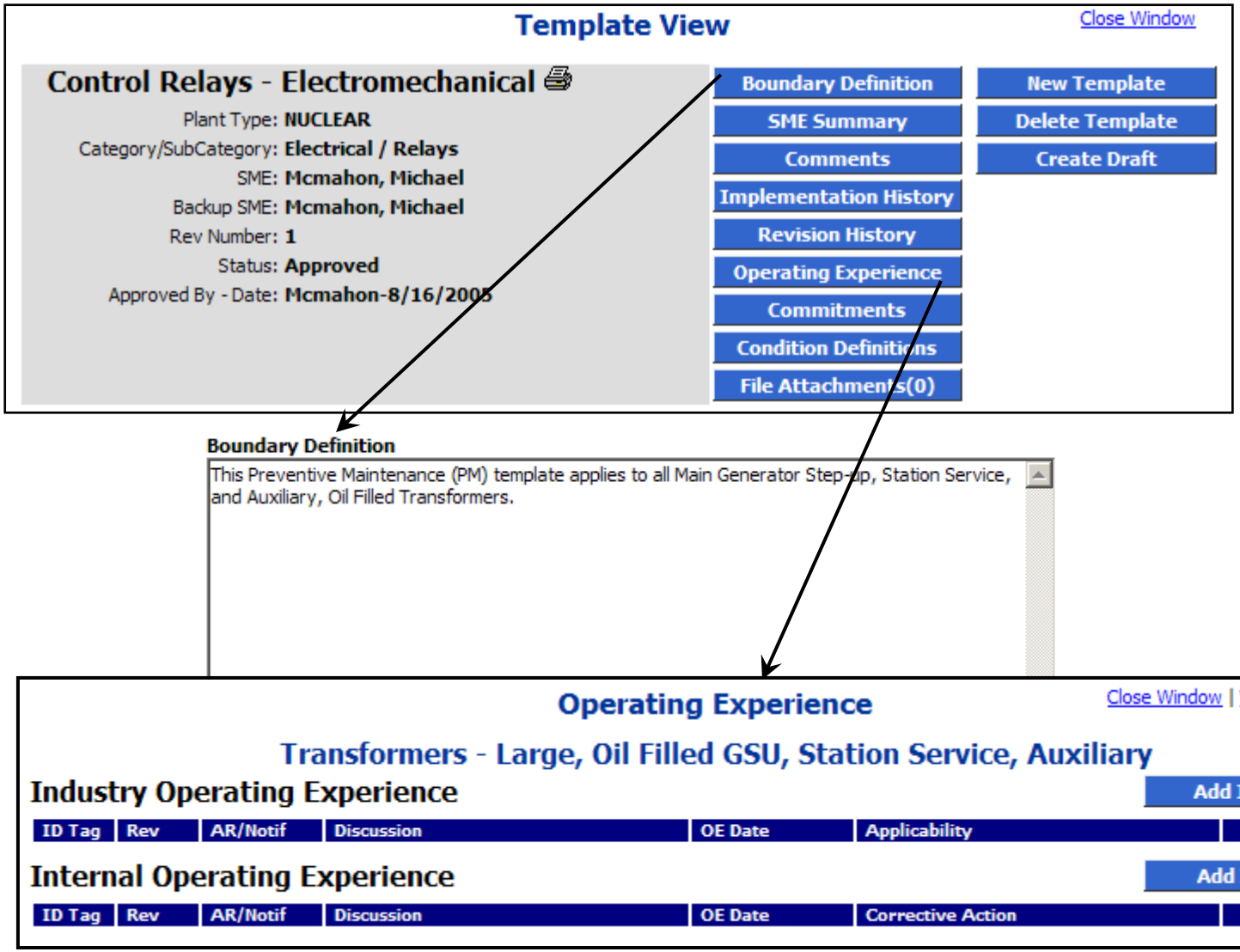
Component Classification		CHS	CLS	CHM	CLM	SHS	SLS	SHM	SLM	EHS	ELS	EHM	ELM
Criticality	Critical	x	x	x	x								
	Significant					x	x	x	x				
	Economic									x	x	x	x
Duty Cycle	High	x		x		x		x		x		x	
	Low		x		x		x		x		x		x
Service Condition	Severe	x	x			x	x			x	x		
	Mild			x	x			x	x			x	x
Condition Monitoring													
Coupling Inspection		18 M	18 M	18 M	18 M	5 Y	5 Y	5 Y	5 Y	AR	AR	AR	AR
Failure Mode		Coupling Wear											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Oil Analysis		1 Q	1 Q	1 Q	1 Q	1 Q	1 Q	1 Q	1 Q	6 M	6 M	6 M	6 M
Failure Mode		Black Oil, Hot Radial Bearings, Hot Thrust Bearing											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Performance Trending		1 Q	1 Q	1 Q	1 Q	6 M	6 M	6 M	6 M	1 Y	1 Y	1 Y	1 Y
Failure Mode		Accelerated Material Erosion/Corrosion, Excessive Noise, High Impact Loading, High Motor Amps, Hot Radial Bearings, Hot Thrust Bearing, Hydraulic Instability, Premature Opening of Pump Internal Clearances, Seal Leakage											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
System Engineer Walkdown		1 Q	1 Q	1 Q	1 Q	1 Y	1 Y	1 Y	1 Y	1 Y	1 Y	1 Y	1 Y
Failure Mode		Casing Leakage, Coupling Wear, Excessive Noise, Hot Radial Bearings, Hot Thrust Bearing, Seal Leakage											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Thermography		6 M	6 M	6 M	6 M	6 M	6 M	6 M	6 M	AR	AR	AR	AR
Failure Mode		Hot Thrust Bearing											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Vibration Analysis		1 M	1 M	1 M	1 M	1 Q	1 Q	1 Q	1 Q	6 M	6 M	6 M	6 M
Failure Mode		Accelerated Material Erosion/Corrosion, Coupling Wear, Excessive Noise, High Impact Loading, High Motor Amps, Hot Radial Bearings, Hot Thrust Bearing, Hydraulic Instability, Premature Opening of Pump Internal Clearances											
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Condition Directed													
Partial Disassembly		AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR
Failure Mode													
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					
Refurbishment		AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR
Failure Mode													
		Man Hours Needed: 0		Hours Unavailable: 0				Sort Order: 0					

PM Template – FMECA View

- FMECA – Failure Modes, Effects, & Criticality Analysis
  - Normally required before tasks are created/designed.
- Centrifugal Pumps
  - Example

Functions Affected	Failure Mode	Parts	Failure Cause	Tasks	Actions
Performance	Accelerated Material Erosion/Corrosion	Impeller, Diffuser	Hydraulic Instability	Performance Trending	Notes
Performance	Black Oil	Bearings	Insufficient Preload, Improper Oil Level, Improper Oil Viscosity, Excessive Thrust Loads, Axial Shuttling	Oil Analysis	Notes
Performance	Casing Leakage	Pump Casing	Deteriorated Gaskets, Excessive Pipe Strain	System Engineer Walkdown	Notes
Performance	Coupling Wear	Coupling, Coupling Insert	Abnormal Material Wear/Deterioration	Coupling Inspection	Notes
Performance	Excessive Noise	Impeller, Diffuser, Shaft, Bearing	Hydraulic Instability, Internal Rubbing, Tight Gap B	Performance Trending	Notes
Performance	High Impact Loading	Impeller, Diffuser	Off-peak Operation, (Small Gap B)	Performance Trending	Notes
Performance	High Motor Amps	Impeller, Diffuser, Wear Ring	Internal Rubbing	Performance Trending	Notes
Performance	Hot Radial Bearings	Bearing, Seal	Misalignment, Oil Contamination, Insufficient Lubrication, Defective Bearing, Tight Clearances, Low Flow Operation	Oil Analysis	Notes
Performance	Hot Thrust Bearing	Bearing, Balance Device	Misalignment, Insuficient Lubrication, Oil Contamination, Hydraulic Instability, Defective Bearing, High Oil Level (ball bearings), Improper Thrust Collar Setting (KTB), Insufficient Bearing End Play, Improper Preload (ball bearings)	Oil Analysis	Notes
Performance	Hydraulic Instability	Impeller, Diffuser, Shaft, Seal, Bearing	Inlet Separation or Discharge Recirculation (Large Gap A/B)	Performance Trending	Notes
Performance	Premature Opening of Pump Internal Clearances	Impeller, Diffuser, Wear Ring	Misalignment, Abnormal Wear	Performance Trending	Notes
Performance	Seal Leakage	Seal	Misalignment, Axial Shuttling, Excessive Shaft Deflection, Pipe Strain, High Vibration	Performance Trending	Notes

PM Template – Header and other Key Information



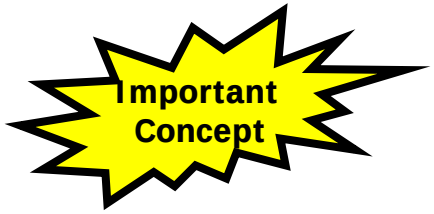
PM Template Implementation

- Templates must be firmly tied to Component Identifiers in the MEL
- Template Association is by Component Type
- Can be Performed in Mass – Productivity
  - Software Tool makes efficient
- Some Components will Not have a Templates
  - Does not mean Out of Scope
  - Still can have a Maintenance Strategy ...
- Goal for PMO In Scope Components
  - 60 – 80% of Components Associated/Covered by a Template

Component-Based Maintenance Strategies

INSERT KEY SOLUTIONS

Component Classification + Template Association
= Recommended
Component Maintenance Strategy



Component ID	Equipment Desc	Component Classification	Template	Status	Actions
1RY1D306/T2	EMERGENCY SEAL OIL PP RY	Critical, Low Duty Cycle, Mild Service Condition	Electromechanical Control Relays - Timing	Approved	View Add
1RY1E01/51M	GENERATOR LIMIT ALARM	Critical, Low Duty Cycle, Mild Service Condition	Protective Relays - Solid State	Approved	View Add
1RY1E01/51M2	EXCITATION CONTROL UNIT 1	Critical, Low Duty Cycle, Mild Service Condition	Electromechanical Control Relays - Timing	Approved	View Add
1RY1E01/51MX	EXCITATION CONTROL UNIT 1	Critical, Low Duty Cycle, Mild Service Condition	Control Relays - Electromechanical	Approved	View Add
1RY1E01/51R	GENERATOR LIMIT ALARM	Critical, Low Duty Cycle, Mild Service Condition	Protective Relays - Solid State	Approved	View Add
1RY1E01/51R2	EXCITATION CONTROL UNIT 1	Critical, Low Duty Cycle, Mild Service Condition	Electromechanical Control Relays - Timing	Approved	View Add
1RY1E01/51RX	EXCITATION CONTROL UNIT 1	Critical, Low Duty Cycle, Mild Service Condition	Control Relays - Electromechanical	Approved	View Add
1RY1E01/64E	VOLT REG GND DET. EXCITER	Critical, Low Duty Cycle, Mild Service Condition	Protective Relays - Solid State	Approved	View Add
1RY1E01/64EX	EXCIT. FIELD GND. DETECTION ANNUN.	Critical, Low Duty Cycle, Mild Service Condition	Control Relays - Electromechanical	Approved	View Add
1RY1E01/64G	VOLT REG GND DET. GENERATOR	Critical, Low Duty Cycle, Mild Service Condition	Protective Relays - Solid State	Approved	View Add
1RY1E01/64GX	GEN. FIELD GND. DETECTION ANNUN.	Critical, Low Duty Cycle, Mild Service	Control Relays -	Approved	View Add

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Component-Based Maintenance Strategies

INSERT KEY SOLUTIONS

- Component Classification + Template Association = Recommended Component Maintenance Strategy

Control Relays - Electromechanical

Plant Type: **NUCLEAR**
Category/SubCategory: **Electrical / Relays**
SME: **Mcmahon, Michael**
Backup SME: **Mcmahon, Michael**
Rev Number: **1**
Status: **Approved**
Approved By - Date: **Mcmahon-8/16/2005**

Boundary Definition | New Template
SME Summary | Delete Template
Comments | Create Draft
Implementation History
Revision History
Operating Experience
Commitments
Condition Definitions
File Attachments(0)

Task View | FMECA View

☐ View Basis Text

Component Classification		CHS	CLS	CHM	CLM	SHS	SLS	SHM	SLM	EHS	ELS	EHM	ELM
Criticality	Critical	x	x	x	x								
	Significant					x	x	x	x				
	Economic									x	x	x	x
Duty Cycle	High	x		x		x		x		x		x	
	Low		x		x		x		x		x		x
Service Condition	Severe	x	x			x	x			x	x		
	Mild			x	x			x	x			x	x
Failure Finding													
Functional Testing		2 Y	2 Y	2 Y	2 Y	AR	NR	AR	NR	NR	NR	NR	NR
Failure Mode		Fails to Operate											
		Man Hours Needed: 0			Hours Unavailable: 0				Sort Order: 0				
Condition Monitoring													
Thermography		2 Y	AR	2 Y	AR	NR	NR	NR	NR	NR	NR	NR	NR
Failure Mode		Fails to Govern/Regulate/Control											
		Man Hours Needed: 0			Hours Unavailable: 0				Sort Order: 0				
Time Directed													
Calibration		4 Y	6 Y	6 Y	8 Y	8 Y	12 Y	8 Y	NR	NR	NR	NR	NR
Failure Mode		Fails to Operate											
		Man Hours Needed: 0			Hours Unavailable: 0				Sort Order: 0				
Replacement		10 Y	10 Y	10 Y	AR	AR	NR	AR	NR	NR	NR	NR	NR
Failure Mode													
		Man Hours Needed: 0			Hours Unavailable: 0				Sort Order: 0				

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Component-Based Maintenance Strategies

INSERT KEY SOLUTIONS

Simplified Summary View of Maintenance Strategy

Example for a Single Feedwater Motor in the MEL

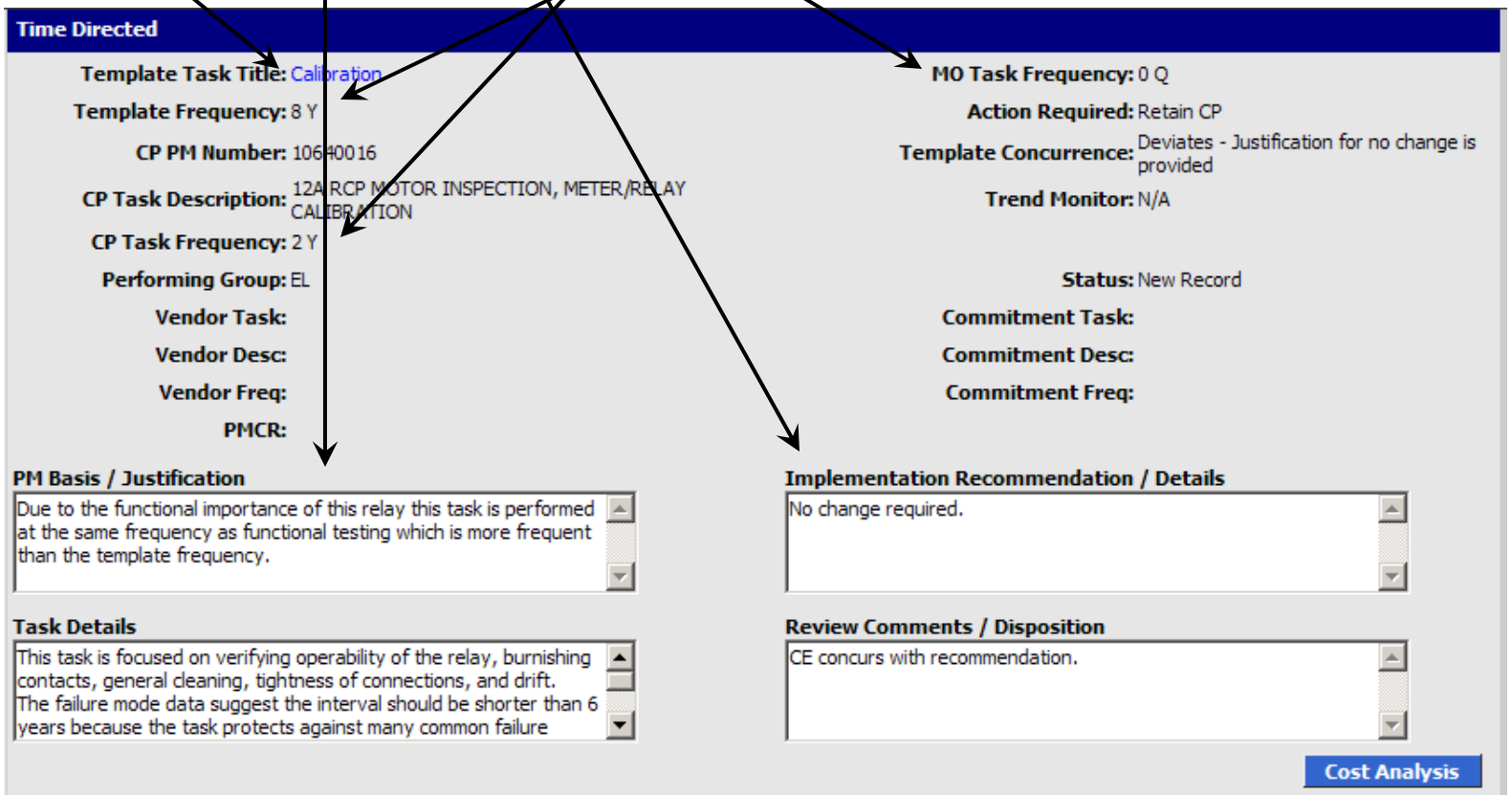
Template Tasks

Template Task Title	Template Frequency	Optimized Frequency	CP RT Number	CP RT Description	CP RT Frequency	Action Required	Status	Template Concurrence
Condition Monitoring								
Operator Rounds	1.00 SH						New Record	
Parameter Trending	0 AR	0 AR			0 D	No Action Required	Active	Concurrs With Template
Predictive Maintenance								
Off Line Diagnostic Testing	4.00 Y	4.00 Y	37115-14391-1	AFWP 1-3: TEST MOTOR W/ BAKER AWA	4.00 Y	No Action Required	Active	Concurrs With Template
Oil Analysis	6.00 M	9.00 M	35883-13159-1	AFWP 1-3: MOTOR BEARING OIL SAMPLE	9.00 M	No Action Required	Active	Concurrs With Template
On Line Diagnostic Testing	0 AR	0 N/A			0 D	No Action Required	Not Performed	Task Not Performed
Partial Discharge Testing	0 N/A	0 N/A			0 D	No Action Required	Not Performed	Task Not Performed
Thermography	6.00 M	0 AR			0 D	No Action Required	Active	Concurrs With Template
Vibration Monitoring	3.00 M	92.00 D	30991-8267-1	P AFWFF13 FULL FLOW MD AFW PP 1-3 (CSD @	92.00 D	No Action Required	Active	Concurrs With Template
Periodic								
Change Oil	0 AR	9.00 M	35883-13159-1	AFWP 1-3: MOTOR BEARING OIL SAMPLE	9.00 M	No Action Required	Active	Concurrs With Template
Clean and Inspect	2.00 Y	2.00 Y	35884-13160-1	AFWP 1-3 MOTOR: CLEAN, INSPECT & TEST	2.00 Y	No Action Required	Active	Concurrs With Template
Overhaul	0 AR	0 AR	35890-13166-1	AFWP 1-3: MOTOR OVERHAUL	99.00 Y	No Action Required	Active	Concurrs With Template
Replace Surge Capacitors	0 AR	0 N/A			0 D	No Action Required	Not Performed	Task Not Applicable
Planned Renewal								
Rewind	0 AR	0 AR			0 D	No Action Required	Active	Concurrs With Template

Component-Based Maintenance Strategies

INSERT KEY SOLUTIONS

- Result is a Complete Component-Based Maintenance Strategy
  - What Why How When



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What do you need to know?

INSERT KEY SOLUTIONS

Function

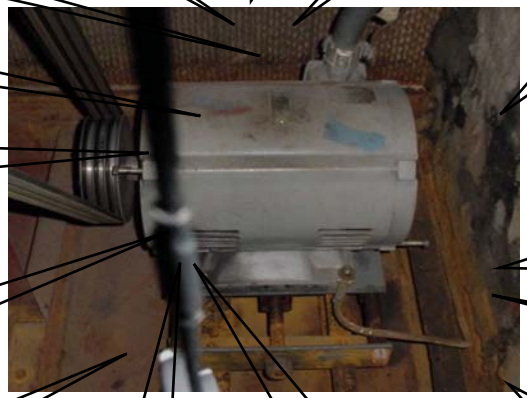
What is installed

Current PMs and Change History

Criticality

Work History

Duty Cycles



Operating Experience

- EPIX
- EPRI PMs
- LCM Source Books
- INPO
- NRC

Service Conditions

How Component is likely to Fail

Commitments

Other Utilities

Vendor Recommendations

?? ???

Other Experts

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PMO Results – Managing Change

- PMO will create change to Current Practice
  - Alignment/Reconciliation of Current Practice and Optimized Practice
    - Frequency Changes
    - Basis/Scope Changes
    - Add/Remove Tasks
  - Must consider resource impact
  - Risk Level – Non-Critical Equipment

- New Optimized Basis Requires Review and Approval
  - Who is responsible in your Organization?

- Change has to get executed!
  - Accountability

Maintenance Basis - Continuous Improvement

INSERT KEY SOLUTIONS

- Maintenance Basis Initial Development (PMO)
  - Strive for 85 - 90% Accuracy.
    - Perfection impossible on first pass.
  - Approach 100% through continuous improvement processes.
  - Maintenance Basis drives Work Identification!

- Continuous Improvement Processes – Living Program
  - Craft Feedback – After Work Completes
    - As Found Condition Codes, Completion Comments
    - Review, Evaluate, and Trend
  - Just-in-Time Reviews – Before Work Executes
    - Cross-Functional Team Reviews
  - Corrective Action Process (CAP)
    - Failure and Root Cause Analysis
  - Internal/External Operating Experience (OE)
    - Industry Databases (e.g. EPIX)

PMO Software Tools/Automation

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- PMO requires extensive data manipulation/management
  - Fleet Master Equipment Lists can be millions of records
  - Exceeds limits of Microsoft Access/Excel
- Productivity Tools very important
  - Grouping of similar components
  - Bulk data manipulation
- "Living" Maintenance Basis
  - Needs to be Shared – Self Service Environment
  - Will continue to change over time
- Metrics and Performance Indicators
  - Needed for Management and to track progress
  - No time to generate manually – Very time consuming
    - Need to be automated

Wrap Up

- Questions/Discussion?