ELECTRIC POWER RESEARCH INSTITUTE

Generation Maintenance Applications Center: Combined-Cycle Combustion Turbine Steam By-Pass Model Maintenance Guide

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Generation Maintenance Applications Center: Combined-Cycle Combustion Turbine Steam Bypass Model Maintenance Guide

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PRODUCT DESCRIPTION

Background

Combustion turbine combined-cycle (CTCC) facilities use various systems and components that are unique to this type of power generation plants and are not typically found in a nuclear or fossil power plant. As such, current CTCC facility owners' use of the Electric Power Research Institute's (EPRI's) Preventive Maintenance Basis Database is limited to those components that are common to both types of power plants and have been previously added to the EPRI Preventive Maintenance Basis Database. With the growth in the number of CTCC facilities, EPRI's Generation Maintenance Applications Center is committed to providing maintenance guidance for many of these unique or unaddressed components and systems and to facilitate the addition of these to the Preventive Maintenance Basis Database.

Objectives

The primary objective of the project that is the subject of this report is to provide information to CTCC owners to properly operate and care for the equipment and systems installed at their facilities. The guidance from the project will promote the safe, efficient, and cost-effective operation and maintenance of major types of equipment and systems that are unique to CTCC facilities. Furthermore, this report pilots the system template in the Preventive Maintenance Basis Database and moves the industry closer to automating the maintenance basis. The benefit to the public is that combustion turbines can produce low-carbon electricity at minimal cost with high reliability.

Approach

EPRI worked with a collaboration of owners, operators, original equipment manufacturers, and vendors to develop tactical guidance addressing common failure mechanisms of CTCC components and systems and to subsequently provide guidance for appropriate preventive maintenance (PM), repair and replacement, and troubleshooting of major components installed at a CTCC facility. The guidance in this report was developed in conjunction with the expert elicitation process.

Results

This report provides a comprehensive insight for managers of CTCC facilities to effectively address ongoing maintenance issues. The report provides an overview of steam bypass design parameters and familiarizes the user with the components that make up the types of attemperators installed at a CTCC and their functions. But the focus of the report is providing site personnel with insight to various failure mechanisms and detailed guidance for performing PM on a typical steam bypass system. The report also provides guidance regarding the repair and/or replacement of system components, which components are typically repaired or refurbished on-site, and troubleshooting guidance. The report also documents the decision-making process of implementing a maintenance basis.

Applications, Value, and Use

This report can be used for the in-house development of maintenance crews, providing training for contract maintenance travelers to overcome the loss of knowledge resulting from turnover, to provide a consistent maintenance program for major components of a CTCC facility, and to facilitate the implementation of the maintenance basis. By developing a reliability-based program using standard guidelines, owners can use it as a strength in bidding maintenance to a larger resource pool. It can be used as a basis for specifying long-term maintenance contracts that can be relied upon and to assist in stabilizing projected maintenance costs.

Keywords

Combined cycle
Combustion turbine
Preventive maintenance (PM)
Steam bypass
Troubleshooting

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1 INTRODUCTION

This report provides system and component-level information regarding the maintenance of major systems typically installed at a combined-cycle facility. It combines those recommendations offered by major equipment manufacturers with lessons learned from owner/operators of combined-cycle facilities.

1.1 Background

Combustion turbine combined-cycle (CTCC) facilities use various systems and components that are unique to this type of power generation plants and are not typically found in a nuclear or fossil power plant. As such, the use of the Electric Power Research Institute (EPRI) Preventive Maintenance Basis Database (PMBD) by current owners is limited to those components that are common to both types of power plants and have been previously added to the EPRI PMBD. With the growth in the number of CTCC facilities, EPRI Generation Maintenance Applications Center is committed to providing maintenance guidance for many of these unique or unaddressed components and systems, and to facilitate the addition of these to the PMBD.

1.2 Objectives

The primary objective of the project that is the subject of this report is to provide information to CTCC owners to properly operate and care for the equipment installed in their steam bypass system. The guidance from the project will promote the safe, efficient, and cost-effective operation and maintenance of major types of equipment that are unique to CTCC facilities. Furthermore, this report pilots the concept of the model maintenance program that provides a broad yet comprehensive maintenance basis for major components in the steam bypass system. The benefit to the public is that combustion turbines can produce low-carbon electricity at minimal cost with high reliability.

1.3 Contents of the Report

Figure 1-1 illustrates the general structure and content of this report. It identifies key sections in the report that provide guidance to owners to effectively address CTCC component maintenance issues.

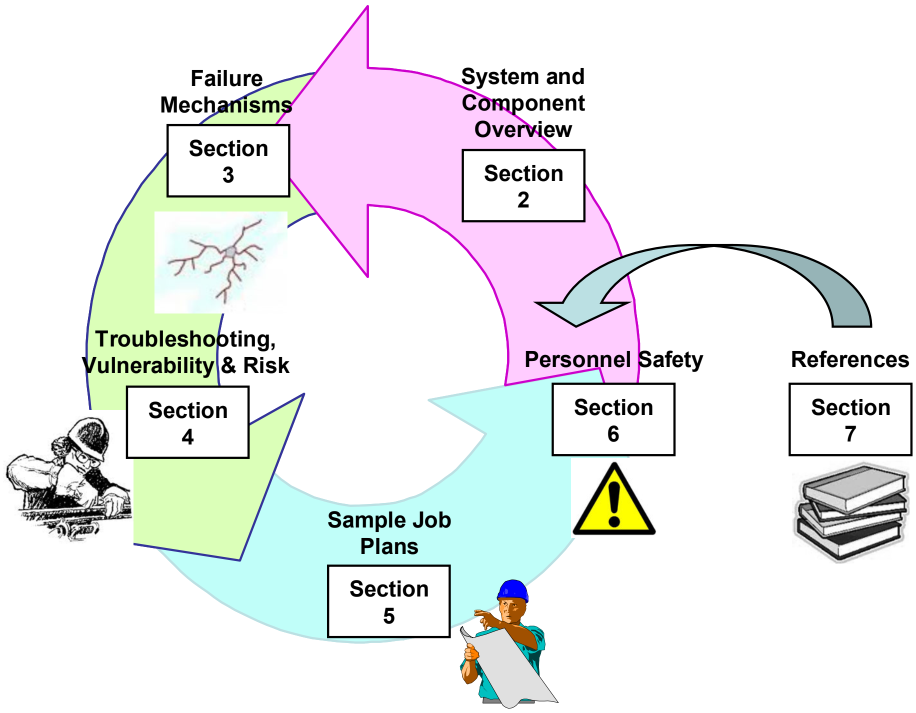

Figure 1-1
Scope and content of this EPRI report

This section provides an introduction to the report, and Section 2 provides an overview of system design parameters and familiarizes the user with steam bypass system components and their functions. The focus of the report is Sections 3 and 4, which provide insight into various failure mechanisms and detailed guidance for system troubleshooting, vulnerability, and risk analyses for variation from the standard preventive maintenance (PM) guidance provided in the PMBD. Examples of various job plans are provided in Section 5. Personnel safety guidelines are provided in Section 6, and Section 7 provides the user with a complete listing of references that were used during the development of this report.

Appendix A of the report is a complete listing of the Key Points. Guidance on the use of the PMBD vulnerability tool is provided in Appendix B, and Appendices C and D provide the baseline guidance from the PMBD for PM activities associated with mechanical and instrumentation and control (I&C) components, respectively.

1.4 Industry Definitions and Nomenclature

Condition-based maintenance (CBM). A methodology for performing PM activities based on the actual condition of the equipment rather than on the basis of fixed intervals or hours of operation.

Corrective maintenance. Maintenance tasks generated as a result of equipment failure. Corrective tasks are generated when equipment is purposely operated to failure or to correct a deficiency of a plant component that has failed or is significantly deficient so that failure is imminent (within its operating cycle/PM interval) and it no longer conforms to its design function.

Facilities. Structures, systems, and components not associated with power generation. Structures can include training facilities, warehouses, maintenance shops, and administrative offices. Systems can include fire protection, plumbing, lighting, sewer, and drainage.

Frequency-based or periodic maintenance. Activities that include time-based actions that preclude, mitigate, or detect degradation of a structure, system, or component to restore it to original like-new condition or extend its useful life by mitigating degradation to an acceptable level.

Preventive maintenance (PM). Activities performed to prevent unsatisfactory equipment conditions or performance from occurring.

Work instruction. Instructions for performance of the work to be accomplished, the level of detail of which is dependent on the assigned planning level. When applicable, approved procedures may be referenced and may suffice as work instructions.

Work order. A document used to control work and/or testing activities.

1.5 Definitions of Terms Associated with Maintenance Activities

The following sections provide an overview of the various types of maintenance activities that can be performed on the compressor section of the combustion turbine. The four types or categories of maintenance are shown in Figure 1-2.

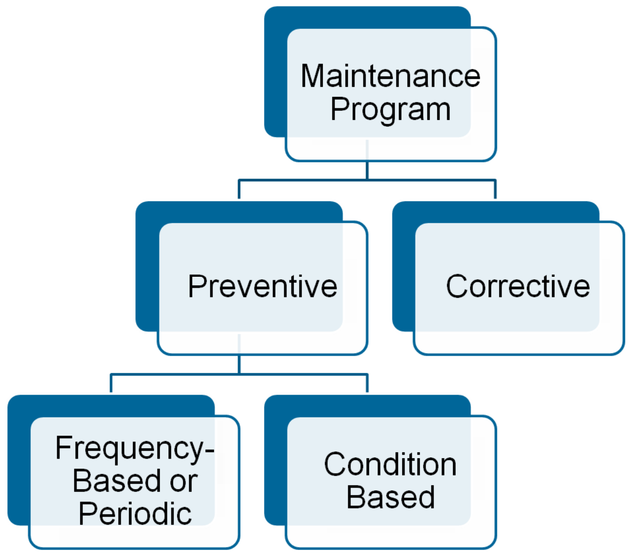

Figure 1-2
Types or categories of maintenance

1.5.1 Preventive Maintenance

PM tasks are performed to prevent unsatisfactory equipment conditions or performance from occurring. The distinction between predictive maintenance and periodic maintenance is presented in the following sections.

1.5.1.1 Periodic Maintenance

Periodic maintenance includes time-based actions that preclude, mitigate, or detect degradation of a structure, system, or component to either restore it to original like-new condition or extend its useful life by mitigating degradation to an acceptable level. Periodic maintenance can be performed to prevent breakdown and can involve servicing, such as lubrication, filter changes, cleaning, testing, adjustments, calibrations, and inspections. Periodic maintenance can also be initiated because of the results of predictive maintenance, vendor recommendations, or experience. The following are examples of periodic maintenance:

- Scheduled valve repacking because of anticipated leakage based on previous experience
- Major or minor overhauls based on experience factors or vendor recommendations
- Instrument calibrations used to meet plant specifications that are not part of a routine surveillance

1.5.1.2 Condition-Based Maintenance

Condition-based maintenance (CBM) is a methodology for performing PM activities based on the actual condition of the equipment rather than on the basis of fixed intervals or hours of operation. The following are examples of condition monitoring:

- Vibration analysis for all rotating equipment
- Thermography for temperature surveys on electrical equipment, leak detection, and overheating
- Oil analysis (tribology) to determine the equipment condition and also the lubricant condition
- Electrical testing for motor and generators

CBM would constitute the work triggered by condition monitoring, as listed in the preceding examples.

1.5.2 Corrective Maintenance

Corrective maintenance involves tasks generated as a result of equipment failure. Corrective tasks are generated when equipment is purposely operated to failure or to correct a deficiency of a plant component that has failed or is significantly deficient so that failure is imminent (within its operating cycle/PM interval) and it no longer conforms to its design function.

Detailed guidance regarding the repair of system components is provided in Section 5 of this report.

1.5.3 Initial Basis for PM Tasks and Frequencies

The maintenance information described in Sections 4 and 5 of this report provides insight into the PM tasks and frequencies initially developed in the EPRI PMBD. However, the user of this report should recognize that the PM tasks and frequencies recommended in Section 6 were developed with input from CTCC facility personnel with extensive maintenance, engineering, and operations experience. As such, the guidance contained in this report takes into consideration actual plant operating history and wear data, as well as the gas turbine manufacturer's initial recommendations for scheduled PM activities.

1.6 Definitions Associated with the Preventive Maintenance Basis

The following definitions are provided for the purposes of establishing the PM tasks and frequencies described in Sections 4 and 5 of this report.

1.6.1 Functional Importance

Critical. Functionally important—for example, required for power production or to support or meet regulatory requirements.

Minor. Functionally not important, but economically important—for example, high frequency of corrective maintenance, more expensive to replace or repair than to do PM, or has a high potential to cause the failure of other critical or economically important equipment. If the failure is not functionally important and also not economically important, this would correspond to run-to-failure, but these cases are excluded from the PMBD template.

1.6.2 Duty Cycle

High. Continuously run, alternated, or frequently cycled.

Low. Standby.

1.6.3 Service Conditions

Severe. High or excessive humidity, excessively high or low temperatures, excessive temperature variations, or excessive environmental conditions (such as dust, salt, or corrosive spray).

Mild. The absence of the preceding conditions, operated within design parameters.

1.7 Acronyms

AC	alternating current
ANSI	American National Standards Institute
AOV	air-operated valve
CBM	condition-based maintenance
CFR	Code of Federal Regulations
CHM	critical, high-duty, and mild service
CHS	critical, high-duty, and severe
CTCC	combustion turbine combined cycle
DC	direct current
DCS	distributed control system
DP	delta pressure
E/P	voltage to pressure
EPRI	Electric Power Research Institute
FAC	flow-accelerated corrosion
FME	foreign material exclusion
HGP	hot-gas path
HP	high pressure
HRH	hot reheat
HRSG	heat recovery steam generator
I&C	instrumentation and control
I/P	current to pressure
IP	intermediate pressure

ISA	International Society of Automation
LOTO	lock-out-tag-out
LP	low pressure
MCC	motor control center
MO	motor operator
MOV	motor-operated valve
MSDS	material safety data sheet
NDE	nondestructive evaluation
NHM	noncritical, high-cycle, and mild stress
NIST	National Institute of Standards and Technology
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
PCB	printed circuit board
PM	preventive maintenance
PMBD	Preventive Maintenance Basis Database
PPE	personal protection equipment
UW	unconditional wear-out

1.8 Conversion Factors for Units Used in This Report

1 in. = 25.4 mm

1 ft = 0.3 m

1°F = (°C x 9/5) + 32

1 lb = 0.45 kg

1.9 Listing of Key Points

Appendix A of this report contains a listing of all Key Points in each category. The listing restates each Key Point and provides a reference to its location in the body of the report. By reviewing this listing, users of this report can determine whether they have taken advantage of key information that the writers of this report believe would benefit their plants.

Throughout this report, key information is summarized in Key Points. Key Points are bold-lettered boxes that succinctly restate information covered in detail in the surrounding text, making the Key Point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to act for the benefit of their plant. EPRI personnel who reviewed this report assisted in the selection of the information included in these Key Points.

The Key Points are organized into four categories: Human Performance, Operations and Maintenance (O&M) Cost, Technical, and Supervisory Observation. Each category has an identifying icon to draw attention to it for the benefit of readers who are quickly reviewing the report. The Key Points are shown in the following way:

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Key Technical Point

Targets information that will lead to improved equipment reliability.

Key Supervisory Observation Point

Identifies tasks or series of tasks that can or should be observed by maintenance first line supervisors to improve the performance of the maintenance staff and improve the reliability of the component.

2
SYSTEM/COMPONENT DESCRIPTION

The purpose of this section is to provide owner maintenance and engineering personnel with an overview of steam bypass systems typically installed at a gas turbine combined-cycle plant.

2.1 Typical Steam Bypass System Installation

Figure 2-1 illustrates a simplified schematic of a typical steam bypass system that can be found at a CTCC facility.

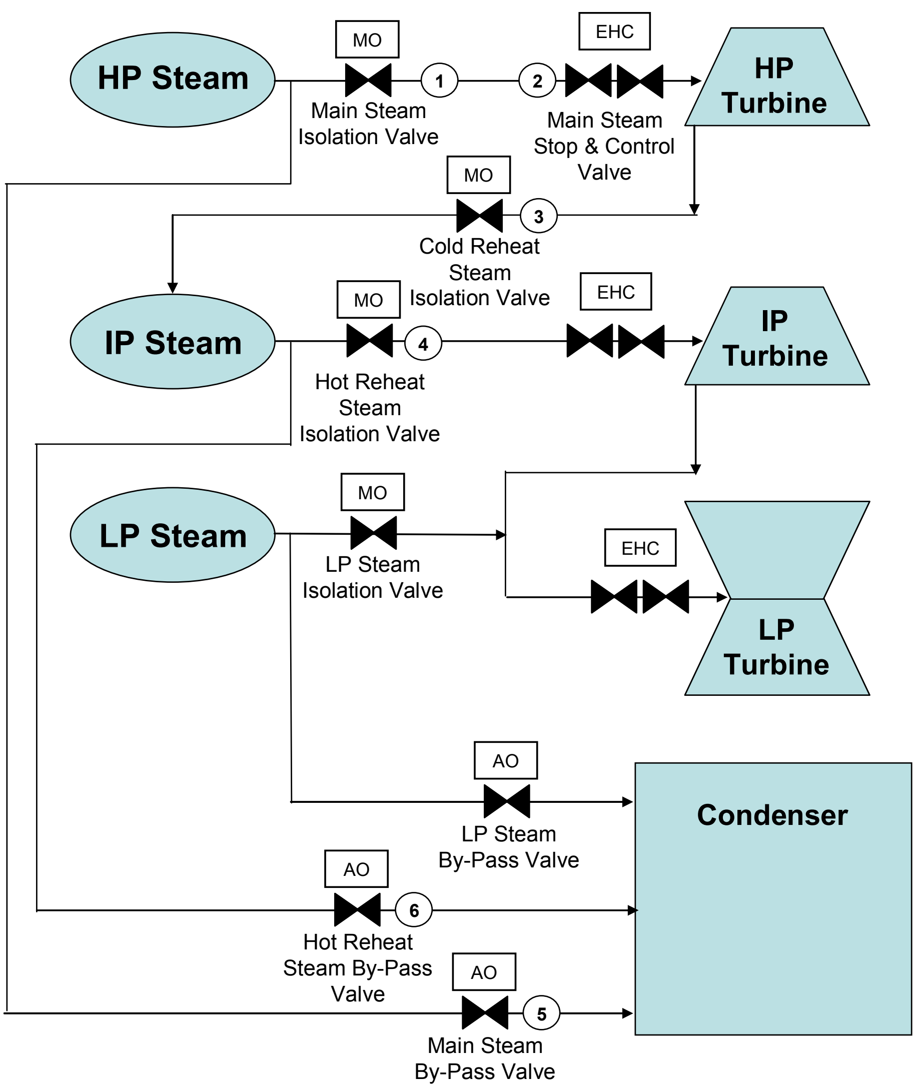

Figure 2-1
A steam bypass system at a CTCC plant

2.2 System Description and Boundary Statement

2.2.1 System Description

The steam bypass valves provide the following functions:

- Steam pressure regulation during startup as required to place the steam turbine into operation and also during simple cycle operation of the combustion turbine alone by maintaining sufficient pressure in the heat recovery steam generator (HRSG)
- Protection of the condenser from overpressurization and protection of steam piping from temperature excursions should the bypass desuperheaters malfunction
- Emergency pressure relief should the steam turbine trip, so that steam drum levels are not depressed to a level that would require a combustion turbines trip

The high-pressure (HP) bypass valve is released for operation after the combustion turbine flame is established. The current operating pressure is placed into memory and used as the initial setpoint for the bypass valve, and the setpoint is slowly adjusted toward a calculated setpoint. While condenser hogging is in progress, HP steam is diverted around the steam turbine to the cold reheat piping, back to the HRSG reheater, and vented to atmosphere by the HRSG reheater sky vent. Intermediate-pressure (IP) steam is likewise released through the HRSG reheater sky vent. Low-pressure (LP) steam is released through the LP sky vent. During hogging, the reheater and LP bypass valves are held closed. When condenser vacuum is established, they are released to regulate. The current operating pressure is placed into memory and used as the initial setpoint for each bypass valve, and the setpoint is slowly adjusted toward the valves' respective calculated setpoints. The pressure setpoint of the reheater and LP sky vents are maintained slightly above the setpoint of their associated bypass valve. Consequently, when the bypass valve begins passing steam to the condenser, each sky vent regulates to the closed position.

Pressure setpoints are calculated from individual HP flows until the four motorized steam isolation valves on both HRSGs are open and the steam turbine is in inlet pressure control mode. If both combustion turbine/HRSG sets are to be placed in operation with the steam turbine (2 x 1), the HP steam flows from both HRSGs are combined to calculate the required bypass valve pressure setpoint. The transition between 1 x 1 and 2 x 1 pressure setpoints is rate-limited to provide a smooth transition.

On a steam turbine trip, the normal distributed control system (DCS) pressure control response (tuning) is usually too slow to maintain a stable pressure. Consequently, on a steam turbine trip, each bypass valve is immediately driven to a fixed valve position. This position is calculated by the DCS based on upstream pressure, temperature, flow, and bypass valve flow capacity. This fixed position is typically held for 10 seconds, and then a gradual transition back to the normal pressure control is initiated. HP and LP valve positions are determined using the HP and LP steam flow meters, respectively. Reheater valve position is determined using cold reheat and IP steam flow measurements plus HRSG reheater desuperheater spray water flow. If the respective bypass valve is fully open, the reheater and LP sky vents will open if required to hold constant pressure. A DCS calculation determines whether the bypass has sufficient flow capacity to hold pressure. If not, the sky vent is driven to a fixed position to relieve the excess steam. This fixed position of the sky vent is held for 10 seconds, and then a gradual transition back to the normal pressure control is initiated, which will gradually close the sky vent.

The bypass valve desuperheater spray control valve is positioned by the combination of a feed-forward and feedback signal component. The feed-forward component is determined by a steam and water mass balance calculation. The feedback component is provided by downstream temperature feedback into the DCS proportional integral derivative temperature controller. The feed-forward component allows the spray valve to respond rapidly when the steam turbine trips.

2.2.2 Boundary Statements

The following sections and figures describe the boundaries associated with three portions of the steam bypass systems installed at a CTCC facility.

2.2.2.1 HP Steam Bypass System to Cold Reheat System Boundaries

Figure 2-2 illustrates a simplified schematic of the HP steam bypass system to cold reheat system.

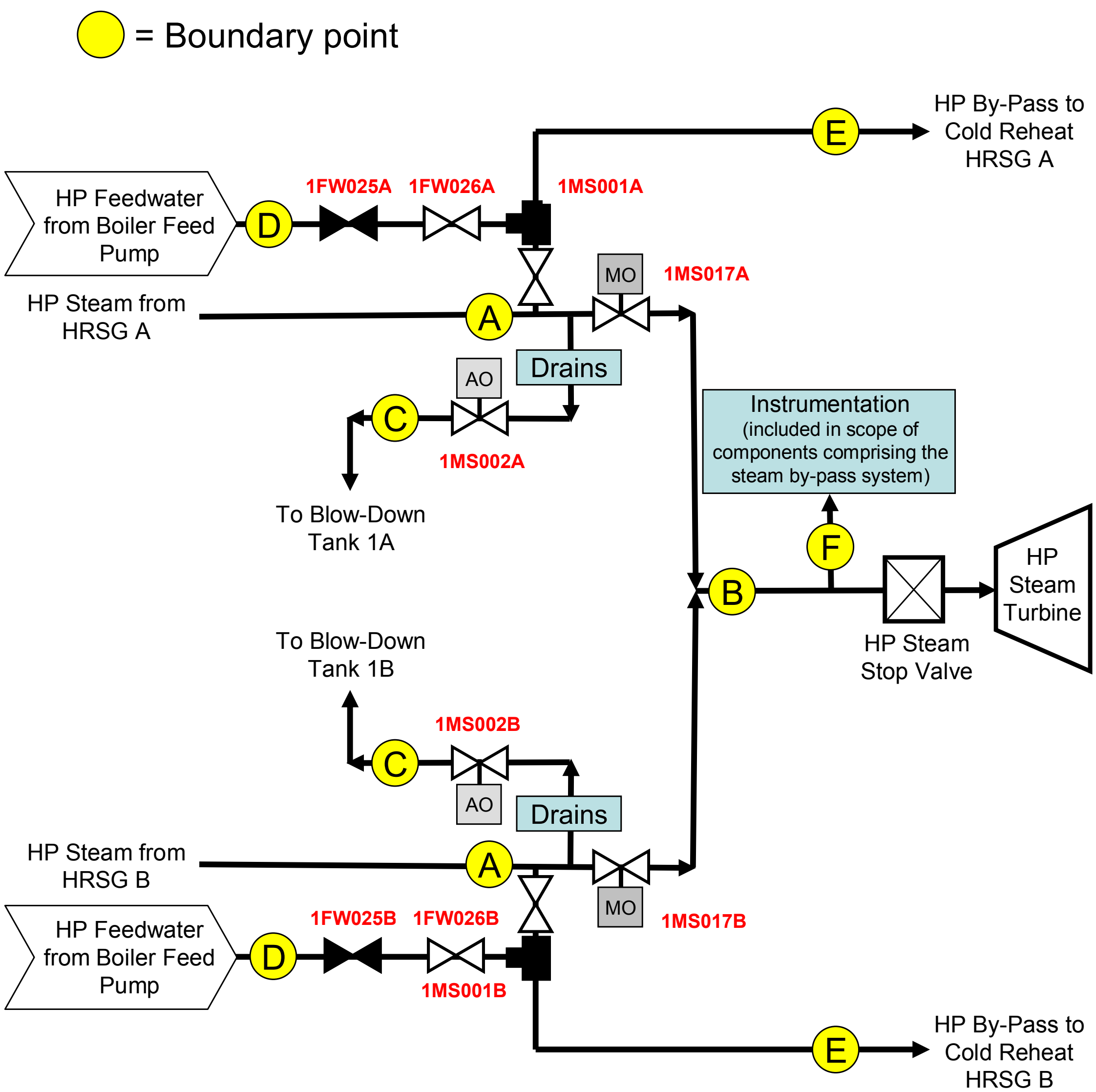

Figure 2-2
HP steam bypass system to cold reheat system boundaries

The following describes the technical boundary that is shown in Figure 2-2:

- Boundary Point A
  - The connection between 1MS001AA-10-in., main steam line from HRSG A, and 1MS003AA-6 in.-HP bypass line
  - The connection between 1MS001AB-10 in., main steam line from HRSG B, and 1MS003AB-6 in.-HP bypass line
- Boundary Point B
  - The point downstream of motor-operated valves (MOVs) 1MS017A and 1MS017B, where 1MS001AA-10-in. line and 1MS001AB-10-in. join to form 1MS002A-14-in. main steam line
- Boundary Point C
  - The discharge side of the outlet block valve 1MS005A, to air-operated valve (AOV) 1MS002A, to the boiler blowdown tank
  - The discharge side of the outlet block valve 1MS005B, to AOV 1MS002B, to the boiler blowdown tank
- Boundary Point D
  - The inlet to isolation valve 1FW025A on the HP feedwater line from boiler feed pump
  - The inlet to isolation valve 1FW025B on the HP feedwater line from boiler feed pump
- Boundary Point E
  - The connection between 1MS003CA-14-in., HP bypass line, and cold reheat HRSG A
  - The connection between 1MS003CB-14-in., HP bypass line, and cold reheat HRSG B
- Boundary Point F
  - Main steam pressure transducers MS205A, MS205B, and MS205C
  - Main steam temperature transducers MS206A, MS206B, and MS206C

2.2.2.2 Hot Reheat Steam Bypass System to Condenser System Boundaries

Figure 2-3 illustrates a simplified schematic of the hot reheat (HRH) steam bypass system to condenser system.

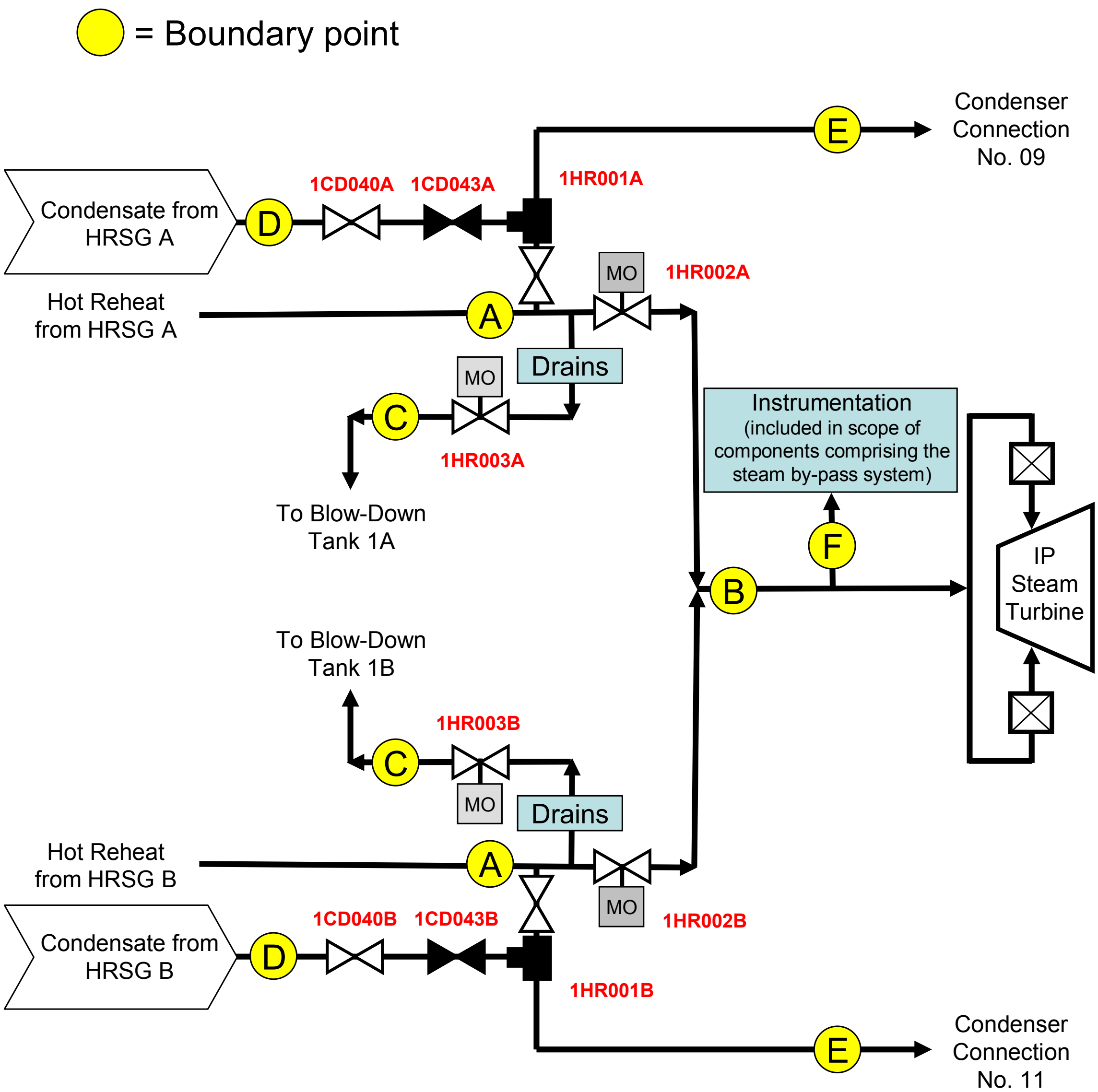

Figure 2-3
HRH steam bypass system to condenser system boundaries

The following describes the technical boundary that is shown in Figure 2-3:

- Boundary Point A
  - The connection between 1HR001AA-24-in. and the 1HR003AA-14-in., the point at which the HRH bypass line ties into the main HRH steam header from HRSG A
  - The connection between 1HR001AB-24-in. and the 1HR003AA-14-in., the point at which the HRH bypass line ties into the main HRH steam header from HRSG B
- Boundary Point B
  - The main HRH steam header 1HR001AA-24-in. upstream of the split to the upper and lower HRH steam turbine control valves but downstream of the HRH steam pressure/temperature elements
  - On 1HR010A-14-in. steam line to the sky vent just downstream of the T-connection between 1HR010A-14-in. and 1HR001AA-24 in.
  - On 1HR004A-6-in. steam line to header drain line to the condenser just downstream of the T-connection between 1HR004A-6-in. and 1HR001AA-24-in.
- Boundary Point C
  - The discharge side of the outlet block valve 1HR006A (RH1STM-HB-RS-VLV-HR006A) for the MOV 1HR003A (RH1STM-HB-RS-MOV-HR003A) to the boiler blowdown tank
  - The discharge side of the outlet block valve 1HR006B (RH1STM-HB-RS-VLV-HR006B) for the MOV 1HR003B (RH1STM-HB-RS-MOV-HR003B) to the boiler blowdown tank
- Boundary Point D
  - The inlet to isolation valve 1CD040A (RH1STM-HC-CD-VLV-040A) on condensate line 1CD019AA from HRSG A lead
  - The inlet to isolation valve 1CD040B (RH1STM-HC-CD-VLV-040B) on condensate line 1CD019AA from HRSG B lead
- Boundary Point E
  - The connection between 1HR003A-18-in., the discharge line for the dump valve, to the condenser at connection number 09
  - The connection between 1HR003B-18-in., the discharge line for the dump valve, to the condenser at connection number 11
- Boundary Point F
  - HRH steam pressure transducers HR205A—(RH1STM-HB-RS-XMT-PTHR205A), HR205B—(RH1STM-HB-RS-XMT-PTHR205B), and HR205C—(RH1STM-HB-RS-XMT-PTHR205C)
  - HRH steam temperature transducers HR206A—(RH1STM-HB-RS-TEU-TEHR206A), HR206B—(RH1STM-HB-RS-TEU-TEHR206B), and HR206C—(RH1STM-HB-RS-TEU-TEHR206C)

2.2.2.3 LP Steam Bypass System to Condenser System Boundaries

Figure 2-4 illustrates a simplified schematic of the LP steam bypass system to condenser system.

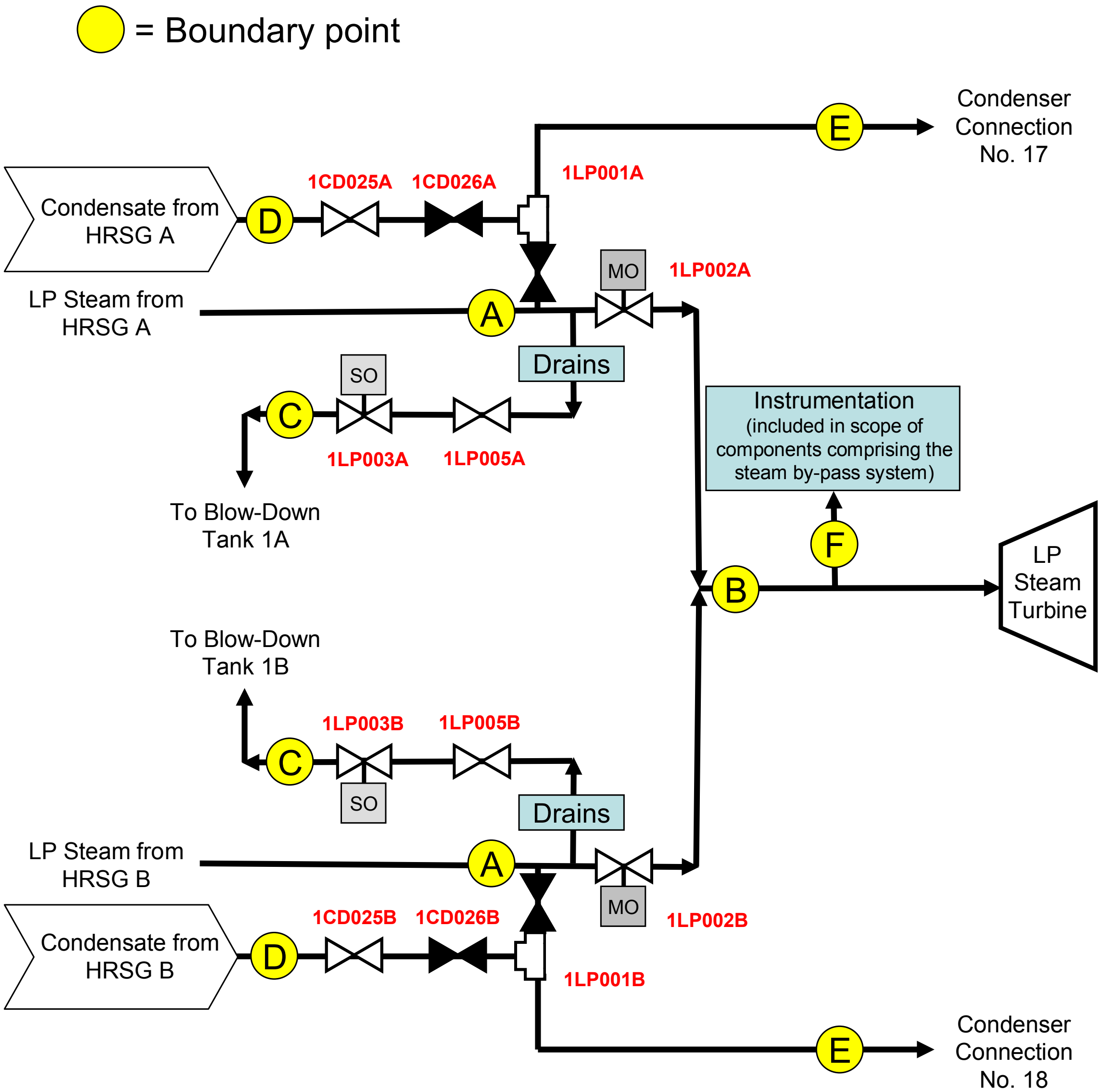

Figure 2-4
LP steam bypass system to condenser system boundaries

The following describes the technical boundary that is shown in Figure 2-4:

- Boundary Point A
  - The connection between 1LP001AA-12 in. and the 1LP004AA-10 in., the point at which the LP bypass line ties into the main LP steam header from HRSG A
  - The connection between 1LP001AB-12 in. and the 1LP004AB-14 in., the point at which the LP bypass line ties into the main LP steam header from HRSG B
- Boundary Point B
  - The main LP steam header 1LP002A-16 in. upstream of the LP admission to the steam turbine but downstream of the LP steam pressure/temperature elements
  - On 1LP009A-8-in. steam line upstream of the sky vent
- Boundary Point C
  - The discharge side of the outlet block valve 1LP005A (RH1CTA-HB-MR-VLV-LP005A), for the solenoid-operated valve 1LSV LP002A (RH1CTA-HB-MR-AOV-LP002A), to the boiler blowdown tank
  - The discharge side of the outlet block valve 1LP005B (RH1CTA-HB-MR-VLV-LP005B), for the solenoid-operated valve 1LSV LP002B (RH1CTA-HB-MR-AOV-LP002B), to the boiler blowdown tank
- Boundary Point D
  - The inlet to isolation valve 1CD025A (RH2STM-HC-CD-VLV-025A) on condensate line 1CD012AA from HRSG A lead
  - The inlet to isolation valve 1CD025B (RH2STM-HC-CD-VLV-025B) on condensate line 1CD012AB from HRSG B lead
- Boundary Point E
  - The connection between 1LP004BA-12 in., the discharge line for the dump valve, to the condenser at connection number 17
  - The connection between 1LP004BB-12 in., the discharge line for the dump valve, to the condenser at connection number 18
- Boundary Point F
  - LP steam pressure transducers 1LPT203A—(RH1STM-HB-MR-XMT-PTLP203A), 1LPT203B—(RH1STM-HB-MR-XMT-PTLP203B), and 1LPT203C—(RH1STM-HB-MR-XMT-PTLP203)
  - LP steam temperature transducers 1TELP205A—(RH1STM-HB-MR-TEU-TELP205A), 1TELP205B—(RH1STM-HB-MR-TEU-TELP205B), and 1TELP205C—(RH1STM-HB-MR-TEU-TELP205C)

2.2.3 System Components (Unit 1 Typical)

The following section describes the components associated with three portions of the steam bypass systems installed at a CTCC facility.

- 1PY MS001A—(RH1CTA-HB-MR-AOV-MS001A)—Pressure relay/controller to control downstream pressure and temperature of HP steam to cold reheat
- 1ZT MS001A—Position transmitter
- 1MS001A—CCI drag velocity control element
- 1FW036A—feedwater block valve (locked open)
- 1PDIFW216A—(RH1CTA-HC-FW-IND-DPI216A)—feedwater pressure differential indicator
- 1FWO35A—(RH1CTA-HC-FW-VLV-035A)—manual block valve (locked open)
- 1FW062A—(RH1CTA-HC-FW-VLV-062A)—feedwater strainer blowdown valve normally closed (NC)
- 1FW067A—(RH1CTA-HC-FW-VLV-067A)—feedwater strainer blowdown valve (NC)
- 1FW027A—(RH1CTA-HC-FW-VLV-027A)—feedwater drain line valve (NC)—between the temperature control valve and the downstream block
- 1FW028A—(RH1CTA-HC-FW-VLV-028A)—feedwater drain line valve (NC)—between the temperature control valve and the downstream block
- 1TY FW026A—(RH1CTA-HC-FW-VLV-026A)—temperature control valve fails open (FO)
- 1FW026A—valve body (FO)
- 1TE MS201A—(RH1CTA-HB-MR-TEU-TEMS201A)—downstream temperature element
- 1TEW MS201A—downstream thermowell
- 1PT MS202A—(RH1CTA-HB-MR-XMT-PTMS202A)—downstream pressure transmitter
- 1ZT FW026A—position transmitter on temperature control valve
- 1ZSV FW025A—(RH1CTA-HC-FW-VLV-025A)—solenoid operator (air) feedwater on/off valve (FC)
- 1FW025A—valve body
- 1ZSO FW025A—open limit switch on 1ZSV FW025A
- 1ZSC FW025A—closed limit switch on 1ZSV FW025A
- 1FW043A—(RH1CTA-HC-FW-VLV-043A)—feedwater drain line between on/off valve and temperature control valve
- 1FW044A—(RH1CTA-HC-FW-VLV-044A)—feedwater drain line between on/off valve and temperature control valve

- 1FW041A—(RH1CTA-HC-FW-VLV-041A)—feedwater drain line between on/off valve and manual block
- 1FW042A—(RH1CTA-HC-FW-VLV-042A)—feedwater drain line between on/off valve and manual block
- Motor operator (MO) 1MS017A—(RH1CTA-HB-MR-MOV-MS017A)—MOV for block to turbine
- RH1CTA-HB-MR-VLV-MS017ABYP—bypass warm up valve on 1MS017A
- 1ZSO MS017A—position switch open for MOV
- 1ZSO MS017A—position switch closed for MOV
- AOV 1MS002A—(RH1CTA-HB-MR-AOV-MS002A)—AOV to drain main steam header to blowdown tank upstream of 1MS017A
- 1ZSO MS002A—position switch open for MOV
- 1ZSO MS002A—position switch closed for MOV
- 1MS029A—(RH1CTA-HB-MR-VLV-MS029A)—upstream block valve to MS001A (ball valve)
- 1MS005A—downstream block valve to MS001A (ball valve)
- 1TEW MS203A—thermowell for upstream temperature control to MOV 1MS002A
- 1TE MS203A—(RH1CTA-HB-MR-TEU-TEMS203A)—temperature element for upstream temperature control to MOV 1MS002A
- 1MS020A—(RH1CTA-HB-MR-VLV-MS020A)—drain line downstream of MO 1MS001A
- 1FW021A—(RH1CTA-HB-MR-VLV-MS021A)—drain line downstream of MO 1MS001A
- MO 1CR002A—(RH1STM-HB-RS-MOV-CR002A) motor-operated block valve on cold reheat header to reheater
- RH1STM-HB-RS-VLV-CR002ABYP—bypass warm-up valve on MO 1CR002A
- 1ZSO CR002A—position switch open for MOV
- 1ZSC CR002A—position switch closed for MOV
- 1FSV CR034—(RH1STM-HB-RS-AOV-CR034)—solenoid-operated flow valve to drain cold reheat line to blowdown tank
- 1ZSO CR034—position switch open for drain valve
- 1ZSC CR034—position switch closed for drain valve
- RH1STM-HB-RS-VLV-CR035—downstream block valve on solenoid-operated drain valve
- RH1STM-HB-RS-VLV-CR033—upstream block valve on solenoid-operated drain valve
- RH1STM-HB-RS-VLV-CR032—upstream block valve on solenoid-operated drain valve

- 1PT 205A—(RH1STM-HB-MR-XMT-PTMS205A)—pressure transmitters main steam to HP steam turbine
- 1PT 205B—(RH1STM-HB-MR-XMT-PTMS205B)—pressure transmitters main steam to HP steam turbine
- 1PT 205C—(RH1STM-HB-MR-XMT-PTMS205C)—pressure transmitters main steam to HP steam turbine
- 1TE 206A—(RH1STM-HB-MR-TEU-TEMS206A)—temperature element main steam to Steam turbine
- 1TE 206B—(RH1STM-HB-MR-TEU-TEMS206B)—temperature element main steam to steam turbine
- 1TE 206C—(RH1STM-HB-MR-TEU-TEMS206C)—temperature element main steam to steam turbine
- 1TEW 206A—thermowell main steam to steam turbine
- 1TEW 206B—temperature main steam to steam turbine
- 1TEW 206C—temperature main steam to steam turbine
- Instrument air

2.3 Typical Steam Bypass System Logic

2.3.1 General Description

The steam bypass valves provide the following three functions:

- Steam pressure regulation during startup as required to place the steam turbine into operation and also during simple cycle operation of the combustion turbines alone by maintaining sufficient pressure in the HRSG
- Protection of the condenser from overpressurization and protection of steam piping from temperature excursions should bypass desuperheaters malfunction
- Emergency pressure relief should the steam turbine trip, so that steam drum levels are not depressed to a level that would require a combustion turbine trip

Bypass valve control is typically completely automatic, including pressure set-point adjustment.

Key Supervisory Observation Point

Manual control can be turned on independently for each valve from the DCS engineering station, when no valve trip signal exists.

Manual stroking of a bypass valve is rate-limited. A description of the automatic control concept follows.

In combined-cycle operation, the steam turbine produces a backpressure, at each admission level, based on its resistance to steam flow. Minimum pressure is developed when a steam turbine throttle valve is wide open.

Key Technical Point

The pressure developed at the valve wide open condition is referred to as *natural pressure*.

Natural pressure can be estimated with sufficient accuracy by measuring HP steam flow.

Each bypass valve pressure setpoint is maintained above natural pressure, or the steam turbine inlet pressure control setting, by a small margin, by adjusting the setpoint upward as HP steam flow increases. As the steam turbine admits steam, the bypass valve will close in an effort to keep pressure at its setpoint. If the steam turbine trips or partially rejects steam, the bypass valves will open to maintain pressure at the current operating level.

Each HRSG has an HP steam flow element to measure its contribution.

Key Technical Point

When two HRSGs are operating with the steam turbine, flow measurements from both are combined to calculate the bypass valve setpoint.

HRSG steam flows are combined for control purposes when the HRSG motor-operated isolation valves to the steam turbine are proven open on both units (open limit switches) and the steam turbine is operating in inlet pressure control mode (control system feedback). When a single HRSG is operating with the steam turbine, or the steam turbine is not operating, steam flow of the respective HRSG is used to calculate individual setpoints.

Change in pressure setpoint is rate-limited. Rate of change is limited to 5°F per minute of steam saturation temperature for each pressure level. The intent is to limit thermal stress on steam drums, limit drum level swell and shrink, and prevent loss of net positive suction head to the boiler feed pump, which takes suction from the LP drum. The rate of pressure change is nonlinear with faster pressure change allowed at higher drum pressures.

The reheater and LP sky vents are likewise operated automatically. The sky vent setpoint is maintained above bypass setpoint by a small margin. There are no process conditions that trip the sky vents closed.

The automatically generated setpoint for the bypass valves is shown in the Figures 2-5 through 2-7. Points marked by an *X* represent expected steam turbine valve wide open operating points (typical).

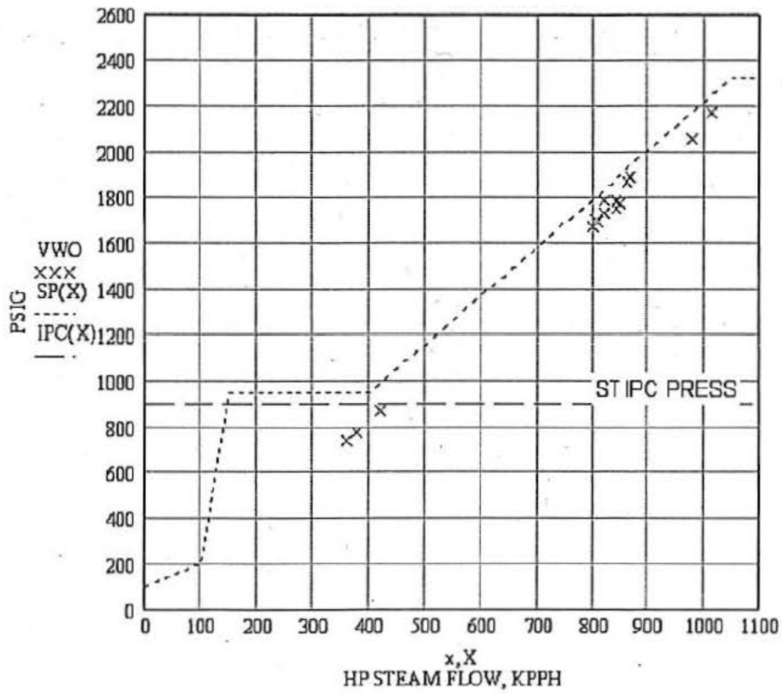

Figure 2-5
HP bypass setpoint
Used with permission from APS

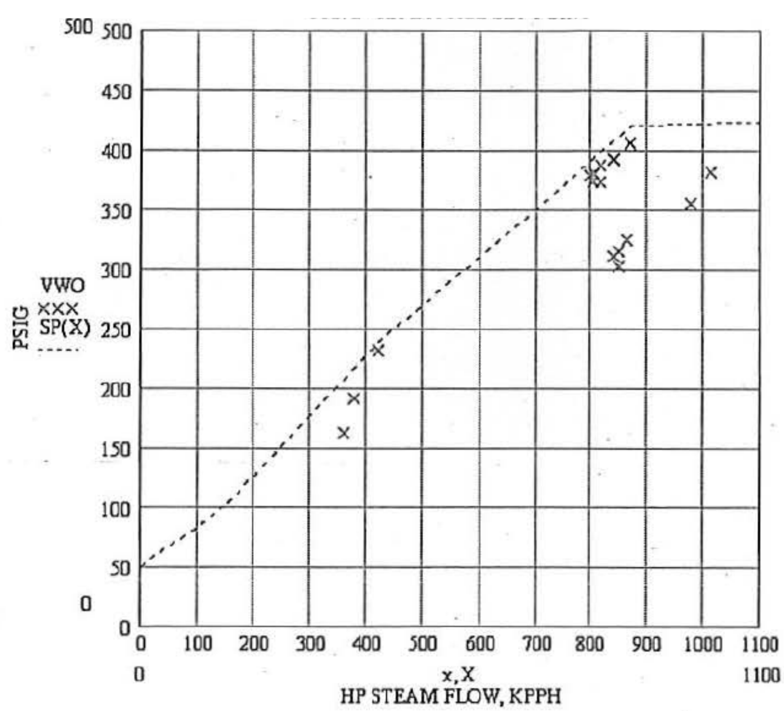

Figure 2-6
HRH bypass setpoint
Used with permission from APS

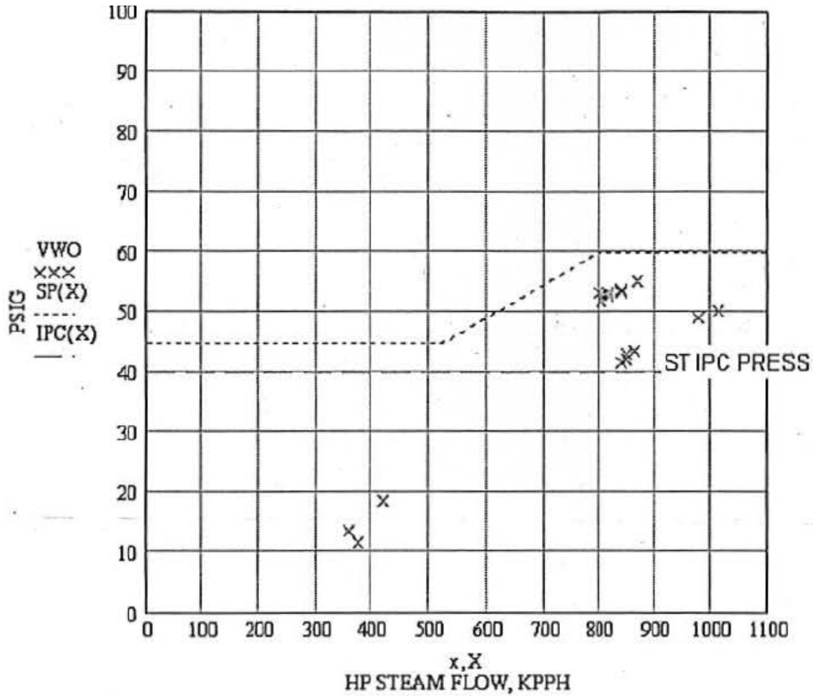

Figure 2-7
LP bypass setpoint
Used with permission from APS

2.3.2 Conditions Causing the Unit to Trip

Process conditions are monitored, and the bypass valves are automatically tripped closed when any of the following conditions occurs:

Trip Conditions Common to Reheater and LP Bypass Valves

- Condenser vacuum is less than 9.4 in. Hg, and steam turbine speed is less than 2940 revolutions per minute (rpm). Above 2940 rpm, the trip value increases linearly to a value of 19.77 in. Hg at 3600 rpm.
- No condensate pump is running.
- No circulating water pump is running.
- Condenser level is above 37 in.

Other Reheater Bypass Trip Conditions

- Temperature downstream of the bypass valve desuperheater is greater than 500°F for 20 seconds.
- Pressure in the pipe downstream of the bypass valve is above the line in Figure 2-8 for 15 seconds.

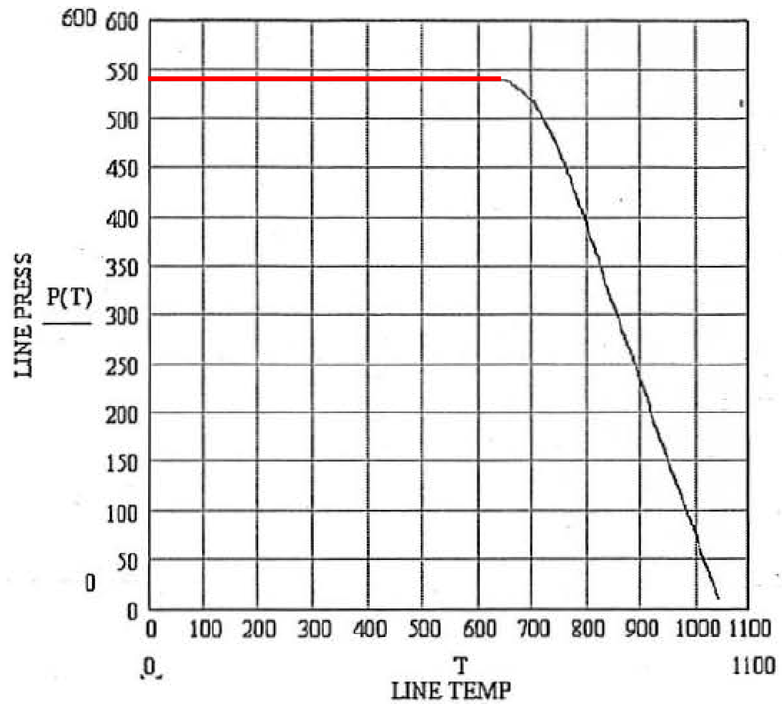

Figure 2-8
Trip caused by elevated pressure in bypass valve downstream piping
Used with permission from APS

Other LP Bypass Trip Conditions

- Temperature downstream of the bypass valve desuperheater is greater than 500°F for 20 seconds.

HP Bypass Trip Conditions

- Temperature downstream of the bypass valve desuperheater is greater than 775°F for 20 seconds.

After a trip condition clears, reset the bypass valve from the control pop-up located by each valve on the respective DCS screen.

After the combustion turbine flame is off for 1 minute, all bypass valves are closed. The HP bypass valve is released for operation after the combustion turbine flame is established.

3
STEAM BYPASS SYSTEM FAILURE MECHANISMS

3.1 Problems Associated with Steam Bypass Systems

Turbine bypass systems are used during startup, shutdown, and load rejection. The most common arrangement uses an HP bypass to cold reheat and an HRH or IP/LP bypass to condenser.

Key O&M Cost Point

The service life of the bypass system can be dramatically shortened by installation and control problems that cause severe thermal stresses and consequent thermal fatigue cracks.

Experience suggests that these cracks have occurred in valve trims, bodies, desuperheaters, and downstream pipes. These problems are most acute in plants with daily load cycling operation.

CTCC facilities with turbine bypass systems should establish PM and inspection practices to identify whether cracks are present or developing. Normal measures of plant cycle life, such as the number of starts, duration of starts, and number of trips, are not sufficient to provide a good indication of the condition of the bypass systems. The following areas should be considered when establishing PM tasks and frequencies to assess the condition of the steam bypass system:

- Temperature gradients in the bypass system
- The condition of adjacent pipes and butt welds
- The condition of the steam valve, spray valve, desuperheater, and dump devices
- Installation of the bypass system
- Desuperheater control logic and startup and shutdown data from the DCS

3.2 Detailed Failure Mechanism Data

Tables 3-1 through 3-3 provide detailed information regarding the location and types of various failure mechanisms associated with major mechanical components typically installed in the steam bypass system of the HRSG at a CTCC facility. The failure mechanism tables regarding valves are based on information published in EPRI report 1021271, *Generation Maintenance Application Center: Combined Cycle Combustion Turbine Duct Burner Maintenance Guide*. The failure mechanism table regarding the attemperator is based on information published in EPRI report 1026632, *Generation Maintenance Application Center: Combined Cycle Combustion Turbine Attemperator Maintenance Guide.*

Table 3-1
Steam bypass system failure locations, mechanisms, and influences for MOVs

Failure Location	Degradation Mechanism	Degradation Influence
Drive train	Damage to clutch mechanism	Normal wear
	Damage to clutch mechanism	Personnel error—excessive force
	Drive sleeve/gear case seal failure	Normal wear
	Drive sleeve/gear case seal failure	Personnel error—installation
	Incorrect preloading of the thrust bearing	Personnel error
	Key and keyway failures	Inappropriate key material
	Misalignment of worm to worm gear	Personnel error
	Stem nut or worm bearing locknut failure	Personnel error
	Worn or damaged gears	Excessive force
	Worn or seized bearings	Contamination, inactivity
Fasteners	Loose or missing	Personnel or procedural error
Lubricant—gearbox	Degraded, dirty—that is, loss of efficiency	Aging, temperature
	Degraded, dirty—that is, loss of efficiency	Contamination from moisture and rust
	Degraded, dirty—that is, worn gearbox components	Aging, temperature
Lubricant—limit switch compartment	Degraded, dirty	Aging, temperature
	Degraded, dirty	Contamination from moisture and rust
Lubricant—valve stem	Degraded, dirty—that is, reduced thrust output	Aging, temperature
	Degraded, dirty—that is, reduced thrust output	Contamination from moisture and rust
Motor	Degraded insulation	Age, temperature
	Degraded insulation	Moisture
	Magnesium rotor bar corrosion	Design defect, duty cycle
Packing	Leakage	Gouged stem
	Leakage	Incorrect torque
	Leakage	Normal wear

Table 3-1 (continued)
Steam bypass system failure locations, mechanisms, and influences for MOVs

Failure Location	Degradation Mechanism	Degradation Influence
Seat	Chipped or cracked	Debris
	Chipped or cracked	Design or manufacturing defect
	Crud buildup	Fluid quality
	Distorted	Excessive seating force—that is, actuator misadjustment
	Leak through	Normal wear
Spring pack	Binding	Misalignment
	Hydraulic lock	Design defect
	Spring relaxation	Aging
Switch—limit	Misadjusted, misaligned	Personnel error
	No contact	Contamination from moisture and rust
	No contact	Normal wear, loss of spring tension
Switch—torque	Misadjusted, misaligned	Personnel error
	Roll pin failure	Design valve/actuator time loading characteristics
	Roll pin failure	Excessive torque, predominately on wedge-type gate valves
	Roll pin failure	Hammering during diagnostic testing
Valve guides	Worn guides	Duty cycle, chronic operation under delta pressure (DP) in any orientation; also horizontal orientation with no DP
Valve stem	Bent	Improper setup or testing (overthrust or overtorque)
	Cracked	Improper setup or testing (overthrust or overtorque)
	Stem or stem-nut thread damage—that is, low output thrust	Corrosion, moisture
	Stem or stem-nut thread damage—that is, low output thrust	Misalignment or debris
Wiring	Cracked terminal blocks	Personnel error
	Degraded insulation	Aging, temperature
	Loose wires or lugs, poor crimps	Personnel error
	Pinched wires, cracked or damaged insulation	Personnel error

Table 3-2
Steam bypass system failure locations, mechanisms, and influences for AOVs

Failure Location	Degradation Mechanism	Degradation Influence
Actuator	Broken spring	Fatigue
	Bushing/cylinder wear	Actuator orientation other than vertical
		Improper installation
		Improper lubrication
		Misalignment—for example, valve wear
	Elastomer failure—leakage (piston, bushings)	Actuator orientation other than vertical
	Elastomer failure—leakage (piston, bushings, top hat/cylinder seals)	Age
		Alignment of piston shaft
		Chemical/air contamination
		Compression set
		Heat from ambient and process conditions
		Heat from packing leak
		Improper installation
		Improper lubricant
		Lack of lubrication
		Rough sealing surfaces/burrs/foreign material exclusion (FME) from plant or manufacturing errors
	Mechanical failure—handwheel manual operator	Overstressed
	Improperly positioned—handwheel manual operator	Personnel error
	Restricted vent path (filter, muffler, screens, and speed control device)	Condensation in certain orientations
		Paint/FME
	Spring relaxation	Application
		Heat from ambient and process conditions
		Initial preload
		Material type

Table 3-2 (continued)
Steam bypass system failure locations, mechanisms, and influences for AOVs

Failure Location	Degradation Mechanism	Degradation Influence
Air pump	Bound spool piece	Contamination
	Elastomer failure	Age
		Chemical/air contamination
		Compression set
		Heat from ambient and process conditions
		Heat from packing leak
		Improper installation
		Improper lubricant
		Lack of lubrication
		Overpressurization—personnel error
		Overpressurization (regulator failure)
		Rough sealing surfaces/burrs/FME from plant or manufacturing errors
Check valves—air line	Stuck	Aging of elastomers
		Contamination
		Spring degradation
Check valves—piston/actuator	Stuck	Aging of elastomers
		Contamination
		Spring degradation
Coupling: direct	Binding between antirotation plate and coupling block	Manufacturing defect
		Misalignment of coupling block
	Incorrect setup	Personnel error
	Loose	Damaged threads
		Fatigue—repeated use of same set screws
		Improper fastener torquing

Table 3-2 (continued)
Steam bypass system failure locations, mechanisms, and influences for AOVs

Failure Location	Degradation Mechanism	Degradation Influence
Coupling: fixed moment arm	Broken/bent linkages	Misadjustment
	Bushing/bearing wear	Age—number of cycles
	Bushing/bearing wear	Improper fastener torquing
	Incorrect setup	Personnel error
	Loose linkages	Improper fastener torquing
	Worn key	Misadjustment
Coupling: rack and pinion	Gear wear	End stop adjustment
Coupling: scotch yoke	Bushing/bearing wear	Age—number of cycles
	Bushing/bearing wear	Lack of lubrication
	Incorrect setup	Personnel error
	Roller pin failure	Duty cycle and wear of other components
	Roller pin failure	End stop adjustment
	Worn yoke	Duty cycle
External air filter	Clogged	Contaminated air
	Leaks	Degraded elastomers
Limit switches	Contact misalignment	Vibration
	Corroded contacts	Water and humidity
	Corroded wiring, terminals, or connections	Environment
	Elastomer failure	Age
		Chemical contamination
		Compression set
		Heat from ambient and process conditions
		Heat from packing leak
		Improper installation
		Improper lubricant
		Lack of lubrication
		Rough sealing surfaces/burrs/FME from plant or manufacturing errors

Table 3-2 (continued)
Steam bypass system failure locations, mechanisms, and influences for AOVs

Failure Location	Degradation Mechanism	Degradation Influence
Limit switches	Loose connections or terminals	Vibration
	Misadjusted	Loose fasteners
		Personnel error
	Wear—for example, cams, lever arms, bushings	Improper installation
		Material properties and design
		Vibration
Packing	Excessive friction	Improper packing configuration
		Improper torque of the gland
	Leakage	Age
		Gouged stem
		Improper packing configuration
		Improper torque of the gland
		Scored stuffing box
Pneumatic tubing	Crushed or damaged	Personnel error
	Improper installation	Personnel error
	Leaking fittings and tubing	Vibration
Seat (moving part)	Broken spring in pilot valves	Fatigue
	Chipped	Debris
		Improper installation
	Cracked	Debris
		Design
		Manufacturing defect
	Crud buildup	Fluid quality
	Wear/erosion	Inadequate seat load
Speed control valves	Inappropriate response	Aging of elastomers
		Contamination
		Improper lubrication, including excessive
		Misadjustment
		Spring degradation

Table 3-2 (continued)
Steam bypass system failure locations, mechanisms, and influences for AOVs

Failure Location	Degradation Mechanism	Degradation Influence
Valve body bearing/bushing, if present	Wear	System dynamics/flow-induced vibration
Valve body seat	Chipped	Debris
		Improper installation
	Cracked	Debris
		Design
		Manufacturing defect
	Crud buildup	Fluid quality
	Wear/erosion, including soft or hard seating materials	Inadequate seat load
Valve guides	Worn	High-duty cycle under DP in any orientation
		Orientation (horizontal only)
Valve stem	Bent	Overthrust
	Rough surface leading to excessive friction	Packing components
	Wear	Normal wear from packing

Table 3-3
Steam bypass system failure locations, mechanisms, and influences for attemperators

Failure Location	Degradation Mechanism	Degradation Influence
Header ring, if present	Cracked	Failed weld
Liner	Cracked	Thermal cycling, duty cycle
	Cracked weld	Fatigue, improper spray
	Cracked weld	Thermal cycling, duty cycle
	Damaged or broken	Fatigue, improper spray
Spray nozzles	Corroded	Extended layup
	Damaged, broken	Fatigue, run time
	Damaged, broken	Personnel error
	Eroded	Normal use, run time
	Incorrect installation—for example, misaligned	Personnel error
	Leaking at flanged joint	Improper torquing
	Leaking at flanged joint	Relaxed studs from thermal cycling, run time
	Missing hardware	Normal use, run time
	Plugged	Buildup of deposits, especially under low spray flows
	Plugged	Debris
	Warped	Thermal cycling, duty cycle
	Wrong nozzle, incorrect depth	Personnel error
Spray nozzles—spring type, if present	Broken spring	Fatigue
	Eroded swirl chamber	Normal use, run time
	Leakage	Debris
	Leakage from loss of spring constant	Normal use, creep, run time
	Loose or missing retaining nut	Broken locking pin
Steam pipe attachment	Cracked	Failed weld

Table 3-3 (continued)
Steam bypass system failure locations, mechanisms, and influences for attemperators

Failure Location	Degradation Mechanism	Degradation Influence
Steam pipe flange	Cracked	Failed weld
	Leakage	Failed gasket from age, thermal cycling, duty cycle
	Leakage	Incorrect fastener material
	Leakage	Incorrect or poorly installed or tightened gasket
	Leakage	Steam cut
Strainer	Clogged	Contaminant buildup, run time
	Erosion or corrosion	Debris
	Erosion or corrosion	Improper material
Water pipe attachment	Cracked	Failed weld
Water pipe flange	Cracked	Failed weld
	Leakage	Failed gasket from age, thermal cycling, duty cycle
	Leakage	Incorrect fastener material
	Leakage	Incorrect or poorly installed or tightened gasket
	Leakage	Steam cut, from flashing

4
SYSTEM TROUBLESHOOTING, VULNERABILITY, AND RISK ANALYSIS

This section and Section 5 (on job plans) were built working with site personnel, industry experts, and the EPRI PMBD to craft a useful troubleshooting guide and optimized maintenance program. Using site experience and methodology in described Appendix B, a program is provided that fits into current CTCC maintenance programs by fitting time-based inspections into annual, hot-gas path (HGP), and major inspection intervals and handling degradation surveillance through condition-monitoring tasks, such as operator rounds and valve diagnostics. The source tasks from the PMBD are included in Appendices C and D for quick reference by the user.

4.1 System Troubleshooting

Figure 4-1 illustrates the generic process for performing preliminary troubleshooting of a given power generation system, such as an attemperator in an HRSG. The figure emphasizes the need to define the problem, determine and validate system operating conditions, and subsequently determine whether the symptoms adversely affect system/component performance or reliability.

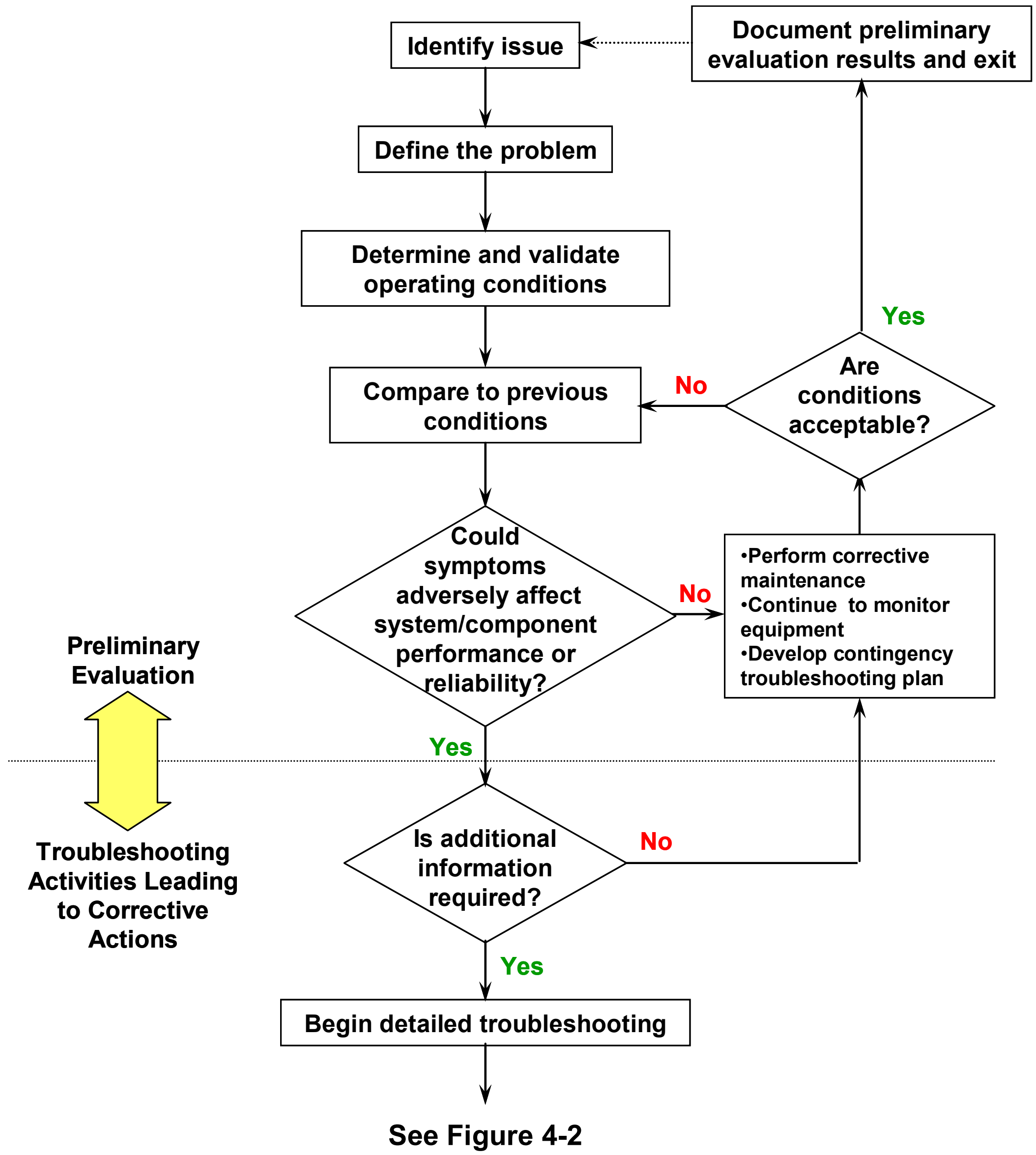

Figure 4-1
Generic process system troubleshooting (preliminary evaluation) [EPRI 1003093]

Figure 4-2 illustrates the detailed system troubleshooting process that can be undertaken to investigate the symptoms and performance problems being experienced. Figure 4-2 emphasizes the need to identify failure modes, develop a troubleshooting plan (especially if the system is evaluated while online), identify the cause(s) of the problem, and restore system performance. Additional guidance regarding system and component troubleshooting is provided in EPRI report 1003093, *System and Equipment Troubleshooting Guideline*.

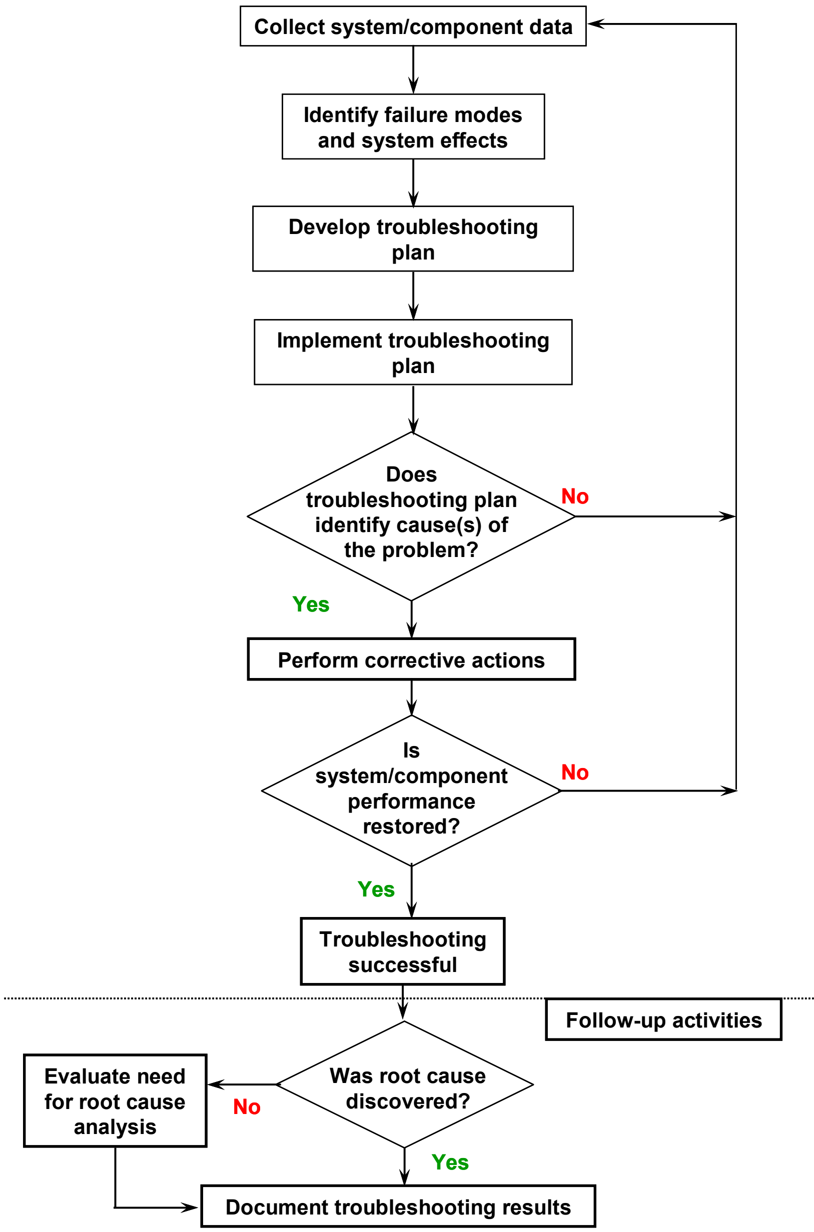

Figure 4-2
Generic process system troubleshooting (detailed system troubleshooting) [EPRI 1003093]

4.2 Troubleshooting the Steam Bypass System

4.2.1 Background

The following information was developed with the assistance of plant personnel from the Redhawk Power Station, owned and operated by Arizona Public Service.

4.2.2 System Troubleshooting Guidance

Table 4-1 illustrates typical troubleshooting techniques for components typically installed in the steam bypass system.

Table 4-1
Troubleshooting steam bypass system components

Component	Symptom	Possible Cause	Corrective Action
Attemperator controls	• High-low temperature	• Failure to control	• Verify that attemperator supply is lined up. • Check loose wiring. • Check proper control system settings and parameters.
Attemperator valve	• High-low temperature	• Failure to control • Loose wiring	• Verify that attemperator supply is lined up. • Check for loose wiring. • Check proper control system settings and parameters. • Inspect actuator/valve stem connection.
	• Water valve operating during nondumping operating scenarios • Temperature differential downstream of nozzle between top of pipe and bottom of pipe	• Leakage	• During unit shutdown, inspect dump valve seat for cracking, proper seating, evidence of leak-by, debris in valve body, or other signs of steam leakage.
	• Water/steam leakage at valve steam	• Leakage at packing gland	• Check adequate grease on packing gland. • Tighten packing gland.
Attemperator spray nozzles	• High/low temperature • Temperature differential downstream of nozzle between top of pipe and bottom of pipe	• Erratic control	• During shutdown, investigate possible loose/broken nozzles. • Check piping to individual spray heads.
Attemperator regulators	• High/low temperature	• Failure to control	• Check calibration of regulators. • Check air supply. • Check power supplies.
Attemperator piping	• Continuously wet/damaged insulation	• Leakage	• Remove insulation, and inspect piping for signs of damage.

Table 4-1 (continued)
Troubleshooting steam bypass system components

Component	Symptom	Possible Cause	Corrective Action
MOV motor	• Downstream flow • High temperature	• Failure to isolate/operate	• Check power supplies. • Inspect actuator/valve stem connection.
	• Downstream flow • High temperatures/electrical faults	• Breaker/starter tripping/fusing	• Check power supplies.
MOV valve	• Loss of flow	• Failure to isolate/operate	• Inspect actuator/valve stem connection.
	• Water/steam leaking at valve steam	• Leakage at packing gland	• Check adequate grease on packing gland. • Tighten packing gland.
Block valves	• Downstream flow	• Failure to isolate/operate	• Open valve, flush, and try to reseat.
Pressure/temperature regulator diaphragm	• Downstream pressure decay	• Failure to control • Erratic control	• Inspect diaphragms for cracking and tearing.
Pressure/temperature regulator valve	• Loss of flow	• Failure to isolate/operate	• Inspect actuator to valve stem connection.
Pressure/temperature sensing elements	• Loss of indication	• Improper calibration • Loose wiring • Defective temperature element	• Calibrate pressure transducer or transmitter. • Check for plugging in sensing line. • Test temperature elements. • Verify that the correct temperature element is installed. • Check for loose wiring.
AOV diaphragms	• Failure or erratic flow	• Elements switched • Diaphragm damaged	• Switch temperature elements (if dual element). • Inspect diaphragm for cracking and tearing.

Table 4-1 (continued)
Troubleshooting steam bypass system components

Component	Symptom	Possible Cause	Corrective Action
AOV	• Loss of flow	• Failure to isolate/operate	• Inspect actuator to valve stem connection.
	• Water/steam leaking at valve steam	• Leakage at packing gland	• Check for adequate grease on packing gland. • Tighten packing gland.
AOV solenoid	• Valve is sluggish or inoperable (electrical supply and pressure check out)	• Inadequate control voltage or air supply pressure • Seized plunger • Damaged springs • Plugged pilot/bleed holes	• Verify solenoid control voltage or air supply pressure. • Disassemble solenoid, and verify that plunger is free to move and not contaminated. • Verify that springs are intact and functioning freely. • Check diaphragms (if present) for tears, or pilot/bleed holes for plugging.
	• External leakage at control head	• Loose bolts • Damaged O-rings	• Check flange bolts and O-rings.
	• Internal leakage	• Debris in valve	• Disassemble solenoid, and clean.
	• Chatter or buzzing when solenoid is energized	• Inadequate clearance • Contamination	• Remove power from coil, and check plunger/sleeve clearance and possible contamination.
Limit switches	• Failure to indicate open/closed	• Faulty wiring • Broken linkages	• Check mechanical linkages and wiring.

Table 4-1 (continued)
Troubleshooting steam bypass system components

<table>
<tr><th>Component</th><th>Symptom</th><th>Possible Cause</th><th>Corrective Action</th></tr>
<tr><td>Pressure differential Indicators</td><td>• Failure to indicate</td><td>• Plugged sensing lines</td><td>• When shut down, check for plugging in sensing line.
• Check blowdown strainer/filter.
• Verify solenoid control voltage or air supply pressure.</td></tr>
<tr><td rowspan="4">Solenoids</td><td>• Valve sluggish or inoperable (electrical supply and pressure check out)</td><td>• Inadequate control voltage or air supply pressure
• Seized plunger
• Damaged springs
• Plugged pilot/bleed holes</td><td>• Verify solenoid control voltage or air supply pressure.
• Disassemble solenoid, and verify that plunger is free to move and not contaminated.
• Verify that springs are intact and functioning freely.
• Check diaphragms (if present) for tears or pilot/bleed holes for plugging.</td></tr>
<tr><td>• External leakage at the control head</td><td>• Loose flange bolts
• Worn or damaged O-rings</td><td>• Check flange bolts and O-rings.</td></tr>
<tr><td>• Internal leakage</td><td>• Internal debris or dirt</td><td>• Disassemble solenoid and clean.</td></tr>
<tr><td>• Chatter or buzzing when solenoid is energized</td><td>• Worn plunger/sleeve
• Internal debris or dirt</td><td>• Remove power from coil, and check plunger/sleeve clearance and possible contamination.</td></tr>
</table>

4.3 System Vulnerabilities and Risks

The purpose of this section is to cover vulnerabilities and risks associated with modifying PM task scopes and frequencies of system components covered in Sections 4 and 5 of this report.

4.3.1 Objectives of the Model Maintenance Program

As noted previously in this report, the objective of the model maintenance program is to provide a system-level tool that can assist CTCC facility owners in implementing a maintenance program that will ultimately improve system reliability and plant availability. Specifically, the objectives are to accomplish the following:

- Establish maintenance tasks that leverage the EPRI PMBD resource
- Adjust task descriptions and intervals to reflect the reality of combined-cycle operation and design
- Provide a template for other combined-cycle stations to build a maintenance program with a strong technical basis

4.3.2 Overview of the Model Maintenance Program for the Steam Bypass System

Table 4-2 provides an overview of the major tasks that the analysis team developed for the entire system.

Table 4-2
Overview of the model maintenance program for the steam bypass system

Task	Annual	HGP	Major Inspection
MOV—Diagnostic		X	X
MOV—Valve Internal Inspection			X
AOV—Inspection and Calibration		X	X
AOV—Valve and Actuator Overhaul			X
Attemperator Inspection		X	X
Piping Inspection			X
Hanger Inspection		X	X
Drain Line Leak Check		X	X
Calibration—Nonredundant, Critical	X		
Calibration—Redundant, Critical		X	X
Calibration—Noncritical			X

By adjusting the intervals of most of the tasks to HGP and major inspection, the program for this system is simplified and adapted from the calendar-based baseline in the PMBD without incurring excessive vulnerability to the failure modes of the critical equipment.

4.3.3 Observations from Vulnerability Analysis

4.3.3.1 Aligning to Hours/Starts-Based Inspections

One challenge in using current PMBD data is that the data are collected and communicated in a calendar-year based format. Wear-out time codes are in years—for example, an unconditional wear-out (UW) of two years is *UW2*, and if it were six months, it would be *UW0.5*. The challenge is that combined-cycle facilities handle major maintenance not in calendar years but in combination of run hours and major equipment starts as a base and sometimes even using operational factors, such as how quick a particular start was or whether power augmentation was in use during a run.

The methodology used by the team was that, in a common run hours-based scenario, the HGP inspection would be estimated as three calendar years and a major inspection would be six calendar years. The equivalency could vary from site to site, but given that the hours and starts-based rationale factors in the duty cycle automatically and that most operators manage their outages mainly around the HGP and major inspections, a maintenance plan that is aligned with these is usable.

4.3.3.2 Program Comparison Using the PMBD

The EPRI PMBD includes a vulnerability tool that allows for analysis of the entire program against the baseline by reporting the change in the level of degradation surveillance the planned tasks give for identified failure modes.

The program provides a number of outputs. The two key outputs that were used for building these programs were *Reliability Benefit Compared to Baseline* and *Program Effectiveness*.

Reliability Benefit Compared to Baseline

Reliability Benefit Compared to Baseline can be expressed in a percentage. The calculation uses three factors (Annual Failure Rate with No PM Program, Annual Failure Rate with Baseline PM Program, and Annual Failure Rate with Custom PM Program). The factors are determined as follows:

- **Annual Failure Rate with No PM Program** is determined by the program using the time code and stressor sensitivity for each degradation mode to estimate the number of failures over the life of the component. These factors are summed up and annualized. This yields the Annual Failure Rate with No PM Program.
- **Annual Failure Rate with Baseline PM Program** is determined by using individual failure rates for each degradation mode and reducing that rate based on the cumulative effectiveness of the tasks using the baseline selections and intervals. Those factors are summed up and annualized. This yields the Annual Failure Rate with Baseline PM Program.
- **Annual Failure Rate with Custom PM Program** is determined by using the calculation method for the Annual Failure Rate with Baseline PM Program but using the task and interval mix for the Custom PM Program.

After these factors are calculated, *Reliability Benefit Compared to Baseline* is calculated as follows:

$$\textit{Reliability Benefit Compared to Baseline} =$$

$$1 - \left(\frac{Annual\ Failure\ Rate\ with\ Custom\ PM\ Program - Annual\ Failure\ Rate\ with\ Baseline\ PM\ Program}{Annual\ Failure\ Rate\ with\ No\ PM\ Program - Annual\ Failure\ Rate\ with\ Baseline\ PM\ Program}\right)$$

In this case, a custom program with the same failure rate as baseline would yield 1.00 or 100% reliability benefit where a custom program with no protection at all would then yield the same annual failure rate as with no PM program, resulting in 0.00 or 0% reliability benefit compared with baseline.

Program Effectiveness

The second output is *Program Effectiveness*, and it is a bit more qualitative than *Reliability Benefit Compared to Baseline*. Table 4-3 shows how this output is determined.

Table 4-3
Determining the *Program Effectiveness* output

Program Effectiveness	Degradation Mode Coverage
Green	Mode is covered by two or more tasks of high effectiveness.
Yellow	Mode is covered by one task of high effectiveness.
Orange	Mode is covered by one or more tasks of medium effectiveness but no tasks of high effectiveness.
Red	Mode is covered by one or more tasks of low effectiveness but no tasks of high or medium effectiveness.

The important lesson learned for users is that PMBD output is used for initial guidance and each user should examine the output against site experience to justify the task mix. In the tables in the following sections that describe certain failure modes affected by the model maintenance program, new risks are introduced in some cases. In other instances, the risk of a given failure mode is improved as a result of implementing the model maintenance program.

4.3.4 MOV Analysis

The EPRI Baseline MOV program for critical, high-duty, and severe (CHS) conditions from the EPRI PMBD is shown in Table 4-4.

Table 4-4
EPRI PMBD baseline PM for MOVs

Task Name	EPRI PMBD (CHS)
Actuator—Detailed Inspection/Clean/Lubricate	8Y
Actuator—General Visual—Offline	4Y
Actuator—General Visual—Online	2Y
Diagnostics—Electrical Force	2Y
Valve Stem Lubrication	2Y
Functional Test—Leak	AR
Functional Test—Operability	AR
Functional Test—Timed Stroke	AR
Packing Adjustment/Replacement	AR

AR = as required Y = years

The EPRI program derives most of its reliability benefit from the Actuator—Detailed Inspection/Clean/Lubricate task given the nuclear origins of the task template. A vulnerability analysis shows that that task alone yields 45% of the reliability benefit for the entire program and that eliminating it from the baseline program increases the failure rate by 55%.

However, the team determined that in a combined-cycle environment, an intrusive inspection with an eight-year timeframe on a heavily used, largely automated system did not provide the type of feedback that less intrusive diagnostics could. The resulting model maintenance program tasks for motor-operated steam isolation valves are listed in Table 4-5.

Table 4-5
Model maintenance program for motor-operated steam isolation valves

Task Name	Model Maintenance Program
Diagnostics	HGP inspection
Valve Internal Inspection	Major inspection

The diagnostic task includes the following tasks from the PMBD: Actuator—General Visual—Off-Line, Functional Test—Operability, Functional Test—Timed Stroke, Packing Adjustment/Replacement, and Valve Stem Lubrication. Using a three-year interval, the reliability benefit is at 87%. Table 4-6 shows the failure modes affected for MOVs.

Table 4-6
Failure modes affected by model maintenance program for MOVs

Risk Effect	Baseline Program	Model Maintenance Program	Failure Location	Degradation Mechanism	Degradation Influence	Time Code
New	Green	Yellow	Wiring	Degraded insulation	Aging, temperature	UW25
New	Green	Yellow	Motor	Degraded insulation	Age, temperature	UW40
Improved	Yellow	Green	Switch—limit	No contact	Normal wear, loss of spring tension	UW10

The team added a megger test on the motor to the scope of the diagnostic task to cover the new failure risks.

At this site, the valves were not able to be isolated online safely (that is, double-block and bleed); therefore, the maintenance would have to be performed off-line. If the design allows for work to be done on the valve online, much of the work could be performed outside of an outage.

4.3.5 AOV Analysis

The EPRI Baseline AOV program for CHS conditions from the EPRI PMBD is shown in Table 4-7.

Table 4-7
EPRI PMBD baseline PM for AOVs

Task Name	EPRI PMBD (CHS)
Actuator Assembly Overhaul	5Y
Calibration of Accessories	2Y
Calibration of Actuator	2Y
Operator Rounds	1S
Packing Inspection/Adjustment	2Y
Packing Replacement	5Y
Rebuild/Replace Accessories	5Y

Y = years   S = shift

The resulting model maintenance program tasks for air-operated steam bypass valves are listed in Table 4-8.

Table 4-8
Model maintenance program for air-operated steam bypass valves

Task Name	Model Maintenance Program
Inspection and Calibration	HGP inspection
Valve and Actuator Overhaul	Major inspection
Operator Rounds	1S

S = shift

The Inspection and Calibration task is inclusive of the calibration tasks from the PMBD (actuator and accessories) and Packing Replacement tasks. Also included is additional guidance from site resources. The valve and actuator overhaul task includes the Inspection and Calibration task scope and adds the actuator assembly overhaul and rebuild/replace accessories from the PMBD with some valve maintenance guidance from site resources.

Using the time-based equivalency of major inspection being six years and HGP inspection being three years, the vulnerability analysis showed an 83% reliability benefit as compared with baseline.

Table 4-9 illustrates the failure modes affected for AOVs.

Table 4-9
Failure modes affected by model maintenance program for AOVs

Risk Effect	Baseline Program	Model Maintenance Program	Failure Location	Degradation Mechanism	Degradation Influence	Time Code
New	Yellow	Orange	Packing	Leakage	Normal wear	UW5
New	Green	Orange	Actuator	Elastomer failure: diaphragm (loss of elasticity)	Age	UW5
New	Yellow	Orange	Actuator	Elastomer failure: O-rings and gaskets (bushings, top hat/cover)	Age	UW5
New	Green	Orange	Coupling: scotch yoke	Worn yoke	Duty cycle	UW10
New	Green	Yellow	External air filter	Leaks	Degraded elastomers	UW5_10
New	Green	Orange	Actuator	Elastomer failure: diaphragm (loss of elasticity)	Heat from ambient and process conditions	W5
New	Yellow	Orange	Actuator	Elastomer failure: O-rings and gaskets (bushings, top hat/cover)	Heat from ambient and process conditions	W5
New	Yellow	Orange	Limit switches	Elastomer failure	Heat from ambient and process conditions	W5
New	Yellow	Orange	Actuator	Bushing wear	Actuator orientation other than vertical	W5_10
New	Green	Orange	Coupling: scotch yoke	Bushing/bearing wear	Lack of lubrication	W5
New	Orange	Red	Limit switches	Wear—for example, cams, lever arms, and bushings	Material properties and design	W1.5

The justification for the deviation from baseline can be summarized as follows:

- The actuators in question do not have scotch yokes, and filtration is handled by air systems.
- The UW5 failure modes, while Orange effectiveness, would still get adequate coverage under this program, given site and combined-cycle industry experience.
- The site was in the desert with the AOVs exposed to external conditions. The HGP and major inspection task would likely be performed to cover those items with a degradation influence. Heat from ambient and process conditions and those conditions would limit any extension of the actuator tasks beyond three and six years without justification for exposure to these failure modes.
- The site had its valve oriented horizontally. This limits the interval for AOV tasks to the HGP and major inspection intervals. Those sites with vertically oriented valves may experience less bushing wear, which could justify a task extension.

Other sites could reconsider these intervals under the following conditions:

- Valves are not exposed to temperature extremes by being indoors.
- Valve actuators are vertically oriented.

4.3.6 Attemperator Analysis

At the time this report was published, the attemperator was not listed as a separate component in the EPRI PMBD, but it is included in the HRSG HP, IP and reheater data tables. Consistent with the failure data provided in Section 3 of this report, Table 4-10 describes the location, type, and cause of each failure mode along with a time code that describes how long the failure-free period is estimated based on an expert analysis.

Table 4-10
Failure modes affected by model maintenance program for attemperators

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Header ring, if present	Cracked	Failed weld	R
Liner	Cracked	Thermal cycling, duty cycle	UW10
Liner	Cracked weld	Fatigue, improper spray	R
Liner	Cracked weld	Thermal cycling, duty cycle	UW8
Liner	Damaged or broken	Fatigue, improper spray	R
Spray nozzles	Corroded	Extended layup	R
Spray nozzles	Damaged, broken	Fatigue, run time	UW1_2
Spray nozzles	Damaged, broken	Personnel error	R
Spray nozzles	Eroded	Normal use, run time	UW8
Spray nozzles	Incorrect installation—for example, misaligned	Personnel error	R

Table 4-10 (continued)
Failure modes affected by model maintenance program for attemperators

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Spray nozzles	Leaking at flanged joint	Improper torquing	R
Spray nozzles	Leaking at flanged joint	Relaxed studs from thermal cycling, run time	UW10
Spray nozzles	Missing hardware	Normal use, run time	UW8
Spray nozzles	Plugged	Buildup of deposits, especially under low spray flows	R
Spray nozzles	Plugged	Debris	R
Spray nozzles	Warped	Thermal cycling, duty cycle	UW8
Spray nozzles	Wrong nozzle, incorrect depth	Personnel error	R
Spray nozzles—spring type, if present	Broken spring	Fatigue	R
Spray nozzles—spring type, if present	Eroded swirl chamber	Normal use, run time	UW8
Spray nozzles—spring type, if present	Leakage	Debris	R
Spray nozzles—spring type, if present	Leakage from loss of spring constant	Normal use, creep, run time	UW10
Spray nozzles—spring type, if present	Loose or missing retaining nut	Broken locking pin	R
Steam pipe attachment	Cracked	Failed weld	R
Steam pipe flange	Cracked	Failed weld	R
Steam pipe flange	Leakage	Failed gasket from age, thermal cycling, duty cycle	UW10
Steam pipe flange	Leakage	Incorrect fastener material	R
Steam pipe flange	Leakage	Incorrect, or poorly installed or tightened gasket	R
Steam pipe flange	Leakage	Steam cut	R
Strainer	Clogged	Contaminant buildup, run time	UW10
Strainer	Erosion or corrosion	Debris	R

Table 4-10 (continued)
Failure modes affected by model maintenance program for attemperators

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Strainer	Erosion or corrosion	Improper material	R
Water pipe Attachment	Cracked	Failed weld	R
Water pipe flange	Cracked	Failed weld	R
Water pipe flange	Leakage	Failed gasket from age, thermal cycling, duty cycle	UW10
Water pipe flange	Leakage	Incorrect fastener material	R
Water pipe flange	Leakage	Incorrect, or poorly installed, or tightened gasket	R
Water pipe flange	Leakage	Steam cut, from flashing	R

R = random

Using an estimate that the HGP inspection would be analogous to three years of operation, the failure mode that would not be fully covered by this program is listed in Table 4-11.

Table 4-11
Failure modes not fully covered by the model maintenance program for attemperators

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Spray nozzles	Damaged, broken	Fatigue, run time	UW1_2

A review of the experience at the host site suggested that its experience was less frequent than the EPRI analysis. The HGP interval would be appropriate in this case, but the inspection should not be extended beyond that.

4.3.7 Piping and Hanger Inspections

There was not a complete template in the PM Basis Database for a piping system, but industry experience suggests that a complete piping inspection in concert with the major inspection and a hanger inspection with the HGP and the major inspection is best practiced and, in most cases, finds issues before they can challenge the system. Because of the varying degradation mechanisms possible in a piping system, an engineering evaluation needs to be performed to determine the degradation progression and, therefore, the subsequent inspection frequency. A separate job plan is provided for each of these inspections because the piping inspection often is performed with assistance from an outside contractor, whereas the hanger inspection is usually not.

4.3.8 Drain Line Leak Check

A minimum interval for the drain line leak check is prior to a planned extended outage (HGP or major inspection) to test for proper isolation. A more frequent interval could be supported by the site's performance program.

4.3.9 I&C Analysis

The model maintenance program calibration tasks are listed in Table 4-12.

Table 4-12
Model maintenance program for calibration of I&Cs

Task	Annual	HGP	Major Inspection
Calibration—Nonredundant, Critical	X		
Calibration—Redundant, Critical		X	X
Calibration—Noncritical		X	X

Given that the steam bypass system is highly automated and requires coordination with several plant systems while the plant transitions between startup and shutdown, and when transitioning through different loads, there was not much justification to extending maintenance intervals for critical instruments beyond one year given the risks associated with malfunction and the information feedback that comes from calibration.

As for redundant and/or noncritical items, most of the wear-out time codes in the database indicate an 18-month failure-free period. These data may be influenced by a bias from the source (that is, nuclear), where instruments are often inspected and calibrated during refueling outages, and those, historically, take place on an 18-month interval. Given that, the HGP interval does not incur excessive risks.

5
EXAMPLES OF JOB PLANS

The purpose of this section is to provide CTCC facility maintenance personnel with sample job plans for the model maintenance program tasks provided in this report. General guidance regarding the content of typical job plans (also referred to as *maintenance instructions* or *work packages*) is provided in this section. The guidance recognizes that unlike a fossil power plant, a CTCC facility will typically not have a separate organization for maintenance planning and might not have individuals designated whose primary function is planning maintenance activities (that is, work planners). As such, the guidance presented in this section should be customized as needed to best meet the needs of each owner's organizational structure.

5.1 Content and Format for Job Plans

5.1.1 General Guidance and Considerations

5.1.1.1 Fundamental Work Package Attributes for Ensuring Quality

Work may be planned to anticipate error-likely situations and to incorporate controls that effectively prevent, catch, or mitigate error during the performance of a specific task by specific individuals.

As noted in the EPRI report, *Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel* (1014547), industry experience also suggests the following regarding work planning:

> Identifying the opportunities for error and eliminating them is one of the key responsibilities of those developing procedures and planning work packages. The planning stage of work management is an opportunity to identify critical steps of an activity. The structure of the task can be planned in light of single-error vulnerabilities to reduce possible consequences should people err. Additional controls or barriers can be built into the procedure to prevent or catch errors. Feedback from previous occasions and industry operating experience relevant to the task can be factored into the work plan.

Key Human Performance Point

One key attribute to consistently developing a quality job plan is to perform a critical task analysis.

A critical task analysis basically consists of the following four steps:

1. Develop a task list.
2. Identify and prioritize critical tasks.
3. Identify critical steps of each particular task, considering the following:
   – Pinpoint error-likely situations at each critical step.
   – Characterize the consequences if error(s) occurs at the critical step.
   – Identify weaknesses in or missing defenses.
4. Identify and incorporate needed controls or safeguards.

Other key (or critical) attributes when developing a quality work package may include ensuring the following:

- That the content is consistent with the knowledge, skills, and experience of the work force as well as with management expectations
- That work packages are developed with site instructions/procedures, which may include, in some cases, the aid of a writer's guide
- That work packages are reviewed to check for technical accuracy and consistency with the writer's guide, if applicable
- That work packages are validated by qualified users (Can the procedure/work instruction be implemented/used as written?)
- That work packages are current and revised appropriately
- That work packages include relevant operating experience and lessons learned, as appropriate
- That a feedback process is used as a means to continuously improve the quality of the work packages

5.1.1.2 Inclusion of Maintenance Experience

The work planner should consider the use of applicable maintenance experience and equipment performance history when planning work instructions. Most owners recognize industry maintenance experience as a source that provides valuable insight on improving work planning processes based on the learning experiences and/or from other utilities.

Maintenance experience that the planner determines may provide safety, quality, time, or cost benefits to maintenance instructions and/or activities should be added to the owner's information management system. A copy of the maintenance experience may also be provided to maintenance team/discipline leader(s) for future reference.

Key Human Performance Point

When planning a job plan or maintenance work package, the planner should search for relevant maintenance experience, and if such information is identified that is relative to the work being performed, it should be placed in the work package.

5.1.1.3 Establishing the Appropriate Level of Detail

The level of detail contained in a work package and work instructions results after careful consideration of numerous factors and will vary from job to job. When the work planner proactively considers inputs and appropriately varies the resulting work package category level, scope, content and level of detail, the planner takes a graded approach to the work planning process.

5.1.2 Recommended Job Plan Content

The format, structure, and content of job plans vary from plant to plant and will vary depending upon the work level categorization. Figure 5-1 illustrates the typical components of a maintenance job plan (work package). Note that the primary difference between job plans is the level of detail of work/special instructions. In some cases, the level of detail is much less because either a higher reliance is placed on the skill of the craft or because those work instruction details are already described in an existing instruction or procedure that is simply cross-referenced in the work package.

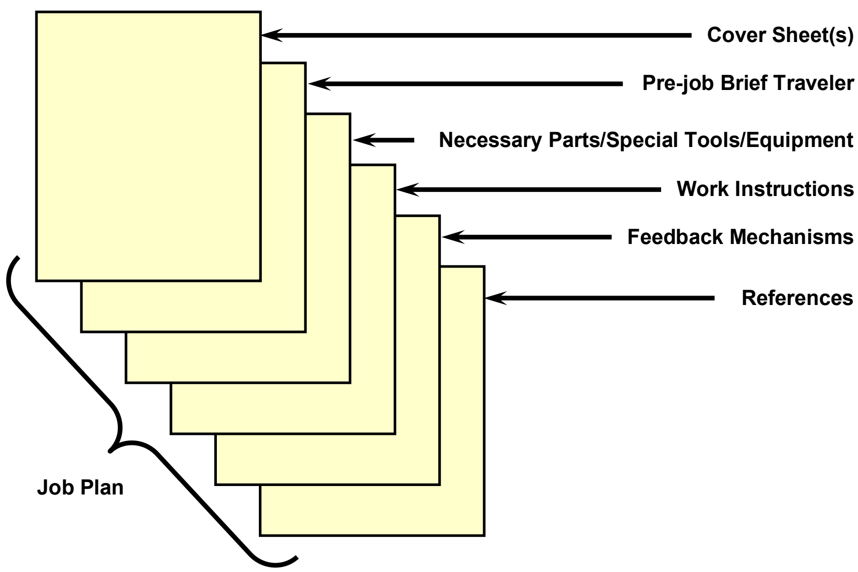

Figure 5-1
Typical elements of a maintenance job plan

5.1.2.1 Cover Sheet(s)

The work planner should ensure that the cover sheet includes the following:

- The unique work order or task number
- Equipment description (the noun name [or tag number] of the component on which the work is being performed, manufacturer/model information, and so forth)
- Problem description—initial problem description as defined by the initiator
- Scope of work—as defined by the work planner after validation of the initial problem description

5.2.2.2 Pre-Job Brief Traveler

Key Human Performance Point
The work planner should typically prepare a pre-job brief traveler for any maintenance activities posing risk to unit operation/generation.

The pre-job brief traveler can be a specific activity incorporated within the work instructions, or it can be a separate item included in the work package. It should be initiated by maintenance planners during the planning process and be expanded upon as the work order progresses to the implementation phase.

Planners should include the following:

- Critical job steps
- Job safety analysis
- Potential adverse outcomes
- Contingency or compensatory actions
- Error-likely situations and defenses
- Relevant maintenance experience
- Review/discussion of the following maintenance procedures:
  - Lock-out-tag-out (LOTO)
  - Calibration
  - FME
- Identification of clearance/tag-out boundary
- Identification of FME potential and mitigation
- Environmental considerations (reference material safety data sheets [MSDSs])
- Need for FME

The traveler should be reviewed during the post job critique to improve work package and pre-job briefing quality, and it should be archived as appropriate to support future work package development.

5.1.2.3 Identification of Necessary Parts, Special Tools, and Equipment

> **Key Human Performance Point**
>
> The work planner should review bill of material, drawings, component maintenance philosophy, and maintenance history to identify parts and consumables that are likely to be needed for the job.

As noted in the preceding section, the planner should also identify/flag contingency parts and communicate to the supply chain organization(s) whether the part will be needed on-site to support the work. It is typically necessary for the planner to ensure that the correct parts/replacement items are installed in the plant for the work being prescribed and planned. Care should also be taken to ensure that replacement parts are consistent with plant design documentation.

> **Key Technical Point**
>
> Only replacement parts that are physically identical to the original should be installed unless a replacement item equivalency evaluation has been performed by the engineering organization and an alternative item has been approved for use.

The planner should also reserve or initiate procurement of the needed parts or services and identify the date that staging is required. Typically, staging represents material that is picked and segregated into kits by work management personnel for each job and placed in a separate and secure location in the warehouse. Staging facilitates a more level workload in the warehouse as well as assisting the craft labor with expeditious issuance of the needed parts.

In some cases it may be beneficial to walk down staged material for certain work activities well in advance of the work, to further ensure efficient delivery of material when warehouse facilities are remote from the plant.

The work planner should notify appropriate organizations when engineering evaluations or reviews are required to support the issue and use of required parts/services, as necessary. If the planner has reason to believe that the needed parts will not be available by the preparation milestone, the planner should identify the restraint.

The work planner should also be made aware of potential obsolescence issues that could adversely impact the procurement and availability of necessary parts. *Obsolescence* is a term commonly used in the fossil industry to refer to one of the following conditions:

- The condition of being out of date due to development of better or more economical products, methods, processes, machinery, or facilities resulting in a loss of value or competitive advantage. Items may be available in the market but are no longer needed in a specific application.
- The condition of no longer being available in the market due to lack of manufacturer support. Items are needed in a specific application but are no longer available or supported by the original manufacturer and are difficult to otherwise procure.

Although the work planner is typically not responsible for resolving part obsolescence issues and procuring alternative items, the work planner should be aware that obsolescence can result from any of the following scenarios:

- Part obsolescence: supplier/manufacturer no longer makes the part
- Obsolete equipment: items in plant service that are no longer manufactured or supported by the original manufacturer or are otherwise difficult to procure

In summary, accurate and timely planning of work should allow the procurement process to optimize the cost of materials and inventory. The work planner should have an appreciation for the criticality of the part(s), and planning of work should take into consideration lead times for obtaining parts where stock is not maintained in inventory.

In some cases the work package may identify and contain guidance regarding the proper application and use of special tools and equipment. Typically, the planner should identify these items and include guidance when there is reason to believe that the craft labor may benefit from additional instructions or the improper use of the special tools/equipment could have an adverse effect on the maintenance work activities or the equipment being serviced.

5.1.2.4 Work Instructions

Typical content of work instructions as well as level of detail is provided in the example job plans in this section.

Table 5-1 provides an overview of the example job plans developed for this report.

Table 5-1
Overview of the job plan examples

Job Plan Task Scope	Report Section
MOV—Diagnostics	5.2
MOV—Valve Internal Inspection	5.3
AOV– Inspection and Calibration	5.4
AOV—Valve And Actuator Overhaul	5.5
Attemperator Inspection	5.6
Piping Inspection	5.7
Hanger Inspection	5.8
Drain Line Leak Check	5.9
Calibration—Nonredundant, Critical	5.10
Calibration—Redundant, Critical	5.11
Calibration—Noncritical	5.12

5.1.2.5 Feedback Mechanism

> **Key Human Performance Point**
>
> The job plan should contain a means for the craft labor to provide feedback to the maintenance organization regarding the quality and clarity of the work package.

This feedback is typically only one of many elements of the plant's maintenance feedback process. Means of providing feedback to the persons planning maintenance work regarding the quality of the work package can be accomplished during several stages of work.

5.1.2.6 References

A listing of source documents and references used to compile and assemble the work package should be included. This list may include the following:

- Existing maintenance work instructions and/or procedures
- Replacement part information (vendor manual, assembly drawing, bill of material, critical spares data base, and so forth)
- Component identification (master equipment list, piping and instrumentation diagram, electrical drawings, and so forth)
- Technical equipment specifications
- Maintenance experience and equipment performance history

5.2 MOV—Diagnostics Job Plan

5.2.1 Task Objective and Purpose

The purpose of this job plan is to evaluate the condition of the motor-operated main steam isolation valves on the HP bypass system, to extend the intervals between valve and actuator overhauls.

5.2.2 Task Timing

This task is to be completed in conjunction with the HGP, for the following reasons:

- Associated wear-out attemperator mechanisms coincide with the HGP.
- HGP automatically adjusts for duty cycle.
- For several failure mechanisms, the electrical diagnostic tests provide the only means of detecting the degradation before the direct thrust diagnostic tests and the detailed inspection are performed at 8 or 16 years.

5.2.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.2.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.2.5 Task Content and Work Instructions

Note: This job plan must be done off-line.

Task content and work instructions are as follows:

- Conduct a thorough visual inspection of the MOV operator and valve body, as follows:
  - Look for any discoloration or other evidence of overheating.
  - Inspect the condition of the geared limit and torque switches for broken or damaged wiring and parts.
  - Inspect the torque switch for free movement of the switch and return spring function.
  - Inspect the torque switch contacts for abnormal wear, pitting, or corrosion.
  - Inspect that the torque switch makes proper contact with the switch fingers and that the fingers are not damaged, burnt, or bent, and are free to move.
  - Inspect the mechanical valve position dial indicator for proper movement and positioning.
  - Inspect the tripper finger assembly, if accessible.
  - Inspect for damaged, loose, or missing parts, fasteners, lugs, terminations, and wiring.
  - Inspect for the general presence of contamination, moisture, and corrosion, especially in the stem and packing areas.
  - Inspect for grease and oil leaks from the motor bearings, actuator gear box, and handwheel assembly.
  - Inspect the condition of the torque arm assembly and the antirotation device for damage, wear, and looseness.
- Perform a megger test on all three phases of the electrical motor leads.
- Tighten packing at packing gland, as necessary to eliminate valve stem steam leakage. Packing should not be torqued beyond the original values specified in your packing program or by the manufacturer, because this could alter the valve testing results.
- Measure the electrical voltage and amperage of the MOV as the MOV is being stroked, and calculate the horsepower and/or torque of the motor, to compare against design and historical values, looking for deviations and degradations over time.
- Time the valve stroke from full open to full close and from full close to full open for comparison to baseline and historical values, looking for deviations and degradations over time.
- Verify that, as the valve is stroked, all limit switch contacts provide appropriate feedback to the control room and that all associated lights and signal feedbacks are functioning appropriately.

5.2.6 Task Justification and Degradation Progression

Most of the failure mechanisms lead to random failure times in the order of a few years. Such failure times can be addressed effectively by electrical diagnostics at a two- to three-year interval. For the few exceptions, a two- to three-year period should be adequate except in severe cycling, which should be addressed with hot gas pass inspections automatic adjustment for cyclic duty.

5.2.7 Example Worksheets

Use the member-specific calibration worksheet that covers the following areas:

- Date performed
- Device being calibrated
- Calibration instrument used
  - Model number
  - Calibration date
  - Calibration span
- Calibration results
  - Target
  - As-found
  - As-left
- Notes

Scope of Instruments should include the following:	
Instruments	**Initials**
Limit switches	
Torque switches	

Calibration Worksheet		
Calibration Point	**As-Found**	**As-Left**

Inspection Worksheet			
Inspection	**As-Found**	**As-Left**	**Notes on Remediation**
Open/close time			
Volts and amps used to calculate torque/horsepower			
Megger motor leads			
Packing			

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Lubricant—valve stem	Degraded, dirty
	Valve stem	Damaged thread
	Packing	Leakage
	Drive train	Leaking oil seal
	Wiring	Damaged terminals
	Wiring	Damaged wiring
	Wiring	Loose wiring or lugs
	Motor	Degraded insulation
	Fasteners	Missing or loose
	Switch—limit	Improper operation
	Switch—torque	Improper operation
	Drive train	Improper operation
	Spring pack	Improper operation
	Switch—limit	Improper operation
	Motor	Degraded insulation
	Drive train	Improper operation
	Switch—torque	Improper operation
	Valve stem	Improper operation

5.2.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up the work area, leaving the work site better than was found.

5.2.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MSDSs
- Vendor technical manual

5.3 MOV—Valve Internal Inspection Job Plan

5.3.1 Task Objective and Purpose

The purpose of this job plan is to evaluate the condition of the internals of the isolation valves on the HP/IP/LP bypass system and to make necessary repairs to ensure reliable operations with no leakage until the next scheduled inspection.

5.3.2 Task Timing

This task is to be completed in conjunction with the major inspection because associated wear-out attemperator mechanisms coincide with the major inspection and major inspections automatically adjust for duty cycle.

Note: This job must be done off-line.

5.3.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.3.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.3.5 Task Content and Work Instructions

Task content and work instructions are as follows:

- Conduct thorough visual inspection of the valve body, including the following:
  - Looking for any discoloration or other evidence of overheating
  - Inspecting for structural integrity
  - Inspecting for damaged, loose, or missing parts, fasteners, and lugs
  - Inspecting for the general presence of contamination, moisture, and corrosion especially in the stem and packing areas
  - Inspecting the isolation valve bypass line and valve
  - Operating the isolation valve bypass valve and check for operability
- After surface cleaning and inspection or repair of the valve externals, begin valve disassembly in accordance with the manufacturer's detailed instructions.
- Inspect valve internals for wear and integrity, including the following components:
  - Valve body
  - Valve body assembly—integral valve guides
  - Valve body assembly—internal valve bearings, bushings, and guides
  - Valve disk or plug—seat or seat ring
- Inspect valve stem and all exposed moving parts.
- Determine whether the valve is to be repaired or replaced.
- If it is to be repaired, make necessary repairs and clean surfaces.
- At reassembly, always use new sealing parts, such as gaskets and stem packing.

5.3.6 Task Justification and Degradation Progression

A vulnerability analysis shows that this task alone yields 45% of the reliability benefit for the entire program and eliminating it from the baseline program increases the failure rate by 55%. However, the team determined that in a combined-cycle environment, an intrusive inspection with an eight-year timeframe on a heavily used, largely automated system did not provide the type of feedback that less intrusive diagnostics could. The conditions that create the justification were related to duty cycle and the need for the valve to positively shut off flow when called upon to do so.

5.3.7 Example Worksheet

The following is an example worksheet.

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Valve stem packing gland	Out of round
	Valve stem packing gland	Excessive friction
	Valve stem packing gland	Leakage
	Valve stem packing gland	End of useful packing life
	Valve body—insulation	Loose, missing, or damaged
	Valve body	Gasket leakage—external
	Valve body	Gasket leakage—internal
	Valve body	Excessive wear
	Valve body	Cracking
	Valve body—bonnet gasket	Leakage
	Valve body—bonnet gasket fit	Excessive wear
	Valve body assembly—integral valve guides	Excessive wear
	Valve body assembly—integral valve guides	Deposits causing insufficient clearances
	Valve body assembly—internal valve bearings, bushings, guides	Bound or galled
	Valve body assembly—internal valve bearings, bushings, guides	Loose
	Valve disk or plug	Broken spring
	Valve disk or plug	Damaged or distorted seating surface
	Valve disk or plug	Cracked seating surface
	valve disk or plug	Crud buildup
	Valve disk or plug	Excessively worn or eroded
	Valve seat or seat ring	Damaged or distorted seating surface
	Valve seat or seat ring	Cracked seating surface
	Valve seat or seat ring	Crud buildup
	Valve seat or seat ring	Excessively worn or eroded
	Valve stem	Bent
	Valve stem	Rough, pitted, or scored surface
	Valve stem	Excessive wear
	Valve stem	Separated stem from the plug or disk

5.3.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.3.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.4 AOV—Inspection and Calibration Job Plan

5.4.1 Task Objective and Purpose

The objective of this job plan is to accomplish the following:

- Inspect and repair valve seat and plug surfaces to prevent any internal leaks
- Calibrate actuator and valve accessories design specifications of the actuator to provide assurance that the valve is capable of performing its design function
- Replace valve packing to prevent external leakage while allowing the valve to perform to specifications
- Replace air filter and desiccant
- Replace soft goods and consumables
- Evaluate as-found and as-left conditions to report back to system owners on degradation trends and any abnormal conditions

5.4.2 Task Timing

The PM activity coincides with the gas turbine HGP inspection (approximately three years in an hours-based situation).

5.4.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity. Specific to this task, consideration should be given to a review/discussion of the following maintenance support documents and issues:

- Applicable procedures, including the following:
  - LOTO
  - Calibration procedure
  - FME
- Identification of clearance/tag-out boundary
- Identification of FME potential and mitigation
- Environmental considerations (reference MSDSs)

5.4.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.4.5 Task Content and Work Instructions

Prior to disassembly an as-found external visual inspection should include the following:

- Structural integrity
- Subcomponent damage
- Loose, broken, missing fasteners, especially in high-vibration areas
- Damaged or loose electrical connections
- Observation of obvious process fluid leaks
- Actuator shaft condition
- Condition of the valve stem
- Disassembly of the valve to inspect and remediate, if necessary, the following:
  - Valve plug
  - Seat ring
  - Disk stack/cage
  - Packing follower

Replace gaskets, balance seal, metal seal, stem packing, and spacer. Also, replace actuator bushing and O-rings. Make note of any excessive damage or abnormal conditions.

Replace air filter and desiccant. Report on any abnormal filter debris, indicating upstream system failure. Report if desiccant was completely used up (this might suggest changing desiccant at a more frequent interval or be evidence of an air system issue).

General inspection of the air supply system for cleanliness and operability should include the following:

- Excessive moisture
- Oil contamination
- Debris
- Restrictions
- Leaks
- Acceptable air pressure
- General damage

Calibration of the actuator and accessories may include the following:

- Spring preload (uncoupled)/bench set
- Checking for air leakage from pneumatic components
- Stroke length
- Inspection of coupling and proper torquing, as required
- Verifying correct position of the handwheel, if applicable
- Setting limit switches
- Pressure regulator setpoint (See I&C—Pressure Regulator)
- I-P/E-P transducer (see I&C—I to P and E to P Transducer)
- Positioner (see I&C—Positioner)
- Booster tuning (see I&C—Booster)
- Pressure switches (see I&C—Pressure Switch)
- Position transmitter (see I&C—Positioner)
- Speed control valves
- Air leakage check—for example, a DP test

5.4.6 Task Justification and Degradation Progression

This task is an assemblage of calibration tasks (actuator and accessories) and Packing Replacement from the EPRI PMBD baseline for AOV—Piston Type (revision 0) combined with a repair vendor recommendation for valve seat and plug inspection. Site experiences suggest that equipment degradation creates conditions that make disassembly difficult if valve disassembly is postponed too long, which subsequently increases the risk of damage to the valve. The conditions that create the justification were related to duty cycle, specifically run hours.

5.4.7 Example Worksheets

The following are example worksheets.

Calibration Worksheet		
Calibration Point	**As-Found**	**As-Left**

Measurement Worksheet		
Measurement	**As-Found**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Actuator	Broken spring
	Actuator	Degraded elastomers
	Actuator	Excessive wear
	Actuator	Failed handwheel
	Actuator	Improper operation
	Actuator	Improperly positioned handwheel
	Actuator	Out of tolerance
	Actuator	Restricted vent path
	Check valves—air line	Stuck
	Check valves—piston/actuator	Out of tolerance
	Check valves—piston/actuator	Stuck
	Coupling: direct	Bound
	Coupling: direct	Incorrect setup
	Coupling: direct	Loose
	Coupling: direct	Out of tolerance
	Coupling: fixed moment arm	Broken or bent linkages
	Coupling: fixed moment arm	Bushing or bearing wear
	Coupling: fixed moment arm	Loose linkages
	Coupling: fixed moment arm	Out of tolerance
	Coupling: fixed moment arm	Worn key
	Coupling: rack and pinion	Out of tolerance

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Coupling: rack and pinion	Worn gear
	Coupling: scotch yoke	Bushing or bearing wear
	Coupling: scotch yoke	Incorrect setup
	Coupling: scotch yoke	Out of tolerance
	Coupling: scotch yoke	Roller pin failure
	Coupling: scotch yoke	Worn yoke
	Desiccant	Consumed
	External air filter	Clogged
	External air filter	Degraded elastomers
	External air filter	Leaking
	Limit switches	Contact misaligned
	Limit switches	Corroded
	Limit switches	Corroded contacts
	Limit switches	Degraded elastomer
	Limit switches	Excessive wear
	Limit switches	Loose connections
	Limit switches	Loose fasteners
	Limit switches	Misadjusted
	Limit switches	Out of tolerance
	Packing	Degraded packing
	Packing	Excessive leakage
	Packing	Gouged stem
	Packing	Scored stuffing box
	Packing follower	Cannot tighten
	Pneumatic tubing	Crushed or damaged
	Pneumatic tubing	Leaking
	Speed control valves	Degraded elastomers
	Speed control valves	Dirty
	Speed control valves	Improper or excessive lubrication
	Speed control valves	Misadjusted
	Speed control valves	Out of tolerance
	Speed control valves	Weak spring
	Valve seat	Cracked
	Valve seat	Loose
	Valve seat	Out of tolerance

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Valve seat	Worn
	Valve plug	Cracked
	Valve plug	Loose
	Valve plug	Out of tolerance
	Valve plug	Worn
	Plug/seat blue check	Improper sealing

5.4.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.4.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.5 AOV—Valve and Actuator Overhaul Job Plan

5.5.1 Task Objective and Purpose

Task objectives for this job plan are as follows:

- Inspect and repair valve seat and plug surfaces to prevent any internal leaks.
- Rebuild and/or replace accessories.
- Replace all soft goods.
- Calibrate actuator and valve accessories design specifications of the actuator to provide assurance that the valve is capable of performing its design function.

- Replace valve packing to prevent external leakage while allowing the valve to perform to specifications.
- Replace air filter and desiccant.
- Evaluate as-found and as-left conditions to report back to system owners on degradation trends and any abnormal conditions.

5.5.2 Task Timing

This task coincides with gas turbine major inspection (or every other HGP, which would be approximately every six years in an hours-based situation).

5.5.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity. Specific to this task, consideration should be given to a review/discussion of the following maintenance support documents and issues:

- Applicable procedures, including the following:
  - LOTO
  - Calibration procedure
  - FME
- Identification of clearance/tag-out boundary
- Identification of FME potential and mitigation
- Environmental considerations (reference MSDS)

5.5.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine the necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.5.5 Task Content and Work Instructions

Prior to disassembly an as-found external visual inspection should include the following:

- Structural integrity
- Subcomponent damage
- Loose, broken, missing fasteners, especially in high-vibration areas
- Damaged or loose electrical connections
- Observation of obvious process fluid leaks
- Actuator shaft condition

- Condition of the valve stem
- Disassembly of valve to inspect and remediate, if necessary, the following:
  - Valve plug
  - Seat ring
  - Disk stack/cage
  - Packing follower
- Actuator assembly internal inspection of the following for damage to, or the condition of, or missing:
  - Sealing surface
  - Bushings
  - Sealing components—diaphragm, seals, O-rings, and so forth
  - Cylinder walls and piston, if applicable
  - Stem
  - Gearing
  - Spring(s)
  - Vents (Are they clear?)
  - System cleanliness

Replace all soft goods. Also, replace actuator bushing and O-rings. Make note of any excessive damage or abnormal conditions.

Replace air filter and desiccant. Report on any abnormal filter debris indicating upstream system failure. Report if desiccant was completely used up (this might suggest changing desiccant at a more frequent interval or be evidence of an air system issue).

Replace or rebuild accessories, including the following:

- Solenoid valves
- Positioners
- Regulators
- I-P/E-P transducers
- Boosters
- Limit switches
- Pressure switches
- External air supply filters
- Pneumatic switches

- Check valves
- Speed control valves
- Position transmitters

General inspection of the air supply system for cleanliness and operability should include the following:

- Excessive moisture
- Oil contamination
- Debris
- Restrictions
- Leaks
- Acceptable air pressure
- General damage

Calibration of the actuator and accessories can include the following:

- Spring preload (uncoupled)/bench set
- Checking for air leakage from pneumatic components
- Stroke length
- Inspection of coupling and proper torquing, as required
- Verifying correct position of the handwheel, if applicable
- Setting limit switches
- Pressure regulator setpoint (see I&C—Pressure Regulator)
- I-P/E-P transducer (see I&C—I to P and E to P Transducer)
- Positioner (see I&C—Positioner)
- Booster tuning (see I&C—Booster)
- Pressure switches (see I&C—Pressure Switch)
- Position transmitter (see I&C—Positioner)
- Speed control valves
- Air leakage check—for example, a DP test

5.5.6 Task Justification and Degradation Progression

This task includes the entire scope of the Critical AOV Control Valves: Inspection and Calibration task in addition to the Actuator Overhaul and Rebuild/Replace Accessories task from the EPRI PMBD.

The main rationale for overhauling the actuator on a regular schedule is to replace the soft goods in the actuator and the accessories because they degrade with age and exposure to the service environments found in most combined-cycle plants.

The timing coincides with various industry practices and degradation analyses but should be adjusted based on operational and calibration data. Severe environments or heavy operations could warrant reducing the interval.

5.5.7 Example Worksheets

The following are example worksheets.

Calibration Worksheet	
Instrument	**Initials**
Pressure regulator	
Positioner	
Limit switches	
Booster	
Pressure switches	
Position transmitter	
Speed control valves	

Use the member-specific calibration sheet that covers the following areas:

- Date performed
- Device being calibrated
- Calibration instrument used, including the following:
  - Model number
  - Calibration date
- Calibration results, including the following:
  - Target
  - As-found
  - As-left
- Notes

Measurement Worksheet		
Measurement	**As-Found**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Actuator	Broken spring
	Actuator	Cannot be calibrated
	Actuator	Degraded elastomers
	Actuator	Excessive wear
	Actuator	Failed handwheel
	Actuator	Improper operation
	Actuator	Improperly positioned handwheel
	Actuator	Out of tolerance
	Actuator	Restricted vent path
	Air pump	Bound spool piece
	Air pump	Cannot be calibrated
	Air pump	Degraded elastomer
	Air pump	Out of tolerance
	Check valves—air line	Cannot be calibrated
	Check valves—air line	Out of tolerance
	Check valves—air line	Stuck
	Check valves—air line	Stuck
	Check valves—piston/actuator	Cannot be calibrated
	Check valves—piston/actuator	Out of tolerance
	Check valves—piston/actuator	Stuck
	Check valves—piston/actuator	Stuck
	Coupling: direct	Bound
	Coupling: direct	Cannot be calibrated
	Coupling: direct	Incorrect setup

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Coupling: direct	Loose
	Coupling: direct	Out of tolerance
	Coupling: fixed moment arm	Broken or bent linkages
	Coupling: fixed moment arm	Bushing or bearing wear
	Coupling: fixed moment arm	Cannot be calibrated
	Coupling: fixed moment arm	Loose linkages
	Coupling: fixed moment arm	Out of tolerance
	Coupling: fixed moment arm	Worn key
	Coupling: rack and pinion	Cannot be calibrated
	Coupling: rack and pinion	Out of tolerance
	Coupling: rack and pinion	Worn gear
	Coupling: scotch yoke	Bushing or bearing wear
	Coupling: scotch yoke	Cannot be calibrated
	Coupling: scotch yoke	Incorrect setup
	Coupling: scotch yoke	Out of tolerance
	Coupling: scotch yoke	Roller pin failure
	Coupling: scotch yoke	Worn yoke
	Desiccant	Completely consumed
	External air filter	Clogged
	External air filter	Clogged
	External air filter	Degraded elastomers
	External air filter	Leaking
	Limit switches	Cannot be calibrated
	Limit switches	Contact misaligned
	Limit switches	Corroded
	Limit switches	Corroded contacts
	Limit switches	Degraded elastomer
	Limit switches	Excessive wear
	Limit switches	Loose connections
	Limit switches	Loose fasteners

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Limit switches	Misadjusted
	Limit switches	Out of tolerance
	Packing	Degraded packing
	Packing	Excessive leakage
	Packing	Gouged stem
	Packing	Improper packing configuration
	Packing	Scored stuffing box
	Pneumatic tubing	Cannot be calibrated
	Pneumatic tubing	Crushed or damaged
	Pneumatic tubing	Leaking
	Pneumatic tubing	Out of tolerance
	Speed control valves	Cannot be calibrated
	Speed control valves	Degraded elastomers
	Speed control valves	Dirty
	Speed control valves	Improper or excessive lubrication
	Speed control valves	Misadjusted
	Speed control valves	Out of tolerance
	Speed control valves	Weak spring
	Valve body seat	Cannot be calibrated
	Valve body seat	Cracked
	Valve body seat	Loose
	Valve body seat	Out of tolerance
	Valve body seat	Worn

5.5.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.5.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.6 Attemperator Inspection Job Plan

5.6.1 Task Objective and Purpose

The purpose of this job plan is to ensure that the attemperator and associated equipment are in good working order to protect downstream equipment, unit performance, and personnel safety

5.6.2 Task Timing

This task is to be completed in conjunction with the HGP, for the following reasons:

- Associated wear-out attemperator mechanisms coincide with the HGP.
- HGP automatically adjusts for duty cycle.
- Further delays will make disassembly very difficult.
- Sufficient cooled down period provided to safely work on the equipment.

5.6.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.6.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.6.5 Task Content and Work Instructions

This job plan consists of the following tasks.

Attemperator Subcomponent	PM Task
Control valve stacked disk, if present	• Visually inspect for plugging. • Replace control valve, or unplug (if feasible), as required.
Control valve stacked disk, if present	• Visually inspect for wear between valve plug and stacked disks. • Replace control valve, or replace worn parts between valve plug and stacked disks, as required.
Header ring, if present	• Visually inspect for cracking. • Replace header ring if cracked.
Spray nozzles	• Visually inspect for corrosion, physical damage, erosion, incorrect installation—for example, misaligned, leaking at flanged joint, missing hardware, plugging, warping, or wrong nozzle/incorrect depth. • Replace spray nozzles if they are excessively corroded, there is physical damage, they are eroded or misaligned, there is leaking at the flanged joint, or they are plugged or warped.
Spray nozzles—spring type, if present	• Visually inspect for broken spring, eroded swirl chamber, leakage, leakage from loss of spring constant, or loose or missing retaining nut. • Replace spring type spray nozzles if the spring is broken or if there is evidence of an eroded swirl chamber, leakage, or leakage from loss of spring constant. Replace any missing retaining nuts, and tighten those that have become loose as required.
Steam pipe attachment	• Visually inspect for cracking. • Look for pitting and/or wear on the inside surface of the first steam pipe elbow downstream of the attemperator. If you cannot reach the elbow with a borescope, consider an appropriate nondestructive evaluation (NDE) technique to detect pits or wear. • Replace steam pipe attachment if it is cracked.
Steam pipe flange	• Visually inspect for cracking or leakage. • Replace steam pipe flange if it is cracked or leaking.
Strainer	• Visually inspect for clogging or erosion/corrosion. • Clean or replace strainer if it is clogged or if there is evidence of excessive erosion/corrosion.
Water pipe attachment	• Visually inspect for cracking. • Replace water pipe attachment if it is cracked.
Water pipe flange	• Visually inspect for cracking or leakage. • Replace water pipe flange if it is cracked or if there is evidence of excessive leakage.
Liner	• Perform borescope inspection for cracking, deformation and erosion.

The following general inspection guidelines should also be considered:

- Following site safety procedures including personal protection equipment (PPE) use and LOTO procedure adherence
- Following good FME practices

5.6.6 Task Justification and Degradation Progression

A PM template for the attemperator does not exist separately in the EPRI PMBD, but it is included in the HRSG HP and IP and reheater data tables. The following table of failure modes describes the location, type, and cause of each failure mode along with a time code that describes how long the failure-free period is estimated based on an expert analysis.

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Header ring, if present	Cracked	Failed weld	R
Liner	Cracked	Thermal cycling, duty cycle	UW10
Liner	Cracked weld	Fatigue, improper spray	R
Liner	Cracked weld	Thermal cycling, duty cycle	UW8
Liner	Damaged or broken	Fatigue, improper spray	R
Spray nozzles	Corroded	Extended layup	R
Spray nozzles	Damaged, broken	Fatigue, run time	UW1_2
Spray nozzles	Damaged, broken	Personnel error	R
Spray nozzles	Eroded	Normal use, run time	UW8
Spray nozzles	Incorrect installation—for example, misaligned	Personnel error	R
Spray nozzles	Leaking at flanged joint	Improper torquing	R
Spray nozzles	Leaking at flanged joint	Relaxed studs from thermal cycling, run time	UW10
Spray nozzles	Missing hardware	Normal use, run time	UW8
Spray nozzles	Plugged	Buildup of deposits, especially under low spray flows	R
Spray nozzles	Plugged	Debris	R
Spray nozzles	Warped	Thermal cycling, duty cycle	UW8
Spray nozzles	Wrong nozzle, incorrect depth	Personnel error	R
Spray nozzles—spring type, if present	Broken spring	Fatigue	R

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Spray nozzles—spring type, if present	Eroded swirl chamber	Normal use, run time	UW8
Spray nozzles—spring type, if present	Leakage	Debris	R
Spray nozzles—spring type, if present	Leakage from loss of spring constant	Normal use, creep, run time	UW10
Spray nozzles—spring type, if present	Loose or missing retaining nut	Broken locking pin	R
Steam pipe attachment	Cracked	Failed weld	R
Steam pipe flange	Cracked	Failed weld	R
Steam pipe flange	Leakage	Failed gasket from age, thermal cycling, duty cycle	UW10
Steam pipe flange	Leakage	Incorrect fastener material	R
Steam pipe flange	Leakage	Incorrect, or poorly installed or tightened gasket	R
Steam pipe flange	Leakage	Steam cut	R
Strainer	Clogged	Contaminant buildup, run time	UW10
Strainer	Erosion or corrosion	Debris	R
Strainer	Erosion or corrosion	Improper material	R
Water pipe attachment	Cracked	Failed weld	R
Water pipe flange	Cracked	Failed weld	R
Water pipe flange	Leakage	Failed gasket from age, thermal cycling, duty cycle	UW10
Water pipe flange	Leakage	Incorrect fastener material	R
Water pipe flange	Leakage	Incorrect, or poorly installed or tightened gasket	R
Water pipe flange	Leakage	Steam cut, from flashing	R

R = random

Using an estimate that the HGP inspection would be analogous to three years of operation, the failure mode that would not be fully covered by this program is the following:

Failure Location	Degradation Mechanism	Degradation Influence	Time Code
Spray nozzles	Damaged, broken	Fatigue, run time	UW1_2

A review of the experience at the host site suggested that its experience was less frequent than the EPRI analysis. The HGP interval would be appropriate in this case, but the inspection should not be extended beyond that.

5.6.7 Example Worksheet

The following is an example worksheet.

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Attemperator—control valve stacked disk, if present	Plugged
	Attemperator—control valve stacked disk, if present	Wear between valve plug and stacked disks
	Attemperator—header ring, if present	Cracked
	Attemperator—liner	Cracked
	Attemperator—liner	Cracked weld
	Attemperator—liner	Damaged or broken
	Attemperator—spray nozzles	Corroded
	Attemperator—spray nozzles	Damaged, broken
	Attemperator—spray nozzles	Eroded
	Attemperator—spray nozzles	Incorrect installation—for example, misaligned
	Attemperator—spray nozzles	Leaking at flanged joint
	Attemperator—spray nozzles	Missing hardware
	Attemperator—spray nozzles	Plugged
	Attemperator—spray nozzles	Warped
	Attemperator—spray Nozzles	Wrong nozzle, incorrect depth
	Attemperator—spray nozzles—spring type, if present	Broken spring
	Attemperator—spray nozzles—spring type, if present	Eroded swirl chamber
	Attemperator—spray nozzles—spring type, if present	Leakage
	Attemperator—spray nozzles—spring type, if present	Leakage from loss of spring constant
	Attemperator—spray nozzles—spring type, if present	Loose or missing retaining nut

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Attemperator—steam pipe attachment	Cracked
	Attemperator—steam pipe flange	Cracked
	Attemperator—steam pipe flange	Leakage
	Attemperator—strainer	Clogged
	Attemperator—strainer	Eroded or corroded
	Attemperator—water pipe attachment	Cracked
	Attemperator—water pipe flange	Cracked
	Attemperator—water pipe flange	Leakage

5.6.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.6.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.7 Piping Inspection Job Plan

5.7.1 Task Objective and Purpose

The objectives of the piping inspection job plan are to ensure that any issues associated with high-energy piping systems are identified prior to the point of incipient failure and to mitigate the risk to plant personnel and to correct issues that might cause undue pipe stress.

5.7.2 Task Timing

Initially, this task is to be completed in conjunction with the unit major inspection, but subsequent inspections/condition assessment frequencies should be performed at periodic intervals as determined by an engineering evaluation. This evaluation should be based on the damage mechanisms found.

A review of industry data suggests that this interval is supported by failure timing associated with the conditions usually found in combined-cycle sites.

The following should be noted:

- This job should be addressed as part of a plantwide piping inspection program.
- This job plan requires extensive computer analysis for pipe stress.
- Using the same contractor from one inspection to the next will help minimize the cost impact associated with performing subsequent inspections and will allow the contractor to trend emergent issues.

5.7.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.7.4 Identification of Necessary Parts, Special Tools, and Equipment

The contract/project manager working with the contractors should determine necessary parts, consumables, special tools and/or equipment that are needed by the personnel prior to the start of this maintenance activity.

5.7.5 Task Content and Work Instructions

This job plan will be executed by an outside contractor with the assistance of plant personnel and consists of the following tasks:

- Preparing isometric diagrams of HP Bypass system and identifying location and type of all hangers, supports, and test locations
- Reviewing recent hanger inspection report or the following:
  - Conducting hot walkdown of each piping system, noting any system deficiencies and interferences and recording the position of all spring can supports relative to their predicted hot position
  - Conducting cold walkdown of each piping system, noting any system deficiencies and interferences and recording the position of all spring can supports relative to their predicted cold position
- Performing an as-found stress analyses for comparison to the as-designed stress analysis
- Conducting a flow-accelerated corrosion (FAC) survey

- Identifying and selecting, based upon collected data and stress analysis, the areas of highest predicted damage locations for prioritize NDE sites
- Modifying isometric diagrams identifying NDE locations, indicating type of NDE tests recommended
- Preparing insulation windows to allow access to piping for NDE evaluations
- Conducting appropriate NDE test methods based upon the location, anticipated fault, and piping material
- Replacing insulation patches
- Conducting multiaxial stress, creep relaxation, and remaining life evaluations
- Developing hanger corrective action recommendations
- Preparing final report, including discussion of the following issues:
  - Findings from cold/hot walkdowns
  - Measurements of each spring can hanger, by number, relative to its design position, in both the hot and cold states
  - Position/condition of all pipe supports and slides
  - Recommended corrective action for any supports or hangers
  - Insulation condition assessment and recommendations
  - Any corrective action or alterations required as a result of the NDE findings
  - Recommendations for follow up inspections and analysis
  - Remaining life assessment
  - Identifying any possible issues with FAC
  - Identifying any issues with piping constructed of ASTM International P91 or T91
  - Identifying any possible pipe stress issues
  - Recommendations for changes in operations or maintenance practices and procedures based upon findings or remaining life

5.7.6 Task Justification and Degradation Progression

A review of industry data suggests that this interval is supported by failure timing associated with the conditions usually found in combined-cycle sites. However, because of the varying degradation mechanisms possible, an engineering evaluation needs to be performed to determine the degradation progression and, therefore, the subsequent inspection frequency.

This job plan represents only the HP bypass system portion of an overall site-specific high-energy piping system job plan, which would have to include all high-energy systems, including boiler feedwater, HRSG systems, HP steam, IP steam, and LP steam as well as bypass systems.

5.7.7 Example Worksheets

There are no worksheets included in this example job plan for this task.

5.7.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.7.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual
- American Society of Mechanical Engineers B31.1

5.8 Hanger Inspection Job Plan

5.8.1 Task Objective and Purpose

The purpose of this job plan is to ensure that any issues associated with high-energy piping systems are identified prior to the point of incipient failure and to mitigate the risk to plant personnel as well as to ensure that critical piping is properly supported through the full range of temperatures to minimize stresses in the piping or the transference of stress onto other equipment.

5.8.2 Task Timing

This task is to be completed in the conjunction with the HGP and major inspection, but subsequent inspection frequencies can be modified based upon the findings and results. A review of industry data suggests that this interval is supported by failure timing associated with the conditions usually found in combined-cycle sites.

Notes: This job should be handled with a plantwide hanger inspection program, and it represents **only** the steam bypass system portion of an overall site-specific hanger inspection job plan, which would have to include **all** high-energy systems, including boiler feedwater, HRSG systems, HP steam, IP steam, and LP steam as well as bypass systems.

5.8.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.8.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.8.5 Task Content and Work Instructions

Task content and work instructions are as follows:

- Conduct hot walkdown of each piping system, noting any system deficiencies and interferences and recording the position of all spring can supports relative to their predicted hot position. Verify that all hangers in their hot position are not bottomed or topped out.
- Conduct cold walkdown of each piping system, noting any system deficiencies and interferences and recording the position of all spring can supports relative to their predicted cold position. Verify that all hangers in their cold position are not bottomed or topped out.
- Develop hanger corrective action recommendations.
- Prepare final report, including the following:
  - Findings from cold/hot walkdowns
  - Measurements of each spring can hanger, by number, relative to its design position, in both the hot and cold states
  - Position/condition of all pipe supports and slides
  - Recommended corrective action for any supports or hangers
  - Recommendations for follow up inspections and analysis
  - Identification of any possible pipe stress issues that need to be considered during the piping inspection

5.8.6 Task Justification and Degradation Progression

All degradations are medium wear-outs.

5.8.7 Example Worksheet

The following is an example worksheet.

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Pipe hangers	Bent
	Pipe hangers	Corrosion
	Pipe hangers	Damaged
	Pipe hangers	Loss of spring tension
	Pipe hangers	Missing hardware
	Pipe hangers	Out of adjustment

5.8.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.8.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.9 Drain Line Leak Check Job Plan

5.9.1 Task Objective and Purpose

The purpose of the drain line leak check job plan is to ensure that any issues associated with high-energy piping systems are identified prior to the point of incipient failure and to mitigate the risk to plant personnel, as well as to correct issues that might cause undue pipe stress.

5.9.2 Task Timing

This task is to be completed in the conjunction with the HGP and the major inspection, but subsequent inspection frequencies can be modified based upon the findings and results. A review of industry data suggests that this interval is supported by failure timing associated with the conditions usually found in combined-cycle sites.

5.9.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.9.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.9.5 Task Content and Work Instructions

The following are task content and work instructions:

- Select the best method to evaluate internal valve leakage, such as one of the following:
  - Thermography
  - Thermocouples
  - Temp sticks
  - Flow detection
  - Acoustics
- Work with operations to determine the system configuration required to accomplish the task, remembering that most methods require system pressure and some also require the system to be at operating temperature.
- Perform an external valve inspection, considering the following:
  - Structural integrity
  - Subcomponent damage
  - Loose, broken, or missing fasteners, especially in high-vibration areas
  - Damaged or loose electrical connections
  - Observation of obvious process fluid leaks
  - Actuator shaft condition
  - Condition of the valve stem
- Complete the test, recording the as-found readings (temperature, flow, and so forth) compared with design.

5.9.6 Task Justification and Degradation Progression

All of the degradation mechanisms addressed lead to failure at intermediate times. They, therefore, require detection on a time scale of no less than just prior to the HGP or major inspection.

5.9.7 Example Worksheets

The following are example worksheets.

Measurement Worksheet		
Expected Measurement	**As-Found Measurement**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)		
Unsatisfactory	**Failure Location**	**Reportable Condition**
	Switch—limit	Improper operation
	Seat	Leaking by
	Lubricant—limit switch compartment	Improper operation
	Switch—torque	Leaking by
	Switch—torque	Improper operation
	Drive train	Improper operation

5.9.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.9.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.10 Calibration Job Plan—Nonredundant, Critical

5.10.1 Task Objective and Purpose

The purpose of this job plan is to ensure that the critical nonredundant instrumentation is accurate and trustworthy and to provide feedback on as-found and as-left calibration history using consistent plant calibration sheets to track and trend system health.

5.10.2 Task Timing

This task is to be performed on an annual basis for the following reasons:

- These instruments protect critical equipment (for example, condenser).
- Inaccuracy can result in unit trips.
- Prudent industry practice for critical nonredundant instrumentation calibration is every 12 months.
- Calibration is performed at this frequency to prevent the many random degradation mechanisms.

5.10.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.10.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.10.5 Task Content and Work Instructions

The following general inspection guidelines should be considered:

- International Society of Automation (ISA) guidelines should be followed in calibrating these instruments.
- Good documentation is needed and should include the following:
  - The make and model of calibrating instrument
  - The calibration date of the calibration instrument
  - The date of the calibration activity
  - The design specification
  - The as-found and as-left measurement
- Only qualified personnel should perform this task.

Task content should include the following activities.

Instrument	PM Task	EPRI Baseline Time Code
Pressure sensor and transmitter	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Temperature switch	Calibration • A visual inspection should be performed to check for tightness of the connections, general cleanliness, overheated components, and cracked terminations and cases. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Pressure switch	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed, or broken tubing; loose tubing connections, loose or missing tubing clamps; or corroded tubing and connectors. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Pressure regulator	Setpoint • A visual inspection for loose, damaged, or missing hardware and parts, or corrosion should be performed. • Set-point verification test should be performed at the device's operational setpoints and compared with historical data. • Adjustments should be made as required.	6Y

Y = years M = months

5.10.6 Task Justification and Degradation Progression

A vulnerability analysis shows the following impact on reliability under critical, high-duty and mild service (CHM) conditions:

Instrument	Calibration PM Reliability Benefit Compared to Baseline
Pressure sensor and transmitter	0.45
Temperature switch	0.80
Pressure switch	0.84
Pressure regulator	0.22

It is believed that for critical equipment with no redundancy that an annual calibration is prudent given the number of random degradation mechanisms. This, of course, can be altered based on the experience of an individual site under specific conditions.

5.10.7 Example Worksheets

The following are example worksheets.

Calibration Worksheet		
Calibration Point	**As-Found**	**As-Left**

Measurement Worksheet		
Measurement	**As-Found**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Temperature switch	Sensing device (other types)	Cannot be calibrated
	Temperature switch	Sensing device (other types)	Out of tolerance

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Temperature switch	Electrical switch	Cannot be calibrated
	Temperature switch	Electrical switch	Out of tolerance
	Temperature switch	Electrical switch	Loose connections
	Temperature switch	Sensing device (temperature bulb and capillary)	Cannot be calibrated
	Temperature switch	Sensing device (temperature bulb and capillary)	Out of tolerance
	Temperature switch	Mechanical linkage	Cannot be calibrated
	Temperature switch	Mechanical linkage	Out of tolerance
	Pressure switch	Sensing line and tube fittings	Broken or cracked line, or loose fitting
	Pressure switch	Sensing line and tube fittings	Fitting and/or tubing leak
	Pressure switch	Sensing line and tube fittings	Leaking valves
	Pressure switch	Sensing device	Cannot be calibrated
	Pressure switch	Sensing device	Out of tolerance
	Pressure switch	Elastomers, gaskets, and O-rings	Cannot be calibrated
	Pressure switch	Elastomers, gaskets, and O-rings	Out of tolerance
	Pressure switch	Electrical switch	Cannot be calibrated
	Pressure switch	Electrical switch	Out of tolerance
	Pressure switch	Mechanical linkage	Cannot be calibrated
	Pressure switch	Mechanical linkage	Out of tolerance
	Pressure sensor and transmitter	Transmitter electronics	Cannot be calibrated
	Pressure sensor and transmitter	Transmitter electronics	Out of tolerance
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Cracked or broken

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Damaged bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Fitting or tubing leak
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Leaking bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Leaking valves
	Pressure sensor and transmitter	Sensor—for example, capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Cannot be calibrated
	Pressure sensor and transmitter	Sensor—for example, capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Out of tolerance
	Pressure sensor and transmitter	Internal wiring and connections	Cannot be calibrated
	Pressure sensor and transmitter	Internal wiring and connections	Out of tolerance
	Pressure sensor and transmitter	Sensor, capacitance cell	Cannot be calibrated
	Pressure sensor and transmitter	Sensor, capacitance cell	Out of tolerance
	Pressure regulator	Regulator	Cannot be calibrated
	Pressure regulator	Regulator	Out of tolerance
	Pressure regulator	Elastomer	Failed
	Pressure regulator	Pneumatic connections	Loose

5.10.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.10.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.11 Calibration Job Plan—Redundant, Critical

5.11.1 Task Objective and Purpose

Calibration ensures that the device is performing within specification and demonstrates the absolute accuracy of the output.

5.11.2 Task Timing

This task is to be performed during the HGP inspection for the following reasons:

- Although these instruments protect critical equipment (for example, condenser), inaccuracy may result in unit trips; however, the presence of online redundancy significantly reduces the risk.
- The age-related effects have wear-out times from three to five years and longer.
- Although the EPRI baseline specifies an 18-month frequency, redundancy provides reasonable protection until the HGP inspection.

5.11.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.11.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.11.5 Task Content and Work Instructions

The following general inspection guidelines should be considered:

- ISA guidelines should be followed in calibrating these instruments.
- Good documentation is needed and should include the following:
  - The make and model of calibrating instrument
  - The calibration date of the calibration instrument
  - The date of the calibration activity
  - The design specification
  - The as-found and as-left measurement
- Only qualified personnel should perform this task.

Task content should include the following activities:

Instrument	PM Task	EPRI Baseline Time Code
Pressure sensor and transmitter	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Temperature switch	Calibration • A visual inspection should be performed to check for tightness of the connections, general cleanliness, overheated components, and cracked terminations and cases. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Pressure switch	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Pressure regulator	Setpoint • A visual inspection for loose, damaged, or missing hardware and parts, or corrosion should be performed. • A set-point verification test at the device's operational setpoints should be performed and compared with historical data. • Adjustments should be made as required.	6Y

Y = years M = months

5.11.6 Task Justification and Degradation Progression

A vulnerability analysis shows the following impact on reliability under CHM conditions.

Instrument	Calibration PM Reliability Benefit Compared to Baseline
Pressure sensor and transmitter	0.45
Temperature switch	0.80
Pressure switch	0.84
Pressure regulator	0.22

Pressure sensor and transmitter. The age related effects have wear-out times from three to five years and longer. Many other random degradation mechanisms, potentially detected by this task, are not addressed very effectively because calibration is not performed frequently enough.

Temperature switch. Calibration at 18 months to three years will provide good protection from the age-related failure mechanisms but is not very effective against other, random mechanisms. Note that here, and in the listing of degradation mechanisms, remaining failure free means remaining within specifications.

Pressure switch. These failure mechanisms are all wear-out situations with an expected failure free period of at least three years (drift and leaks) or much longer.

Pressure regulator. These are wear-out failure mechanisms with an expected failure free period of five years or more, although a particularly high level of vibration could lead to earlier failure.

5.11.7 Example Worksheets

The following are example worksheets.

Calibration Worksheet		
Calibration Point	**As-Found**	**As-Left**

Measurement Worksheet		
Measurement	**As-Found**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Temperature switch	Sensing device (other types)	Cannot be calibrated
	Temperature switch	Sensing device (other types)	Out of tolerance
	Temperature switch	Electrical switch	Cannot be calibrated
	Temperature switch	Electrical switch	Out of tolerance
	Temperature switch	Electrical switch	Loose connections
	Temperature switch	Sensing device (temperature bulb and capillary)	Cannot be calibrated
	Temperature switch	Sensing device (temperature bulb and capillary)	Out of tolerance
	Temperature switch	Mechanical linkage	Cannot be calibrated
	Temperature switch	Mechanical linkage	Out of tolerance
	Pressure switch	Sensing line and tube fittings	Broken or cracked line, or loose fitting
	Pressure switch	Sensing line and tube fittings	Fitting and/or tubing leak
	Pressure switch	Sensing line and tube fittings	Leaking valves
	Pressure switch	Sensing device	Cannot be calibrated
	Pressure switch	Sensing device	Out of tolerance
	Pressure switch	Elastomers, gaskets, and O-rings	Cannot be calibrated
	Pressure switch	Elastomers, gaskets, and O-rings	Out of tolerance
	Pressure switch	Electrical switch	Cannot be calibrated
	Pressure switch	Electrical switch	Out of tolerance
	Pressure Switch	Mechanical linkage	Cannot be calibrated
	Pressure switch	Mechanical linkage	Out of tolerance
	Pressure sensor and transmitter	Transmitter electronics	Cannot be calibrated
	Pressure sensor and transmitter	Transmitter electronics	Out of tolerance
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Cracked or broken

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Damaged bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Fitting or tubing leak
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves ,and isolation valves	Leaking bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Leaking valves
	Pressure sensor and transmitter	Sensor—for example, Capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Cannot be calibrated
	Pressure sensor and transmitter	Sensor—for example, capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Out of tolerance
	Pressure sensor and transmitter	Internal wiring and connections	Cannot be calibrated
	Pressure sensor and transmitter	Internal wiring and connections	Out of tolerance
	Pressure sensor and transmitter	Sensor, capacitance cell	Cannot be calibrated
	Pressure sensor and transmitter	Sensor, capacitance cell	Out of tolerance
	Pressure regulator	Regulator	Cannot be calibrated
	Pressure regulator	Regulator	Out of tolerance
	Pressure regulator	Elastomer	Failed
	Pressure regulator	Pneumatic connections	Loose

5.11.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.11.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

5.12 Calibration Job Plan—Noncritical

5.12.1 Task Objective and Purpose

The purpose of this job plan is to ensure that the noncritical instrumentation is accurate and trustworthy to minimize impact on unit performance and to provide feedback on as-found and as-left calibration history using consistent plant calibration sheets to track and trend system health.

5.12.2 Task Timing

This task is to be performed during the major inspection for the following reasons:

- Although these instruments are noncritical, inaccuracy can result in poor unit performance.
- The age-related effects have wear-out times from three to five years and longer.
- Vulnerability analysis demonstrates the small risk of performing at major inspection frequency.

5.12.3 Pre-Job Brief

The maintenance supervisor should determine whether there is a need to conduct a pre-job brief with craft personnel prior to the start of this maintenance activity.

5.12.4 Identification of Necessary Parts, Special Tools, and Equipment

The maintenance supervisor should determine necessary parts, consumables, and special tools and/or equipment that are needed by the craft personnel prior to the start of this maintenance activity.

5.12.5 Task Content and Work Instructions

The following general inspection guidelines should be considered:

- ISA guidelines should be followed in calibrating these instruments.
- Good documentation is needed and should include the following:
  - The make and model of calibrating instrument
  - The calibration date of the calibration instrument
  - The date of the calibration activity
  - The design specification
  - The as-found and as-left measurements
- Only qualified personnel should perform this task.

Task content should include the following activities:

Instrument	PM Task	EPRI Baseline Time Code
Pressure sensor and transmitter	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors. • The device's zero span should be verified and adjusted, as needed. • The device's linearity and hysteresis should be verified and adjusted, as needed. • It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.	18M
Temperature switch	Calibration • A visual inspection should be performed to check for tightness of the connections, general cleanliness, overheated components, and cracked terminations and cases. • Operational setpoint versus design setpoint should be checked by insertion into a bath or oven.	18M
Pressure switch	Calibration • A visual inspection or walkdown, as far as practical, should be performed of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors. • Operational setpoint versus design setpoint should be checked using a pressure test device.	18M
Limit switches	• A visual inspection for loose, damaged or missing hardware, parts, corrosion, wear, elastomer failure, contact misalignment, and improper adjustment should be performed. • Repair and replace should be performed for any findings. • A valve stroke test should be performed to determine the appropriate setpoints for the limit switches.	6Y

Y = years M = months

5.12.6 Task Justification and Degradation Progression

A vulnerability analysis shows the following impact on reliability under noncritical, high-cycle, and mild stress (NHM) conditions.

Instrument	Calibration PM Reliability Benefit Compared to Baseline
Pressure sensor and transmitter	0.36
Temperature switch	0.01
Pressure switch	0.45
Pressure regulator	1.00

Under NHM conditions, calibration is recommended on a six-year or as required basis for each of these instruments.

Pressure sensor and transmitter. The age-related effects have wear-out times from three to five years and longer. Many other random degradation mechanisms, potentially detected by this task, are not addressed very effectively because calibration is not performed frequently enough.

Temperature switch. These failure mechanisms are all wear-out situations with an expected failure-free period of at least five years (drift) or much longer.

Pressure switch. These failure mechanisms are all wear-out situations with an expected failure-free period of at least three years (drift and leaks) or much longer.

Pressure regulator. These are both wear-out failure mechanisms with an expected failure-free period of five years or more, although a particularly high level of vibration could lead to earlier failure.

5.12.7 Example Worksheets

The following are example worksheets.

Calibration Worksheet		
Calibration Point	**As-Found**	**As-Left**

Measurement Worksheet		
Measurement	**As-Found**	**Notes on Remediation**

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Temperature switch	Sensing device (other types)	Cannot be calibrated
	Temperature switch	Sensing device (other types)	Out of tolerance
	Temperature switch	Electrical switch	Cannot be calibrated
	Temperature switch	Electrical switch	Out of tolerance
	Temperature switch	Electrical switch	Loose connections
	Temperature switch	Sensing device (temperature bulb and capillary)	Cannot be calibrated
	Temperature switch	Sensing device (temperature bulb and capillary)	Out of tolerance
	Temperature switch	Mechanical linkage	Cannot be calibrated
	Temperature switch	Mechanical linkage	Out of tolerance
	Pressure switch	Sensing line and tube fittings	Broken or cracked line, or loose fitting
	Pressure switch	Sensing line and tube fittings	Fitting and/or tubing leak
	Pressure switch	Sensing line and tube fittings	Leaking valves
	Pressure switch	Sensing device	Cannot be calibrated
	Pressure switch	Sensing device	Out of tolerance
	Pressure switch	Elastomers, gaskets, and O-rings	Cannot be calibrated
	Pressure switch	Elastomers, gaskets, and O-rings	Out of tolerance
	Pressure switch	Electrical switch	Cannot be calibrated
	Pressure switch	Electrical switch	Out of tolerance
	Pressure switch	Mechanical linkage	Cannot be calibrated
	Pressure switch	Mechanical linkage	Out of tolerance
	Pressure sensor and transmitter	Transmitter electronics	Cannot be calibrated
	Pressure sensor and transmitter	Transmitter electronics	Out of tolerance
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Cracked or broken

As-Found Worksheet (Check Off Any Unacceptable Conditions)			
Unsatisfactory	**Component Type Name**	**Failure Location**	**Reportable Condition**
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Damaged bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Fitting or tubing leak
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Leaking bellows
	Pressure sensor and transmitter	Sensing lines and associated components—for example, condensate pot, sealed reference legs, bellows, manifold, root valves, and isolation valves	Leaking valves
	Pressure sensor and transmitter	Sensor—for example, capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Cannot be calibrated
	Pressure sensor and transmitter	Sensor—for example, capacitance cell, Bourdon tube, piezoelectric, and strain gauge	Out of tolerance
	Pressure sensor and transmitter	Internal wiring and connections	Cannot be calibrated
	Pressure sensor and transmitter	Internal wiring and connections	Out of tolerance
	Pressure sensor and transmitter	Sensor, capacitance cell	Cannot be calibrated
	Pressure sensor and transmitter	Sensor, capacitance cell	Out of tolerance
	Pressure regulator	Regulator	Cannot be calibrated
	Pressure regulator	Regulator	Out of tolerance
	Pressure regulator	Elastomer	Failed
	Pressure regulator	Pneumatic connections	Loose

5.12.8 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors, such as the following:

- Perform post job review.
- Initiate any corrective action program documents necessary to resolve any problem areas that were identified.

Clean up work area, leaving the work site better than was found.

5.12.9 References

The following are documents to guide the work:

- Industrial safety manual
- Foreign material control procedure
- MDSSs
- Vendor technical manual

6
PERSONNEL SAFETY ISSUES

The purpose of this section is to provide safety guidance for O&M personnel working on or around a typical combustion turbine installed at a combined-cycle facility. Guidance is also provided for CTCC owners that may be beneficial for enhancing their existing sitewide worker-safety program.

6.1 General

Safety is a basic factor that must be considered at all times during the installation, operation, and maintenance of mechanical equipment. Through the use of proper tools, clothing, and procedures, serious injury and property damage can be prevented. Any accident, regardless of the situation, is generally the result of someone's carelessness or neglect. No amount of training or instruction can replace common sense, sound judgment, and acceptable work practices.

6.2 Safety Guidance for Maintenance Personnel

The following section describes safety guidelines for maintenance personnel working on or around the combustion turbine, performing either the preventive or corrective maintenance activities described in this report.

6.2.1 Personal Protection Equipment

6.2.1.1 General

PPE includes clothing and other accessories designed to create a barrier between the user and workplace hazards. It should be used in conjunction with engineering work practices and/or administrative controls to provide maximum employee safety and health in the workplace. All contractors are responsible for providing training and ensuring the proper use of required PPE.

6.2.1.2 Hard Hats

All contract employees, subcontractors, visitors, and delivery personnel should be required to wear hard hats while at the CTCC facility.

6.2.1.3 Hearing Protection

All contract employees, subcontractors, visitors, and delivery personnel should be required to wear appropriate hearing protection to reduce time-weighted average exposure levels on noise within Occupational Safety and Health Administration (OSHA) permissible exposure limits.

6.2.1.4 Eye and Face Protection

All contract employees, subcontractors, visitors, and delivery personnel should wear, at a minimum, safety eyeglasses with side shields. More specialized eye protection should be required by the contractor as the work being performed demands. All eyewear should meet American National Standards Institute (ANSI) Z87.1-1968 standards.

6.2.1.5 Respiratory Protection

Respiratory protection that conforms to OSHA regulations should be used when engineering controls are not adequate to protect maintenance personnel from exposure to air contaminants. No technician may be assigned to wear a negative pressure respirator unless the technician has first been evaluated by a physician to determine his or her physical ability to wear the respirator and fit-tested.

6.2.1.6 Foot Protection

Steel-toe safety shoes are recommended for all workers. Sneakers, sandals, and canvas shoes are not permitted.

6.2.2 Safety Harnesses and Safety Nets

Safety harnesses, lifeline, and lanyards should be used only for employee safeguarding. Lifelines should be secured above the point of operation to an anchorage or structural member capable of supporting a minimum dead weight of 5400 lb. A lanyard should be a minimum of 0.5-in. nylon rope, or equivalent, with a maximum length to provide for a fall of no greater than 6 ft or to keep the employee from contacting the next lower level.

Safety harnesses should be worn when working on any structure, member, or device that is of a height greater than 4 ft above the next lower level, except when working on an approved scaffold.

Safety nets should be provided when work places are more than 25 ft above the ground, water surface, or other surfaces where the use of ladders, scaffolds, catch platforms, temporary floors, safety lines, or safety harnesses is impractical.

6.2.3 Fire Protection and Prevention

Maintenance personnel in the permanent plant facility should be responsible for the following:

- Reporting all fires in accordance with site-specific procedures, no matter how small
- Providing the appropriate manager(s) with the locations and types of all combustible or flammable materials brought onto the CTCC facility

Regarding fire prevention, maintenance personnel working on or around the combustion turbine should consider the following safety guidelines:

- Practice good housekeeping, and do not let combustible scrap or refuse accumulate in the areas for which they are responsible.
- Obey all posted no-smoking notices, and do not smoke in areas where combustible or flammable material is in use.
- Store oily, paint-soaked, or solvent-soaked rags in covered metal containers.
- Cut or weld only when permitted to do so. Welding or cutting should not take place near locations where flammables are present. An approved fire extinguisher should be located in each welding or cutting area. See Section 6.2.10 of this report for more details.
- Store combustible or flammable liquids in proper containers, and use proper bonding and or grounding when transferring fuels.
- Report all fire hazards to the appropriate site-management personnel.
- Do not permit open fires of any kind.
- Ensure that gas cylinders are transported and stored in an upright position. When stored, keep them at least 25 ft from oxygen cylinders.
- Ensure that no material is stored within 3 ft of an electrical panel, outlet, or fire-suppression system.
- Prohibit smoking within 100 ft of any plant enclosure or gas piping and in the maintenance building and substation control building.

6.2.4 Housekeeping and FME

Maintenance personnel should adhere to the following guidelines when working on or around the combustion turbines:

- Keep aisles clear for the safe passage of people and material.
- Clean up slippery substances, such as grease or oil spilled on floors or other work surfaces. Cover with sand or other nonslip material.
- Keep tools in boxes, racks, or trays when not in use.
- Do not leave nails, pieces of wood with protruding nails, and other sharp objects on floors and walkways. Store them where they cannot be stepped on.
- Keep exits clear. Keep fire extinguishers readily accessible and free of obstruction.
- Do not let materials, such as scrap lumber, metal, and debris, that could create a tripping hazard accumulate.
- Dispose of empty bottles, cans, paper, and other containers by depositing them in the receptacles provided.
- Clean the job site daily, and ensure that debris is disposed of on-site, or off-site, in accordance with all Environmental Protection Agency regulations.

6.2.5 Material Handling

The following safety guidelines regarding material handling should be considered by maintenance personnel working on or around the combustion turbine.

- Proper lifting techniques must be used when handling materials. Lift heavy objects as instructed, with leg muscles and not with the back.
- Stored materials must not block exits, aisles, fire-protection equipment, breakers, or passageways.
- Liquid containers should be labeled.
- Material stored inside buildings or structures under construction must not be placed within 6 ft of any hoistway or other inside floor opening or within 10 ft of an interior wall that does not extend above the top of the material stored.
- Pipe, conduit, and bar stock should be stored on racks or stacked and blocked to prevent movement.
- The quantity of materials stored on scaffolds, platforms, or walkways must not exceed what is required for one day's operation.
- Materials must never be thrown or dropped from a distance of more than 20 ft. The drop area must be barricaded to protect personnel from being struck by falling materials. Trash chutes are required for dropping materials from heights above 20 ft.
- Protruding nails must be bent or pulled when stripping forms or uncrating material.
- All ropes, chains, cables, slings, and other hoist equipment must be inspected each time before use.
- A load should never be lifted and left unattended.
- Safety gloves must be worn when handling materials.
- All materials must be properly stacked and secured prior to lifting or moving to prevent sliding, falling, or collapse.

6.2.6 Rigging

In addition to the following guidelines, maintenance personnel should consider the guidance provided in EPRI report 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, and EPRI report 1009706, *Rigger's Handbook*:

- Rigging equipment should be inspected prior to use on each shift. Defective rigging should be removed from service.
- Rigging equipment should not be loaded in excess of recommended working-load limits.
- Wire rope should be removed from service if there is a marked reduction in rope diameter, excessive broken wires, kink damage, or other mechanical damage.
- Wire rope should never be strained over sharp corners.
- Increasing the angle between the legs of a sling increases the load on each leg.

- Hooks should not be painted.
- Only qualified personnel may be assigned to rigging operations.
- Rigging equipment is not permitted for working closer than 10 ft of any power line.
- All rigging devices should have permanently affixed identification stating size, grade, rated capacity, and manufacturer.
- Shop-made grabs, hooks, clamps, or other lifting devices are prohibited.

6.2.7 Hand Tools and Power Tools

Maintenance personnel should adhere to the following guidelines regarding the safe use of hand and power tools when working on or around the combustion turbines:

- All hand and power tools and similar equipment, whether issued by the employer or furnished by the employee, should be maintained in safe condition and properly stored.
- Wrenches should not be used when jaws are sprung to the point that slippage occurs.
- Impact tools, such as drift pins, wedges, and chisels, should be kept free of mushroomed heads.
- Wooden handles should be free of splinters, cracks, and be tight in the tool.
- Electric power-operated tools should either be of the approved double-insulated type or grounded in accordance with OSHA requirements.
- Any power-operated tools designed with guards should have the guard in place when in use.
- The use of electric cords for hoisting or lowering tools is not permitted.
- Only trained employees are allowed to operate power-actuated tools.
- All power-actuated tools should be tested daily, and all defects must be corrected before use.
- All power-actuated tools should be of the low-velocity, cushioned-pistol-grip, piston-type design.
- Power-actuated tools should not be used in areas in which hazardous, ignitable dust gases or liquids are present.
- All maintenance work on power-actuated tools must be performed according to manufacturer specifications and must be done be qualified persons only.
- All defective tools and equipment must be reported immediately in accordance with site procedures and tagged out of service. Temporary and makeshift repairs are prohibited.
- Floor-stand and bench-mounted grinders should be provided with properly adjusted work rests and grinding-wheel guards.
- Abrasive wheels and tools should comply with the ANSI B7.1-1970 safety code for the use, care, and protection of abrasive wheels.
- All employees using abrasive wheels should be protected by eye-protection equipment appropriate to the equipment and task being performed.
- Gas-powered tools should not be used in unventilated areas, and gas should be dispensed only from Underwriters Laboratories-approved only. All gas-powered tools must be turned off before being refueled.

6.2.8 Welding and Cutting and Other Hot Work

No hot work should be permitted at the CTCC in the presence of flammable or combustible materials. Many facility owners use the Factory Mutual hot work permitting system for all heat- or spark-producing operations except in those areas designate by the owner as safe areas. Hot-work permits are issued by the CTCC site manager and must be in accordance with site procedures.

6.2.9 Gas Welding and Cutting Safety

Maintenance personnel performing gas welding and cutting should adhere to the following guidelines when working on or around the combustion turbines:

- Valve-protection caps should be in place when moving, transporting, and storing compressed gas cylinders.
- Cylinders should be secured on a cylinder truck by a chain or other steadying device while in use.
- Cylinders containing oxygen, acetylene, or other fuel gas should not be taken into confined spaces.
- No defective or damaged cylinders should be used.
- Fuel-gas hose and oxygen hose should be easily distinguishable from each other, be without defects, and be fitted with rotary-motion disconnect fittings.
- Torches should be inspected at the beginning of each work shift. Defective torches should not be used.
- All torches should be fitted with approved flashback-control devices.
- Torches should only be lighted by friction lighters or other approved devices, not by matches or from hot work.
- Employees are required to wear the proper PPE, such as coveralls, safety goggles, face shield, welding hood, or welding jacket, as demanded by the type of work completed.

6.2.10 Arc Welding and Cutting

Maintenance personnel performing arc welding and cutting should adhere to the following guidelines when working on or around the combustion turbines:

- Any faulty or defective machines, cables, or electrode holders must be removed from service and reported to the supervisor.
- All welding, cutting cables, and connectors should be of a completely insulated and flexible type capable of handling the maximum current requirements of the work in progress.
- Only cable that is free from repair or splices for a minimum of 10 ft from the end to which the electrode is connected should be used; insulated connectors or splices whose insulating quality is equal to that of the cable are permitted.
- Maintenance personnel are required to wear the proper PPE, such as coveralls, safety goggles, face shield, welding hood, or welding jacket, as demanded by the type of work completed.

6.2.11 Electrical Safety

Maintenance personnel should adhere to the following electrical safety guidelines when working on or around the combustion turbines:

- All construction electrical installations and temporary wiring should be made in accordance with the National Electric Code ANSI/National Fire Protection Association latest edition and all federal, state, and local codes.
- Temporary lights should be equipped with guards. Broken or burned-out bulbs should be replaced.
- Temporary electric cords must be covered or elevated. They must be kept clear of walkways where they could be exposed to damage or create tripping hazards.
- Extension cords used with portable electric tools and appliances must be heavy-duty (no less than 12-gauge conductors) of the three-wire grounding type and must conform to OSHA standards. No flat electrical cords should be allowed on-site.
- Voltages must be clearly labeled on all electrical equipment and circuits. Circuits must also be clearly marked for the areas of service they provide.
- Prior to performing any work, electricians must lockout and tagout the equipment or machinery. The only exception is when power is required for megging circuits.
- All temporary electrical circuits should be periodically inspected and properly maintained.

Note that many CTCC facility owners are subject to the Power Generation and Transmission OSHA Standard 29CFR1910.269. Contractors working on CTCC premises may also be subject to portions of this regulation.

6.2.12 Lockout and Tagging of Circuits

Maintenance personnel should adhere to the following electrical safety guidelines when lockout and tagging of circuits is required prior to working on or around the combustion turbines:

- Controls that are to be deactivated during the course of work on equipment or circuits should be tagged/locked in accordance with site-specific tagging procedure.
- Equipment or circuits deenergized should be rendered inoperative and should have tags and/or locks attached at all points where such equipment or circuits can be energized.

6.2.13 Scaffolding

In addition to the guidelines noted below, maintenance personnel should consider the guidelines provided in EPRI report 1007914, Lifting*, Rigging, and Small Hoist Usage Program Guide*, and EPRI report 1009706, *Rigger's Handbook*.

- All scaffolds should be erected in accordance with appropriate OSHA standards for the type and application used.
- The footing or anchorage for scaffolds should be sound, rigid, and capable of carrying the maximum intended load without settling or displacement.

- Guardrails, midrails, and toe boards must be installed on all open sides of scaffolds that are 10 ft or more in height. Guardrails must be 2 by 4 in. or equivalent, supported at intervals of not more than 8 ft. Toe boards should be a minimum height of 4 in. Where persons are required to work, or to pass under them, the scaffolds should be provided with a screen between the toe board and rail, extending along the entire opening, consisting of #18-gauge U.S. standard wire 0.5-in. mesh or equivalent.
- Overhead protection should be provided if maintenance personnel working on scaffolds are exposed to overhead hazards.
- Scaffolds and their components should be capable of supporting, without fail, at least four times the maximum load intended.
- Any scaffolding, including all accessories, damaged or weakened from any cause should be immediately repaired or replaced.
- All planking should be scaffold-grade, as recognized by approved grading rules for the species of wood used, and a full 2 by 10 in. in thickness.
- An access ladder, or equivalent safe access, should be provided.
- Scaffold planks should extend at least 6 in. but no more than 12 in. over the end of the support.
- All scaffolds must be two planks wide; no employee may work on a single plank.
- Scaffold planks must be visually inspected before use. Damaged planks must be removed from service.
- Scaffolds must be tied to the building or structure at intervals that do not exceed 30 ft horizontally and 26 ft vertically.
- Lean-to scaffolds and makeshift platforms are prohibited.
- All scaffolds over 10 ft high are required to have load footprints and limits that can be obtained from the scaffold manufacturer.
- When erecting and dismantling scaffolds, OSHA's Project Six-Foot Fall Protection Requirements must be followed.
- Ladders must be used to climb scaffolds at all times. Workers should never climb a scaffold's cross bracing. Both hands should be free of tools/materials when ascending or descending a scaffold. Employees should not propel themselves while working on scaffolds.

6.2.14 Floor and Wall Openings

Maintenance personnel should adhere to the following safety guidelines regarding floor and wall openings when working on or around the combustion turbines:

- Floor openings should be guarded by a standard rail and toe board or cover. In general, the railing should be provided on all exposed sides, except at entrances to stairways.
- Wall openings, from which there is a drop of more than 4 ft and the bottom of the opening is less than 3 ft above the working surface, should have a standard guardrail.

- Open-sided floor or platforms 6 ft or more above the adjacent floors or ground level and runways 4 ft or more above the ground floor level should be provided with standard handrails and toe boards.
- Stairways having four or more risers should be equipped with standard stair railings on both sides.
- Guardrails and/or covers are not to be removed until other means of fall protection are in place. Employees installing or removing guarding or covers should be protected by alternative fall protection.
- Employees are prohibited in any area that could expose them to a fall unless proper fall-protection procedures are in place.
- Stairways should be free of hazardous projections, debris, and other loose materials.

6.2.15 Cranes, Hoist, Elevators, and Conveyors

In addition to the guidelines noted below, maintenance personnel should consider the guidance provided in EPRI report 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, and EPRI report1009706, *Rigger's Handbook*.

Maintenance personnel should adhere to the following safety guidelines regarding the operation of cranes when working on or around the combustion turbines:

- All cranes must be operated and maintained in accordance with established standards, specifications, and limitations.
- Only trained, qualified employees are permitted to operate any crane or rigging equipment. Training includes an in-depth review of the operating characteristics and limitations of the equipment.
- A fire extinguisher is to be kept in the crane's cab at all times.
- Shop-made grabs, hooks, clamps, and other lifting devices are prohibited.
- A licensed engineer must inspect all lifting beams and spreader bars to make sure that they are the proper size for the capacity.
- Slings should not be shortened by using knots, bolts, or other makeshift designs.
- Wire rope slings should be padded to protect against damage from sharp corners.
- Hard hats and proper PPE should be worn while operating or working close to a crane.
- Rated load capacities and recommended operating speeds, special hazard warnings, or instruments should be conspicuously posted.
- Cranes should be inspected prior to each use shift. Records of inspections should be kept as required by law.
- Hand signals to crane operators should be by ANSI standards for the type of crane in use.
- Accessible areas within the swing radius must be barricaded.
- Do not ride hook or load.

- Safety latches are required on all crane hooks.
- Do not operate a crane or bring its loads within 10 ft of electrical distribution lines.
- The use of a crane to hoist employees onto a personnel platform is prohibited, except when the erection, use, and dismantling or conventional means of reaching the work site would be more hazardous or is not possible because of structural design or work-site conditions. The following precautions are required when using cranes to hoist personnel:
  - Hoisting of the personnel platform should be performed in a slow, controlled manner with no sudden movements of the crane platform.
  - Load lines should be capable of supporting without failure at least 10 times the maximum intended load.
  - A trial lift with the unoccupied personnel platform loaded at least to the anticipated lift weight of personnel and material should be made from the ground level with full crane operational tests. The trial lift should be repeated prior to hoisting personnel any time the crane is moved and set up in a new location or returned to a previously used location. In every case, the trial lift must be conducted at the beginning of every shift.

Employees should keep all body parts inside the platform during raising, lowering, or positioning. Employees being hoisted should remain in continuous sight of and in direct communication with the crane operator. Employees occupying the personnel platform should use a body belt/harness system with the lanyard attached to the lower load block, overhaul ball, or structural member within the platform. Finally, hoisting of employees while the crane is traveling is prohibited.

6.2.16 Ladders

Maintenance personnel should adhere to the following safety guidelines regarding ladders when working on or around the combustion turbines:

- All ladders should be inspected for defects prior to use. Any defective ladder should be removed from service and reported to the supervisor for repair or replacement.
- Portable ladders should be placed on a substantial base at a 4:1 pitch, have clear access at top and bottom, extend at least 36 in. above the landing, and be secured against movement when in use.
- Always face the ladder and use both hands when climbing up or down. If you have to raise or lower tools, use a line.
- Do not use metal ladders for electrical work or where they may contact electrical conductors.
- Do not use stepladders as strait ladders.
- Avoid overreaching when working from ladders.
- Manufactured ladders must comply with OSHA, ANSI, manufacturer, and job specifications.
- The 6-ft fall-protection procedure applies when working from a ladder. All ladders should be secured with a rope or other substantial device.

- Ladders should be maintained free of lines, ropes, hoses, wires, cables, oil, grease, and debris. No objects should be left on ladders.
- Never stand or sit on the top rung of a stepladder.
- Never climb or work from the back of a ladder.
- Never work with another person on the same ladder.

6.2.17 Compressed-Gas Cylinders

Maintenance personnel should adhere to the following safety guidelines regarding the use of compressed-gas cylinders when working on or around the combustion turbines:

- The protective caps of gas cylinders must be kept on all cylinders when not in use.
- All cylinders must be properly secured to prevent tipping.
- All gas cylinders, whether in use or in storage, must be secured in an upright position by some substantial means, such as chains or ropes.
- Oxygen and fuel-gas cylinders in storage must be separated from each other by a separation of 20 ft or by a 5-ft-high barrier wall that has a minimum 1-hour fire rating.
- Compressed-gas cylinders should not be taken into confined spaces.

6.2.18 Permit-Required Confined Spaces

Only contract employees who have been trained in compliance with OSHA confined-space standard 29CFR1910.146 may enter permit-required confined spaces. Only trained attendants should be used to monitor permit-required confined spaces while authorized entrants are inside.

No person should enter a confined space until all preparations for entry have been completed, the permit has been approved, all conditions of site-specific entry procedures have been met, and the entry is authorized. Typically, no person should enter a confined space unless an attendant is on duty. The attendant must maintain visual and/or voice contact at all times with personnel in the confined space.

Personnel using monitoring equipment should be trained in its use and calibration. All electrical-shock hazards should be protected by use of low-voltage systems and/or ground-fault protectors. Explosion-proof electrical equipment is required for entry into spaces where potential fire- and/or explosion-risk exists.

No one should enter confined spaces without a permit. The CTCC facility owner should identify all confined spaces by signs, placards, or other appropriate means. Individuals authorized to issue a confined-space permit should be designated and identified to site-maintenance personnel. The individual issuing the permit should personally inspect, examine, and evaluate the confined space before entry and should ensure that all hazards have been identified before allowing entry. They should also discuss the following with all personnel:

- Emergency procedures
- What the emergency-standby person must do
- The fact that all permits are null and void in case of an emergency

- How to request a recheck of the permit
- What the permit does and does not authorize
- The duration of the permit: one shift (or the duration of the entry, whichever is shorter)

The following work rules are unconditionally and automatically required for confined-space entry procedures:

- Ventilation should be of an adequate volume to safely maintain the airflow within the confined space.
- It is the responsibility of maintenance personnel to immediately report unsafe conditions.
- A flashlight should be carried by each person entering a confined space.
- Lighting used must be explosion-proof, a 12-volt system, or a flashlight.
- Welding, cutting, brazing, and purging operations require specific requirements. Consult with the individual issuing the permit and site-specific requirements.
- Chemicals used or transported inside the confined space require specific requirements. Consult with the individual issuing the permit and site-specific requirements.

The following locations and structures are typically designated by CTCC facility owners as permit-required confined spaces at the power plant:

- Exhaust-bearing tunnel
- Inlet-air duct between the evaporative cooler and inlet silencers
- Inlet-air duct between the inlet silencers and compressor
- Electrical vault
- Stack
- Electrohydraulic controls skid reservoir
- Gas-filter separator vessel
- Lube-oil reservoir
- Turbine-building ventilation fan and exhaust-hood enclosures
- Evaporative -cooler water-supply valve pit

6.3 Worker Safety and Health Guidelines for CTCC Facility Owners

6.3.1 General Safety Requirements for CTCC Facility Owners

Owners should provide a work place free of hazardous, unsanitary, and dangerous conditions for all employees. It should be the responsibility of the owner to initiate and maintain such accident-prevention programs, hazardous-material programs, and other programs as may be necessary to comply with federal, state, and local regulations while performing work at the CTCC facility.

It should be the responsibility of the owner to ensure that all subcontractors and contractor employees abide by the safety rules and regulations while at the CTCC facility. Technicians should stay in only their assigned work areas.

The owner should ensure that any gas turbine technicians do not bring any explosives, firearms, alcoholic beverages, or drugs on the CTCC property. Gas turbine technicians should wear appropriate clothing at all times. Short pants and shirtless attire are prohibited. Sturdy shoes with steel toes must be worn at all times. Safety glasses and hard hats must be worn at all times.

Owners should ensure that the following general work practices are followed during maintenance activities:

- Owners should not permit maintenance personnel to work in such proximity to any part of an electrical-power circuit that the employee could contact the electrical-power circuit in the course of work unless the employee is protected against electrical shock by deenergizing the circuit and grounding or guarding it effectively by insulation or other means.
- In work areas where the exact location of underground electrical cables is unknown, employees using jackhammers, bars, or other hand tools, which may contact a line, should be provided with insulated protective gloves. All insulated protective gloves must be tested prior to use, in accordance with the National Electric Code.
- Before work is begun, the owner should ascertain by inquiry, direct observation, or instruments, whether any part of an energized electrical power circuit, exposed or concealed, is located so that the performance of the work may bring any person, tool, or machine into physical contact with the circuit. The owner should post and maintain proper warning signs where such a circuit exists. The owner should advise employees of the location of such lines, the hazards involved, and the protective measures to be taken.

6.3.2 Occupational Safety and Health

Construction, operation, and maintenance activities associated on or around the CTCC facility may expose workers to physical and chemical hazards. Potential worker exposure to these hazards will be minimized through adherence to appropriate engineering-design criteria, implementation of appropriate administrative procedures, use of PPE, and compliance with applicable health and safety requirements.

Formal health and safety procedures and programs should be established and implemented for construction and operations to control the various hazards and provide for a safe workplace. The site-specific injury- and illness-prevention programs and safety-training programs, which are intended to protect worker health and safety during construction and operation of the proposed project, are described in the following sections.

6.3.3 Injury- and Illness-Prevention Program

Prior to beginning construction activities, the CTCC facility owner should develop a site-specific construction injury- and illness-prevention program. When the construction of the proposed project is complete, a site-specific injury- and illness-prevention program for O&M activities will be implemented.

6.3.3.1 Construction Injury- and Illness-Prevention Programs

Consistent with applicable state and OSHA policy on multiemployer work sites, each CTCC-facility owner should be responsible for the health and safety of its own employees. Periodic health and safety audits should be conducted by facility personnel to verify contractor and subcontractor compliance with contractual health and safety obligations.

6.3.3.2 O&M Injury- and Illness-Prevention Plans

Upon completion of construction, startup of the proposed project, and implementation of routine operations, the construction injury- and illness-prevention program should transition into an operations-oriented program that reflects the hazards and controls necessary during routine O&M of the CTCC facility.

Injury- and Illness-Prevention Plan

The primary mitigation measures for worker hazards during normal plant operation and maintenance are contained in the injury- and illness-prevention program, as required by state and OSHA requirements, and site-specific procedures. The written injury- and illness-prevention program should designate an individual who is responsible for implementing the program. It also should describe safety training and procedures for tracking safety training. An injury- and illness-prevention program should contain the following information and procedures:

- Identity of the person(s) with authority and responsibility for implementing the program
- A system for ensuring that employees comply with safe and healthy work practices
- A system for facilitating employer–employee communications regarding safety
- Procedures for identifying and evaluating workplace hazards, including inspections to identify hazards and unsafe conditions
- Methods for correcting unhealthy/unsafe conditions in a timely manner
- An employee training program that includes the following:
  - Introducing the program
  - Training of new, transferred, or promoted employees
  - Training on new processes and equipment
  - Supervisors training
  - Evaluation of contractor training
- Methods of documenting inspections and training and for maintaining appropriate records

Emergency Action Plan

In addition to incorporating various safety and environmental features and design measures to minimize emergencies and their effects on public and worker safety, the CTCC facility should have a site-specific emergency action plan. The emergency action plan should address potential emergencies—including chemical releases, fires, bomb threats, pressure-vessel ruptures, aqueous ammonia releases, and other catastrophic events. It should describe evacuation routes, alarm systems, points of contact, assembly areas, responsibilities, and other actions to be taken in the event of an emergency. The plan includes a layout map, a fire extinguisher list, and a description of arrangements with local emergency-response agencies for responding to emergencies.

Hazardous-Materials Management Program

The storage and handling of chemicals should follow applicable state and OSHA requirements to minimize risk to workers and the surrounding community. Chemicals should be identified and stored in appropriate chemical-storage facilities. Bulk chemicals should be stored in aboveground storage tanks; other chemicals should be stored in their delivery containers. Chemical-storage and chemical-feed areas should be surrounded by temporary or permanent containment or curbing to contain leaks and spills. The containment areas should be sized to hold an appropriate volume (considering the potential for the local hazard contingencies).

Safety showers and emergency eyewash stations or bottles should be provided at all chemical treatment and storage areas, laboratories, and battery rooms in accordance with state and OSHA requirements (within 50 ft, or 10 seconds of travel time). Standard PPE for use during chemical-handling activities should be provided.

Self-contained breathing apparatus sets should be available in the control room. First-aid kits should be located in work areas around the plant. Fire blankets and evacuation stretchers should be located in the control building. Standard PPE should be readily available for use during minor chemical-spill containment and clean-up activities by plant personnel. Adequate supplies of absorbent material should also be available on-site for minor-spill cleanup. A hazardous material emergency response team, trained in managing the accidental release of the chemicals used and stored at the plant, should be available through contract.

Emergency contact numbers should be available to summon assistance from these contractors and for notification of local agencies. These procedures should be detailed in the emergency action plan.

PPE Program

PPE requirements for work at the CTCC facility should be identified during the job-hazard analyses process. The PPE requirements should be developed and incorporated into the site-specific injury- and illness-prevention program. The PPE program should include the following:

- Hazard analysis and prescription of PPE
- Personal protective devices
- Head protection
- Eye and face protection

- Body protection
- Hand protection
- Foot protection
- Safety belts and life lines
- Protection for electric shock
- Respiratory protective equipment

O&M Written Safety Program

Additional written safety programs will be developed and implemented as necessary to address hazards that are identified with operation and maintenance of the CTCC facility. These programs will be made components of the overall O&M injury- and illness-prevention program for the facility. These programs include the following:

- Blood-borne pathogens control program
- Hazard-communication program
- Hearing conservation program
- Hazardous energy control program
- Confined-space entry program
- Safe work practices program
- Ergonomics program
- General facility safety procedures, including the following:
  - Compressed-gas safety procedures
  - Heavy-equipment safety procedures
  - Hand tools and equipment guarding procedures
  - Hoist and rigging safety procedures
  - Slips, trips, and fall-prevention procedures
  - Hot work safety procedures
- Fall-protection program
- Contractor-safety program
- Risk-management plan

6.3.4 Safety-Training Programs

To ensure that employees recognize and understand how to protect themselves from hazards at the CTCC facility, comprehensive training programs for construction and operations personnel should be implemented.

O&M personnel should be given instructions regarding their responsibility for the safe conduct of their work. These instructions should be given at the time the employee is first hired and as an ongoing training program of hazard recognition and avoidance.

Employees will also be instructed in safety procedures pertinent to their employment tasks. Safe working conditions, work practices, and protective-equipment requirements will be communicated in the following manner:

- A new, promoted, or transferred employee will receive safety-training orientation.
- Safety meetings will be held with employees.
- Toolbox/tailgate safety meetings will be conducted periodically for each crew. General safety topics and specific hazards that may be encountered will be discussed. Comments and suggestions from all employees will be encouraged.
- A periodic staff-safety meeting will be held for supervisors.
- Hazard-communication training, including state-required hazardous-material warnings and discharge prohibitions, will be conducted as necessary when new hazardous materials are introduced to the workplace.
- MSDSs will be available as required for all appropriate chemicals.
- A bulletin board with required postings and other information will be maintained at the plant site.
- Warning signs (for example, Hazardous-Waste Storage Area, Confined Space Area) will be posted in hazardous areas that comply with applicable regulations (bilingual, readable font size).

Safety training should be provided to each maintenance technician in the following manner:

- A list of safe work rules for the CTCC facility should be explained to each new employee.
- A copy of the applicable safe work practices should be given to each new employee. The provisions should be incorporated into training for the qualifications programs so that employees may fully understand what the protective provisions mean.
- The hazard communication program and requirements for personal protection for the types of hazards that may be encountered at the CTCC facility site should be explained and documented.
- Unusual hazards that are found on-site should be explained in detail to each new employee, including any specific requirements for personal protection.
- Safety requirements for the new employee's specific job assignment will be explained by the foreperson upon initial assignment and upon any reassignment.

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A
LISTING OF KEY POINTS

A.1 Key O&M Cost Points

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Page Number	Key O&M Cost Point
3-1	The service life of the bypass system can be dramatically shortened by installation and control problems that cause severe thermal stresses and consequent thermal fatigue cracks.
B-11	When contemplating the merits of deferring a PM task, the licensee should also consider the cost if the component associated with this PM fails prior to the PM activity being performed. The cost consequence of deferral of this PM should be acceptable.
C-4	Direct-force testing is typically performed at the valve and requires several technicians and several hours. The analysis of the data typically requires several hours of engineering time.
C-7	Electrical force testing is typically performed at the motor control center and requires a single technician and less than an hour. The analysis of the data typically requires a few hours of engineering time.
C-15	Because the diagnostic test data can be trended, it is possible to use them, with some qualification, to defer overhauls and replacements when the condition of the equipment appears to be good and stable over time or to decide whether an overhaul is appropriate.

A.2 Key Technical Points

Key Technical Point

Targets information that will lead to improved equipment reliability.

Page Number	Key Technical Point
2-12	The pressure developed at the valve wide open condition is referred to as *natural pressure.*
2-12	When two HRSGs are operating with the steam turbine, flow measurements from both are combined to calculate the bypass valve setpoint.
5-5	Only replacement parts that are physically identical to the original should be installed unless a replacement item equivalency evaluation has been performed by the engineering organization and an alternative item has been approved for use.
B-4	The key to optimizing maintenance tasks and frequencies is to do more highly effective tasks, not just more tasks.
B-7	If you experience failures in green and yellow and you are performing the high-effectiveness tasks, you may not be performing them effectively. You should be able to improve PM defenses against such failures by modifying your PM program to be closer to the recommendations.
B-7	If you experience failures in green and yellow and you are currently performing the high-effectiveness tasks, you should suspect that task scope or implementation might be improved.
C-6	Electrical force testing is primarily useful in monitoring changes in MOV performance and health but can be used to set torque switches because of the relationship made between the electrical characteristics of the MOV and motor torque.
C-9	The main rationale for overhauling the actuator on a regular schedule is to replace the soft goods because they degrade with age and exposure to the service environment.
C-15	Travel and seat load information on the seating area can raise the likelihood of internal leakage, which can often be confirmed by acoustic or thermographic techniques.
C-19	Operator walkdowns of attemperators can also include visual inspections detecting bowed pipes, pipe hanger problems, or pipe leaks.

A.3 Key Human Performance Points

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Page Number	Key Human Performance Point
5-1	One key attribute to consistently developing a quality job plan is to perform a critical task analysis.
5-2	When planning a job plan or maintenance work package, the planner should search for relevant maintenance experience, and if such information is identified that is relative to the work being performed, it should be placed in the work package.
5-4	The work planner should typically prepare a pre-job brief traveler for any maintenance activities posing risk to unit operation/generation.
5-5	The work planner should review bill of material, drawings, component maintenance philosophy, and maintenance history to identify parts and consumables that are likely to be needed for the job.
5-7	The job plan should contain a means for the craft labor to provide feedback to the maintenance organization regarding the quality and clarity of the work package.
B-7	If you experience failure in green and yellow and are currently performing high-effectiveness tasks, with the correct task scope, that are implemented properly, you should examine your training program, personnel qualifications, and quality of procedures.
C-4, C-5, C-6	Only a small sample of grease should be carefully taken. Failing that, a simple visual examination of the grease should be possible.
C-4, C-5, C-6	Packing should not be torqued beyond the original values specified in the site's packing program or by the manufacturer, because this could alter the valve testing results.

A.4 Key Supervisory Observation Point

Key Supervisory Observation Point

Identifies tasks or series of tasks that can or should be observed by maintenance first line supervisors to improve the performance of the maintenance staff and improve the reliability of the component.

Page Number	Key Supervisory Observation Point
2-11	Manual control can be turned on independently for each valve from the DCS engineering station, when no valve trip signal exists.

B EFFECTIVE USE OF THE EPRI PMBD VULNERABILITY TOOL

The purpose of this appendix is to provide insight into the use of the vulnerability tool integral to the EPRI PMBD, which should be a key consideration when adjusting any given PM task scope or frequency while transitioning to a CBM strategy.

B.1 Overview of the Vulnerability Tool

The PMBD Template task information is designed to provide the licensee with more detailed information pertaining to an individual task. It displays the task objectives, the time necessary to perform the task, the amount of time the component will be out of service while the task is performed, the task contents, the principal failure locations and causes the task will cover, the progression of degradation in time, and the support for the task and its relationship to other tasks.

One of the features of the PMBD is the vulnerability tool. The vulnerability tab can be used to perform calculations for a component template's baseline tasks versus customized tasks to determine the effect that the omission of tasks or frequency changes will have on the component's reliability. The tool also identifies any new failure modes that are exposed when a task is omitted or an interval is extended.

B.2 Using Vulnerability to Manage Degradation

In a general sense, the PMBD vulnerability tool allows a licensee to accomplish the following:

- Find strengths and weaknesses in the recommended PM program
- Provide information on what tasks are protecting what piece parts and from what mechanisms
- Provide the means to determine how much is enough

Figure B-1 illustrates the relationship between equipment reliability, PM costs, and corrective maintenance costs.

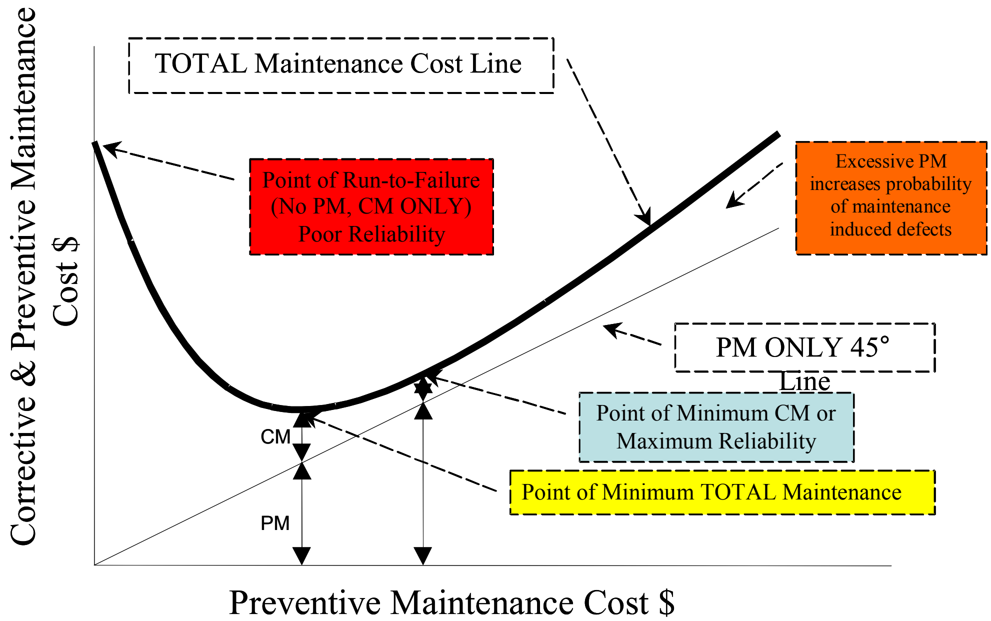

Figure B-1
Relationship between equipment reliability and maintenance costs

The point designated by the blue-gray box represents the point where corrective maintenance costs are minimized and equipment reliability is maximized. The pointed designated by the yellow box represents the point where total maintenance costs are minimized but equipment reliability is not optimized. The vulnerability tool can assist each licensee in optimizing a given component's maintenance and equipment reliability. The tool can be used to perform one or more of the following tasks:

- Get an overview of recommended PMs.
- Understand the technical basis for a given PM.
- Address equipment performance issues, such as the following:
  - Failures or poor condition experienced at the licensee's facility
  - Failures or poor performance experienced at other plants
- Conduct a PM assessment by comparing your plant to the PM Basis.
- Adjust the PM frequency or task scope, which may be beneficial when transitioning toward a CBM strategy.

B.2.1 Evaluating PM Recommendations for Effectiveness

As noted previously, one of the features of the vulnerability tool is to evaluate the effectiveness of recommended PM tasks, which enables the licensee to conduct an equipment-focused PM assessment. The maintenance organization is constantly challenged with trying to ascertain whether what it is doing is enough, or is too much. The objective of a tiered maintenance approach is to apply maintenance resources to a level commensurate with the component's safety classification, economic significance, and other factors. Industry experience suggests that licensees have defined the various maintenance tiers as follows:

- Minimum maintenance
- Moderate maintenance
- Trendable maintenance
- Extensive maintenance

Intrinsic task effectiveness (high [H], medium [M], or low [L]) is basic data stored in the component table fields named with the PM task ID numbers. The intrinsic effectiveness describes how good the task is at detecting the specific degradation mechanism is the task is performed well and on the recommended interval. These values are never changed or overwritten by the code.

Intrinsic task effectiveness, E, connects each PM task to the failure mechanisms it protects against. If E is the probability that a degraded condition will be discovered before it becomes a failure, the probability that a degraded condition will become a failure before it is detected equals (1 - E), where $0<E<1$, assuming that the task is done at the right time.

The overall task effectiveness, E', is the effectiveness of the task on the interval it is performed in the specific PM Program. Overall task effectiveness is calculated each time the vulnerability tool is run. The overall task effectiveness values additionally take account for the task intervals in relation to the timing of the degradation and are recorded in the component table fields named with the normal names of the PM tasks. Overall task effectiveness is reduced more and more as the task interval exceeds the expected time to the first failure. So, H may become M (shown as *hM*), or L (*hL*), or zero. M may become L (*mL*) or zero. The lowercase letter indicates the intrinsic effectiveness of the task if it were being performed on the recommended interval—that is, an hM indicates a task that could be highly effective, h, if it were performed on the recommended interval, but it is only medium effective, M, on the interval it is being performed on in the current calculation.

This reduction in task effectiveness is illustrated in Figure B-2.

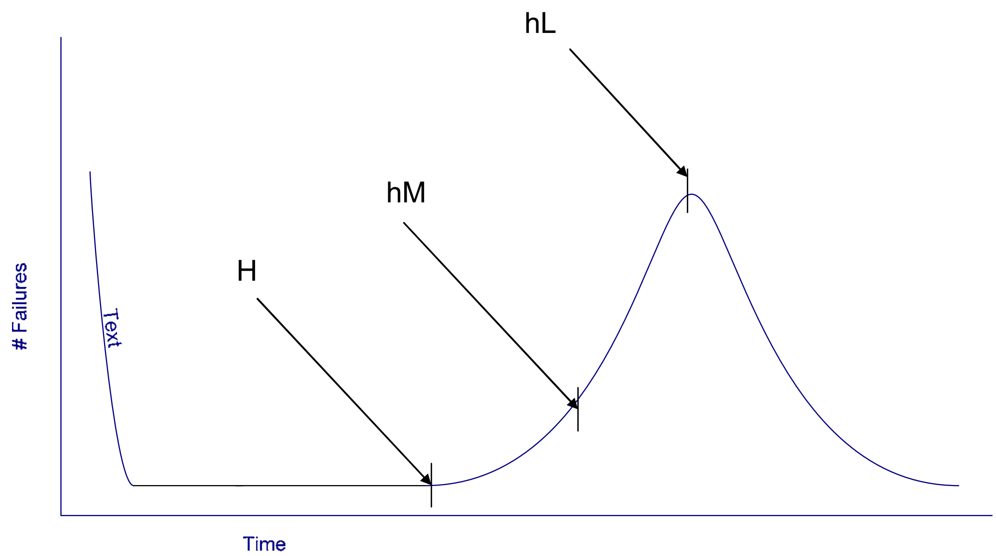

Figure B-2
Reduction of overall effectiveness

For one failure mechanism and one PM task, E is modified by changing factors in the algorithm (I, FTime, W, R, and so forth to become E'. And the resulting failure rate = degraded rate x (1-E'). If multiple tasks are performed, they are dependent tasks rather than independent tasks, and, for a scenario with one failure mechanism and several PM tasks, the factors (1-E') for each task are adjusted to reflect this dependence. In this more complex but common scenario, the failure rate is calculated as follows:

$$\text{Failure rate} = \text{degraded rate} \times (1-E1') \times (1-E2')^{1/2} \times (1-E3')^{1/3} \ldots \times (1-En')^{1/n}$$

For example, if E' is 80% for each of two tasks, the probability of a failure occurring before it is detected is

$$(1-E1') \times (1-E2')^{1/2} = 0.2 \times (0.2)^{1/2}, \text{ which equates to } 0.2 \times 0.45 = 0.09$$

This is greater than what would be calculated if these were independent events, which would render 0.2 x 0.2 = 0.04. Similarly, for three tasks the result is 0.05, not 0.008.

Key Technical Point

The key to optimizing maintenance tasks and frequencies is to do more highly effective tasks, not just more tasks.

B.2.2 Evaluating Failures for Causes and Corrective Actions

The vulnerability tool helps a licensee analyze how well the PM program protects a component against failures. The color codes provide a quick look at the overall effectiveness and a qualitative level of protection for each failure mechanism. They are as follows:

- **Red** indicates that the PM programs provide **poor** protection or none at all.
- **Orange** indicates that the PM programs provide **moderate** protection (80% effectiveness).
- **Yellow** indicates that the PM programs provide **good** protection (at least one task providing 97% effectiveness).
- **Green** indicates that the PM programs provide **excellent** protection (two or more tasks providing 97% effectiveness).

When evaluating the effectiveness of a given PM program, the licensee should use the vulnerability tool to provide an indication of the percentages of total failure modes that are as follows:

- Red
- Red and common
- Red and random
- Red and wear-out

The time codes provided in the PMBD should be interpreted as follows:

- **Random (R)**. Failure can occur at any time.
- **Wear-out (W)**. Has a failure-free interval before failures are expected.

  (Both are conditional on the degradation mechanism being triggered—that is, on the existence of the degradation influence.)
- **UW**. Has a failure-free interval before failures are expected, but wear-out begins at the moment the component is placed in service.

Those combinations of color code and time code should then be compared with the percentage of failure modes that are other colors. And one could make the following conclusions given the existing conditions:

- Greater than 15% Red failure modes means that even a good program gives limited protection.
- Greater than 5% Red and wear-out failure modes are of particular concern. They should be identified, and they probably mean trouble. Note that any Red and wear-out failure modes should cause the licensee to consider shorter scheduled task intervals, or adding tasks.
- A large percentage of Red and random failure modes should cause the licensee to consider shorter condition-monitoring intervals or adding other condition monitoring tasks.

The vulnerability tool can be used to customize a PM program by applying various combinations/choices of tasks and intervals. These customized scenarios should prompt the following analysis and questions regarding the effectiveness of the PM component's vulnerability to failure:

- Are there more Reds and Oranges than the default?
- What color is the failure experience? (Remember that even the default does not protect everything.)
- Are there Red and wear-out failure mode combinations? Try to protect them.
- If there are many Red and random failure mode combinations, the licensee should question whether predictive PM is sufficient.
- If the hL trending pattern is prevalent, the licensee should consider checking the intervals.
- Failure modes in Yellow or Green rows suggest that the licensee should check task content, implementation, skills, and procedures.

B.2.3 Addressing Failures in the Green and Yellow

As noted in the preceding section, the EPRI PMBD is set up and color-coded to provide the following levels of protection against failure modes as follows:

- **Red** indicates that the PMs provide **poor** protection or none at all.
- **Orange** indicates that the PMs provide **moderate** protection (80% effectiveness).
- **Yellow** indicates that the PMs provide **good** protection (at least one task providing 97% effectiveness).
- **Green** indicates that the PMs provide **excellent** protection (two or more tasks providing 97% effectiveness).

Each licensee controls the chance of experiencing failures in the following three ways:

- By the number of unprotected failure mechanisms
- By the degree of reliance placed on the tasks which address priority failure mechanisms (that is, address them with one, two, or more tasks)
- By the choice of task intervals that affect task effectiveness

If failures are still being experienced, the licensee should consider the root cause to be one of the following:

- The PM is performing the **wrong task**.
- The task contains **inadequate content**.
- The task is being **performed incorrectly**.

Key Technical Point

If you experience failures in green and yellow and you are performing the high-effectiveness tasks, you may not be performing them effectively. You should be able to improve PM defenses against such failures by modifying your PM program to be closer to the recommendations.

Key Technical Point

If you experience failures in green and yellow and you are currently performing the high-effectiveness tasks, you should suspect that task scope or implementation might be improved.

Key Human Performance Point

If you experience failure in green and yellow and are currently performing high-effectiveness tasks, with the correct task scope, that are implemented properly, you should examine your training program, personnel qualifications, and quality of procedures.

B.3 Interval Sensitivity

Task effectiveness can be affected by revising the frequency of the task and by stressors. Table B-1 illustrates this relationship.

Table B-1
Interval sensitivity

	H	hM	hL	h_
For UW (*x*)—(no stressor effect)	*Interval* <= *x*	*x* < *Interval* <= 1.5(*x*)	1.5(*x*) < *Interval* <= 2(*x*)	2(*x*) < *Interval*
For UW (*x_y*)—(no stressor effect)	*Interval* <= *x*	*x* < *Interval* <= *y*	*y* < *Interval* <= 2(*y*)	2(*y*) < *Interval*
For UW (*x*)—(stressor effect)	*Interval* <= 0.5(*x*)	*x* < *Interval* <= 1.5(*x*)	1.5(*x*) < *Interval* <= 2(*x*)	2(*x*) < *Interval*
For UW (*x_y*)—(stressor effect)	*Interval* <= 0.5(*x*)	0.5(*x*) < *Interval* <= 0.5(*y*)	0.5(*y*) < *Interval* <= *y*	*y* < *Interval*
W(x)—(both with and without stressors)	*Interval* <= *x*	*x* < *Interval* <= 1.5(*x*)	1.5(*x*) < *Interval* <= 2(*x*)	2(*x*) < *Interval*
W(x_y)—(both with and without stressors)	*Interval* <= *x*	*x* < *Interval* <= *y*	*y* < *Interval* <= 2(*y*)	2(*y*) < *Interval*

Table B-2 illustrates the impact of removing or extending the interval of a particular task on the task effectiveness/program effectiveness (that is, H/Green).

Table B-2
Impacts of removing or extending the interval of a particular task

	L, hL, mL, /gray, [blank]	M, hM	H
Red	Will not change program effectiveness		
Orange	Will not change program effectiveness	Could have impact	
Yellow	Will not change program effectiveness	Will not change program effectiveness	Will have impact
Green	Will not change program effectiveness	Will not change program effectiveness	Could have impact

The vulnerability tool can also be used to evaluate overhaul and refurbishment intervals. The vulnerability tool can calculate annual failures based on program. The failure rate will change as a function of interval by holding everything else constant and changing the interval for refurbishment. Table B-3 shows how annual failure rate is affected by changing the refurbishment interval times.

Table B-3
Impacts of changing refurbishment intervals

Refurbishment Interval (Years)	Annual Failure Rate
5	0.5359
10	0.6500
12	0.7150
15	0.7154
17	0.7475
20	0.7475
25	0.7761
35	0.7819

The graph in Figure B-3 illustrates the general impact that extending refurbishment intervals has on the annual failure rate of a component.

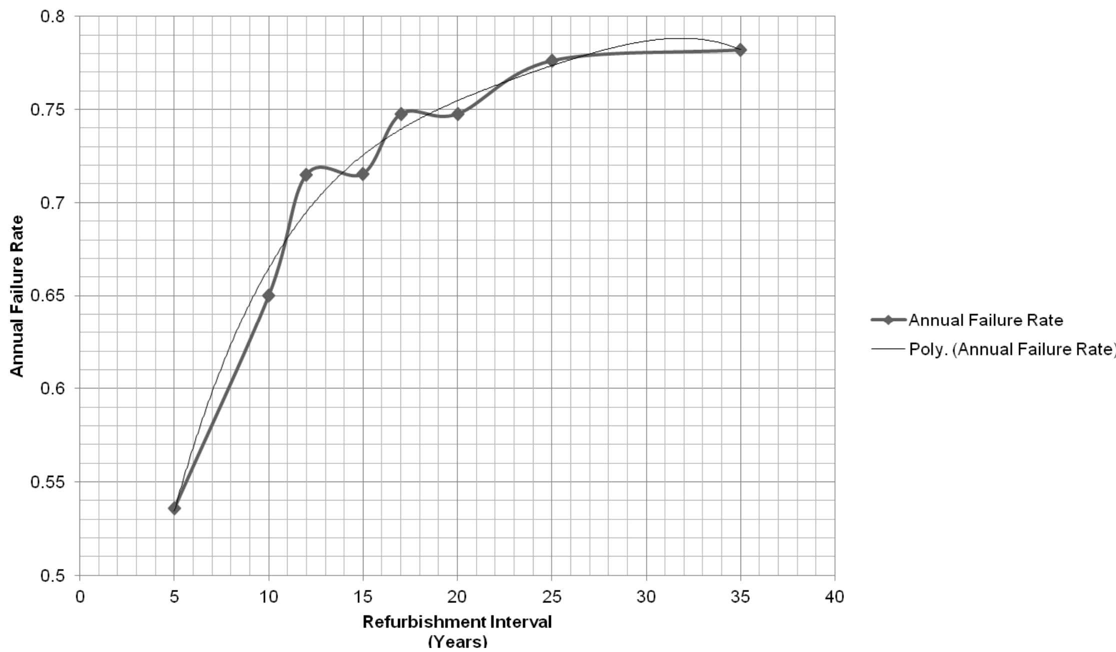

Figure B-3
Impacts of changing refurbishment intervals

B.4 Task Deferral Using the PM Basis

The vulnerability tool can also be used to assess the impact of deferring PM tasks. A deferral is different from changing an interval because the deferral is meant to be done once, whereas changing the interval implies a permanent change that will remain in effect going forward. The following definitions are provided to help the user understand what is meant by a deferral.

- **PM deferral** (postponement). Justification to exceed the grace date based on documented evaluation of the equipment condition and requirements.
- **Grace period**. The allowed frequency extension for a PM task calculated from the due date, not to exceed 25% of the frequency. For PM tasks not allowing grace such as environmentally qualified tasks, the grace date equals the due date.
- **Overdue**. A PM task is considered overdue when it has exceeded its due date.
- **Late date** (past grace). The date when a PM has been determined to have exceeded its due date plus the grace period. Calculated by adding the grace period to the nominal due date
- **Late**. A PM has been determined to be LATE when it has exceeded the late date.

Figure B-4 illustrates a timeline of activities and how tasks may be deferred.

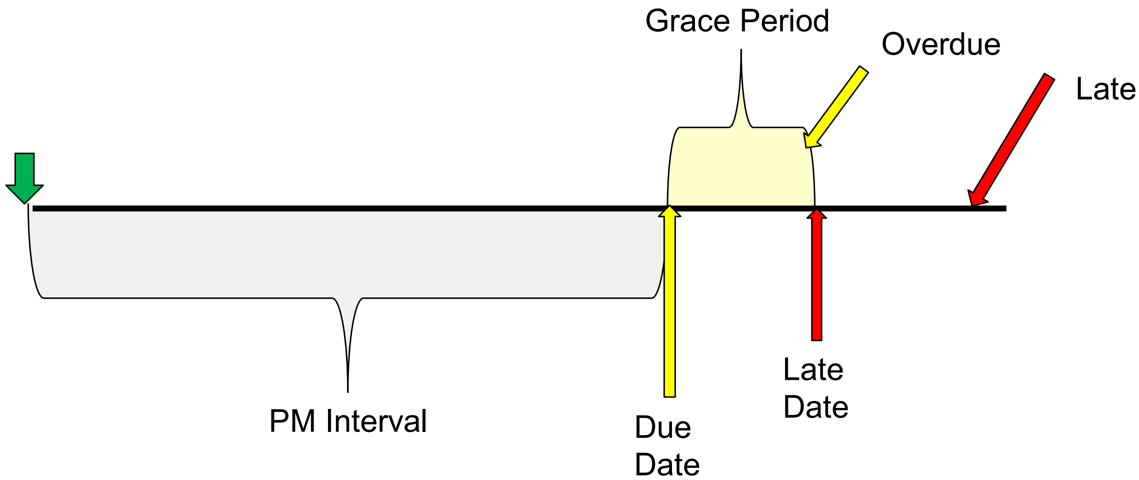

Figure B-4
PM deferrals, grace period, and late dates

The following scenarios typically justify when a deferral is warranted:

- A PM deferral is required when activity is not going to be performed before end of its grace period.
- A PM deferral is not required when a permanent change in PM frequency is more appropriate.
- A PM deferral is not required for the following types of activities:
  - Support activities, such as installation of scaffolding in support of a PM or refueling outage preparations
  - PM activities that have been turned off because the related equipment is out of service and there is no need to perform the PM

The following information is typically needed when justifying a PM deferral:

- Functional importance, duty cycle, and service conditions
- Current scope and basis for the PM activity being proposed for deferral
- Previous maintenance feedback for the PM being proposed for deferral
- Previous deferrals of the PM being proposed for deferral
- Status of other PMs on the component being addressed by the PM being proposed for deferral
- Site-specific failure history associated with this and similar components
- Industry operating experience associated with this type of component

The following activities should be performed when conducting a deferral evaluation for any given PM:

- Criticality, duty cycles, and service conditions for the affected component(s) should be documented. The criticality in this step will be used to determine the consequence of failure. Duty cycles and service conditions are used to aid in determination of the probability of failure.
- The PM Basis should be reviewed to determine whether there is anything in the current PM Basis that would indicate that the PM should not be deferred.
- The following questions should be asked:
  - Are there any commitments that would prevent deferral of this PM?
  - Does the PM being proposed address significant and likely failure modes?

By deferring the PM in the vulnerability tool, the following questions will be answered:

- Does previous feedback on this PM indicate degraded conditions that would indicate that the PM should not be deferred? If so, the risk associated with this deferral is higher.
- Has this PM already been deferred? A second deferral of this PM could significantly increase the risk associated with the failure of this component. A second deferral should be treated as a task interval change.
- Are there any performance issues in health reports that would indicate that this PM should not be deferred?
- What is the probability of this component failing after the late date and prior to the planned performance of this PM (low, medium, or high)?

After using the vulnerability tool, the licensee can then decide whether the technical risk of deferral is acceptable. This will be a qualitative decision. The licensee should then document the basis, or thinking, behind this decision.

Key O&M Cost Point

When contemplating the merits of deferring a PM task, the licensee should also consider the cost if the component associated with this PM fails prior to the PM activity being performed. The cost consequence of deferral of this PM should be acceptable.

The following actions should typically be taken after the deferral is approved:

- Alert operations that this PM activity is being deferred and that closer attention should be paid to this component.
- Use the information from the vulnerability analysis to identify the specific vulnerabilities.
- Identify any additional monitoring or steps that may be appropriate to provide additional protection from the likely failure mode(s).

C

PM TASKS AND FREQUENCIES FOR MECHANICAL COMPONENTS

C.1 Introduction

The purpose of this section is to provide baseline PM guidance for mechanical components typically installed in a steam bypass system at a CTCC facility. The scope of mechanical components covered in this section is summarized in Table C-1.

Table C-1
Scope of mechanical components

Mechanical Component	Sections
Motor-operated steam isolation valves	C.2.1 through C.2.2
Parallel slide gate valves	C.2.3
Air-operated steam bypass valves	C.3.1 through C.3.2
Plug-type steam bypass valves	C.3.3
Attemperators	C.4
Piping and hangers	C.5
Drain line	C.6

The PM guidance regarding valves is based on information published in EPRI report 1021271, *Generation Maintenance Application Center: Combined Cycle Combustion Turbine Duct Burner Maintenance Guide*. The PM guidance table regarding the attemperator is based on information published in EPRI report 1026632, *Generation Maintenance Application Center: Combined Cycle Combustion Turbine Attemperator Maintenance Guide*.

Section 4.3 provides technical justifications for variance from the PM tasks and frequencies provided for each discrete mechanical component taking into account system design, typical failure history, outage schedules, and operating conditions. Although it is left up to the user to assemble these tasks into a useful craft instruction, sample job plans are provided in Section 5 of this report to assist in this aspect of maintenance planning.

C.2 Motor-Operated Steam Isolation Valves

C.2.1 PM Tasks and Frequencies

Table C-2 provides an overview of the PM tasks and frequencies for motor-operated steam isolation valves.

Table C-2
PM tasks and frequencies for motor-operated steam isolation valve components

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Actuator—Detailed Inspection/Clean/Lubricate	C.2.41	8Y	8Y
Actuator—General Visual—Off-Line	C.2.4.2	4Y	4Y
Actuator—General Visual—Online	C.2.4.3	2Y	2Y
Diagnostics—Electrical Force	C.2.4.4	2Y	2Y
Valve Stem Lubrication	C.2.4.5	2Y	2Y
Functional Test—Leak	C.2.4.6	AR	AR
Functional Test—Operability	C.2.4.7	AR	AR
Functional Test—Timed Stroke	C.2.4.8	AR	AR
Packing Adjustment/ Replacement	C.2.49	AR	AR

Y = years AR = as required

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

C.2.2 PM Tasks

C.2.2.1 Actuator—Detailed Inspection/Clean/Lubricate

The main objective of this task is to completely clean out and replace the lubricant from the interior of all parts of the drive train and gear box. The interval is determined by the life of the lubricant, but this cannot be predicted by condition information beyond about 8 to 10 years.

The MOV—Actuator—Detailed Inspection/Clean/Lubricate task should include the following:

- Looking for any discoloration or other evidence of overheating
- Cleaning and inspect all actuator parts
- Inspecting the gears, keys, keyways, shafts, splines, and bearings for wear, fit, and damage
- Inspecting the spring pack and grease relief areas for excessive or hardened grease
- Performing a complete inspection and reassembly of the spring pack (It is suggested that the K-curve value be tested, recorded, and trended to determine the optimum time for replacement of the spring pack, and to verify that the correct spring pack was installed.)

- Replacing the lubricant
- Replacing the seal at the bottom of the drive sleeve in the gear case
- Inspecting the geared limit switch compartment for indication of wear; replacing the grease in this area and testing its lubrication qualities of the old grease
- Inspecting for torque switch roll pin failure
- Inspecting the compensator pack for damage and condition, if present
- Inspecting and test the declutch mechanism
- Inspecting the condition of the actuator motor, its windings, bearings, rotor, shaft, and shaft seal for wear, damage, and general condition
- Inspecting the wiring, wiring harness, motor cables, and connections for damage to the insulation
- Performing an insulation test on the motor windings, cables, and wiring
- Inspecting the valve stem and stem nut for thread damage
- Inspecting the packing, packing gland, and stem for corrosion, leakage, galling, and damage
- Replacing the packing and torque to the proper value as specified in the plant's valve packing program or by the manufacturer
- Reassembling and testing
- Performing diagnostic electrical and direct force signature testing and operability testing before returning to service
- Looking for any discoloration or other evidence of overheating
- Inspecting the condition of the geared limit and torque switches for broken or damaged wiring and parts
- Inspecting the torque switch for free movement of the switch and return spring function
- Inspecting the torque switch contacts for abnormal wear, pitting, or corrosion (Inspect that the torque switch makes proper contact with the switch fingers and that the fingers are not damaged, burnt, or bent, and are free to move.)
- Inspecting the mechanical valve position dial indicator for proper movement and positioning
- Inspecting the tripper finger assembly, if accessible
- Sampling the lubricant near the worm/worm gear interface for condition, presence of contamination such as water, and any metal wear indications of the worm gear assembly
- Testing the insulation resistance of the motor windings
- Inspecting for damaged, loose, or missing parts, fasteners, lugs, terminations, and wiring
- Inspecting for the general presence of contamination, moisture, and corrosion especially in the stem and packing areas

- Inspecting for the general presence of any cracks or discoloration
- Inspecting for grease and oil leaks from the motor bearings, actuator gear box, and handwheel assembly
- Inspecting the general condition of the grease in the gear box, stem area, and in the antirotation device

> **Key Human Performance Point**
>
> Only a small sample of grease should be carefully taken. Failing that, a simple visual examination of the grease should be possible.

- Inspecting for packing leaks and the general condition of the stem and packing gland for wear and corrosion

> **Key Human Performance Point**
>
> Packing should not be torqued beyond the original values specified in the site's packing program or by the manufacturer, because this could alter the valve testing results.

- Inspecting the condition of the torque arm assembly and the antirotation device for damage, wear, and looseness

Techniques and equipment that directly measure the output force of the actuator should be used to ensure correct operation of the MOV under the appropriate DP conditions. Time-based data acquisition of stem thrust (axial force) or/and torque (radial force) is accomplished by using strain gauges attached directly to the stem, yoke, or within a device mounted between the actuator and the valve. These forces are specifically monitored to determine certain switch settings and to assess the overall health of the MOV.

> **Key O&M Cost Point**
>
> Direct-force testing is typically performed at the valve and requires several technicians and several hours. The analysis of the data typically requires several hours of engineering time.

C.2.2.2 Actuator—General Visual—Off-Line

This task is focused on general contamination and corrosion, missing, loose, or damaged parts, and grease or oil leaks, with a scope considerably beyond that for the online inspection, and focused on the actuator. The lower range of intervals is not clearly determined from the failure data, but the upper part of the range is constrained by lubrication degradation and failure of the drive sleeve to gear case seal.

The MOV General Visual Inspection—Off-Line task should include the following:

- Looking for any discoloration or other evidence of overheating
- Inspecting the condition of the geared limit and torque switches for broken or damaged wiring and parts
- Inspecting the torque switch for free movement of the switch and return spring function
- Inspecting the torque switch contacts for abnormal wear, pitting, or corrosion (Inspect that the torque switch makes proper contact with the switch fingers and that the fingers are not damaged, burnt, or bent, and are free to move.)
- Inspecting the mechanical valve position dial indicator for proper movement and positioning
- Inspecting the tripper finger assembly, if accessible
- Sampling the lubricant near the worm/worm gear interface for condition, presence of contamination such as water, and any metal wear indications of the worm gear assembly
- Testing the insulation resistance of the motor windings
- Inspecting for damaged, loose, or missing parts, fasteners, lugs, terminations, and wiring
- Inspecting for the general presence of contamination, moisture, and corrosion, especially in the stem and packing areas
- Inspecting for the general presence of any cracks or discoloration
- Inspecting for grease and oil leaks from the motor bearings, actuator gear box, and handwheel assembly

Key Human Performance Point

Only a small sample of grease should be carefully taken. Failing that, a simple visual examination of the grease should be possible.

- Inspecting for packing leaks and the general condition of the stem and packing gland for wear and corrosion

Key Human Performance Point

Packing should not be torqued beyond the original values specified in the site's packing program or by the manufacturer, because this could alter the valve testing results.

- Inspecting the condition of the torque arm assembly and the antirotation device for damage, wear, and looseness

C.2.2.3 Actuator—General Visual—Online

The task is focused mainly on the actuator, looking for general contamination and corrosion, missing, loose, or damaged parts, and leaks, including packing leaks on the valve. The interval is not determined by the failure data so that some interval exploration may be possible.

The MOV General Visual Inspection—Online task should include the following:

- Inspecting for damaged, loose, or missing parts, fasteners, lugs, terminations, and wiring
- Inspecting for the general presence of contamination, moisture, and corrosion especially in the stem and packing areas
- Inspecting for the general presence of any cracks or discoloration
- Inspecting for grease and oil leaks from the motor bearings, actuator gear box, and handwheel assembly

Key Human Performance Point

Only a small sample of grease should be carefully taken. Failing that, a simple visual examination of the grease should be possible.

- Inspecting for packing leaks and the general condition of the stem and packing gland for wear and corrosion

Key Human Performance Point

Packing should not be torqued beyond the original values specified in the site's packing program or by the manufacturer, because this could alter the valve testing results.

- Inspecting the condition of the torque arm assembly and the antirotation device for damage, wear, and looseness

C.2.2.4 Diagnostics—Electrical Force

Diagnostic tests address the valve-actuator assembly as a combined unit. The interval coincides only with potential relaxation of the spring pack for normally compressed springs, but many random failure modes are also addressed; some flexibility in the interval may be possible under some circumstances.

Diagnostic tests include techniques and equipment that indirectly measure the output force of the actuator. Time-based data acquisition of current and voltage is converted to motor power and, in some cases, motor torque.

Key Technical Point

Electrical force testing is primarily useful in monitoring changes in MOV performance and health but can be used to set torque switches because of the relationship made between the electrical characteristics of the MOV and motor torque.

Key O&M Cost Point

Electrical force testing is typically performed at the motor control center and requires a single technician and less than an hour. The analysis of the data typically requires a few hours of engineering time.

C.2.2.5 Valve Stem Lubrication

This task tests helps to ensure that the lubricant remains fresh and effective.

C.2.2.6 Functional Test—Leak

This task provides assurance that the MOV is not leaking internally.

C.2.2.7 Functional Test—Operability

This task tests whether the valve will change position.

C.2.2.8 Functional Test—Timed Stroke

This task provides assurance that the MOV will open and close within timing specifications.

C.2.2.9 Packing Adjustment/Replacement

The packing is adjusted to prevent leakage around the valve stem.

C.2.3 General Maintenance Activities for Parallel Slide Gate Valves

Typically, the only maintenance required for the valve during operation is periodic inspections. These inspections should include checking for leaks at the stuffing box and cover sealing areas. Also, inspect the valve stem and guide surfaces of the yoke rods and the stem guide antirotation device for cleanliness. Paint, dirt, rust scale, or other foreign matter on these surfaces can greatly hamper the operation of the valve. Clean the surfaces whenever possible.

Most manufacturers recommend that the valve packing be inspected yearly or during the routine plant maintenance outages and replaced accordingly. In many cases, seal or packing replacement, inspection, or repair of the valve internals can be accomplished without removal of the main valve body from the line.

Check the condition of the valve before disassembly. Thoroughly inspect the valve stem and all other exposed moving parts. Foreign material, such as dirt, rust or scale, can greatly hamper the smooth operation of the valve. Clean the surfaces wherever possible. Inspect the joints, connections and stuffing boxes where persistent leakage may occur.

After surface cleaning and inspection or repair of the valve externals, begin valve disassembly in accordance with the manufacturer's detailed instructions. Clean all parts with a wire brush (except seating surfaces) and wash them with an approved cleaning solvent. Wipe the surfaces with a lint-free cloth or allow the parts to air dry. Inspect each part carefully for physical damage. At reassembly, always use new sealing parts, such as gaskets and stem packing.

C.3 Air-Operated Steam Bypass Valves

C.3.1 PM Tasks and Frequencies

Table C-3 provides an overview of the PM tasks and frequencies for piston air for air-operated steam bypass valves.

Table C-3
PM tasks and frequencies for air-operated steam bypass valves

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Actuator Assembly Overhaul	C.3.2.1	5Y	5Y
Calibration of Accessories	C.3.2.2	2Y	5Y
Calibration of Actuator	C.3.2.3	5Y	5Y
Operator Rounds	C.3.2.4	1S	1S
Packing Inspection/Adjustment	C.3.2.5	2Y	5Y
Packing Replacement	C.3.2.6	5Y	10Y
Rebuild/Replace Accessories	C.3.2.7	5Y	5Y
Diagnostic Testing	C.3.2.8	AR	AR
Functional Valve Stroke Test	C.3.2.9	AR	AR
Seat Leakage Test	C.3.2.10	AR	AR
Solenoid-Operated Valve	C.3.2.11	AR	AR
Stroke Time Test	C.3.2.12	AR	AR

Y = years S = shift AR = as required

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

C.3.2 PM Tasks

C.3.2.1 Actuator Assembly Overhaul

The main rationale for overhauling the actuator on a regular schedule is to replace the soft goods. The interval for critical components is not well determined from the failure mode data, but, because the task addresses a large number of common and random failure mechanisms, extending the interval beyond the recommended value requires sound evaluation of equipment history and condition.

The overhaul and inspection activities may contain the following activities:

- Actuator assembly overhaul, including the following:
  - Replacing soft goods—for example, gaskets, packing, diaphragms, and seals
  - Replacing/repair hardware, as required
  - Cleaning/refurbishing seal surfaces
  - Lubricating, as appropriate
- Actuator assembly internal inspection of the following to check for damage to, the condition of, or missing:
  - Sealing surface
  - Bushings
  - Sealing components—for example, diaphragm, seals, and O-rings
  - Cylinder walls and piston, if applicable
  - Stem
  - Gearing
  - Spring(s)
  - Vents (Are they clear?)
  - System cleanliness
- Actuator assembly system engineer walkdown to check the following for damage to, the condition of, or missing:
  - Structural integrity
  - Subcomponent damage
  - Fasteners, which may be loose, especially in high-vibration areas
  - Connections—electrical, pneumatic, and so forth
  - Valve stem
  - Valve stem coupling
  - Fluid/air leaks
  - Manual operator, making sure that it is not engaged

Key Technical Point

The main rationale for overhauling the actuator on a regular schedule is to replace the soft goods because they degrade with age and exposure to the service environment.

The result is that replacement of the soft goods is necessary if failures are to be prevented in some service environments. This would normally be the case for trip-critical valves or valves that are extremely risk significant.

Soft goods, including the diaphragm, are expected to possess a characteristic service life even though this may be a complex function of application, service environment, and duty cycle. It is therefore in principle possible to replace soft goods just in time. Finding the right time without discarding a significant amount of useful life, and without experiencing a significant number of failures, should be a major objective for the most critical applications.

Because degradation of the soft goods is expected to depend in a specific way on service conditions (such as temperature or pressure), duty cycle, and the application (for example, position-sensitive vibration levels), significant differences in degradation rates among actuators should be investigated. Correlation of the degradation rates with these factors may lead to some actuators being permitted longer intervals between overhauls than others. In these cases, reliability should be improved by the use of longer intervals.

Actuator assembly overhaul should also include both an internal and external inspection. During these inspections, it is also prudent to verify the cleanliness of the air supply system. Lubrication is not performed as a regular separate PM for AOVs. Certain subcomponents will receive lubrication as part of normal overhaul activities.

Actuator assembly overhaul should also include both an internal and external inspection. During these inspections, it is also prudent to verify the cleanliness of the air supply system. Lubrication is not performed as a regular separate PM activity for AOVs. Certain subcomponents will receive lubrication as part of normal overhaul activities.

C.3.2.2 Calibration of Accessories

The intent of calibrating the accessories is to ensure that each accessory is functioning correctly within design tolerances (for example, start and stop points, travel, and timing). The two-year task interval for critical, high-duty cycle valves is strongly determined by the failure mode data.

Calibration should include the following:

- Set limit switches
- Pressure regulator setpoint (see I&C—Pressure Regulator)
- I-P/E-P transducer (see I&C—I to P and E to P Transducer)
- Positioner (see I&C—Positioner)
- Booster tuning (see I&C—Booster)
- Pressure switches (see I&C—Pressure Switch)
- Position transmitter (see I&C—Positioner)
- Speed control valves
- Air leakage check—for example, a DP test

The visual inspection should include the following:

- Structural integrity
- Subcomponent damage
- Loose, broken, missing fasteners, especially in high-vibration areas
- Damaged or loose electrical connections
- Observation of obvious process fluid leaks
- Actuator shaft condition
- Condition of the valve stem and coupling

It is recommended that an informal external inspection should be performed every time when maintenance, operations or engineering personnel are physically at the valve. Such informal inspections should not replace the scheduled inspection.

Although this task addresses calibration of accessories, the details of the calibrations are to be found in the relevant sections under the corresponding I&C component. The accessories which can be accessed in this way are: booster, voltage to pressure (E/P) transducers, and current to pressure (I/P) transducers, pneumatic switches, positioners (including position transmitters), and pressure regulators. The task also includes calibration of limit switches and speed control valves, as well as other inspection items.

Calibration measures the dynamic response of individual accessories (E/P, positioner, booster, and so forth) to a control input. The intent is to ensure that each accessory is functioning correctly within design tolerances (for example, start and stop points, travel, or timing). Calibration therefore focuses on design specifications of the accessories. It provides assurance that the process is being controlled properly, with respect to the inputs to the actuator and valve.

Calibrations are useful in providing information on accessory condition. Persistent, significant calibration drifts can be used to identify the need for accessory replacement. No other information might be available for this purpose because it is not cost-effective to internally examine the condition of accessories.

Valve or operator internal degradation can occasionally be inferred from calibration data but not with any precision as to location or quantification of the degradation mechanism. It is more likely that persistent accessory drift might suggest the potential for internal damage to the valve and would be factored into the decision process to investigate further. For example, calibration drifts that suggest a valve has been improperly seating over an extended period could raise the question of erosion of the seat. Timely correction of calibration drifts is, therefore, important in preventing degradation of internals.

Trended accessory calibration data should be used as justification to adjust PM frequencies. This could consist of as-found and as-left data on I/P (E/P) and the positioner. Other factors, such as duty cycle, can influence the interval decision.

C.3.2.3 Calibration of Actuator

The focus of this task is on the design specifications of the actuator to provide assurance that the valve is capable of performing its design function. The interval is suggested but not strongly determined by the failure mode data, except for the scotch yoke type of coupling, where wear-out can be expected in about five years.

Calibration of the actuator may include the following:

- Checking spring preload (uncoupled)/bench set
- Checking for air leakage from pneumatic components
- Checking for stroke length
- Inspection of coupling and proper torquing, as required
- Verifying correct position of the handwheel, if applicable

The visual inspection should also include the following:

- Structural integrity
- Subcomponent damage
- Loose, broken, or missing fasteners, especially in high vibration areas
- Damaged or loose electrical connections
- Obvious process fluid leaks
- Actuator shaft condition
- Condition of the valve stem

It is recommended that an informal external inspection be performed every time when cognizant persons are physically at the valve. Such informal inspections should not replace the scheduled inspection.

Calibration of the actuator verifies that the overall valve is functioning within design tolerances. Focus on the design specifications of the actuator provides assurance that the valve is capable of performing its design function.

C.3.2.4 Operator Rounds

The Operator Rounds task is focused on the detection of obvious leaks of process fluid and air from pneumatic components. The Operator Rounds task generally detects leaks and loose, damaged, or missing fasteners.

C.3.2.5 Packing Inspection/Adjustment

This inspection is intended to detect unacceptable leakage from the packing area and to adjust gland nut torque according to site procedures. The interval is not well determined from the failure mode data.

C.3.2.6 Packing Replacement

Replacement of the packing is intended to prevent unacceptable leakage when retorquing is no longer is feasible. The interval for high-duty cycle valves is not well determined from the failure mode data.

Replacement of packing may include the following:

- Replacement of packing
- Inspection of the following:
  - Stem
  - Gland follower, including correct centering of the gland follower
  - Studs/nuts
  - Stuffing box conditions

Packing deteriorates over time and is expected to leak progressively. Replacement of the packing is performed when retorquing no longer is feasible. Consult your packing program or station procedures for trending and interval modification. If no packing program exists, use the suggested intervals in Table C-3, which are timed to coincide with actuator overhauls.

C.3.2.7 Rebuild/Replace Accessories

The Rebuild/Replace Accessories task is focused mostly on the need to address worn-out or degraded soft goods within each accessory device or component. The interval for critical components is not well determined from the failure mode data, but the task addresses a very large number of common and random failure mechanisms, some of which might occur sooner than the task is performed.

The Rebuild/Replace Accessories task can include the following:

- Solenoid valves
- Positioners
- Regulators
- I-P/E-P transducers
- Boosters
- Limit switches
- Pressure switches
- External air supply filters
- Pneumatic switches
- Check valves
- Speed control valves
- Position transmitters

General inspection of the air supply system for cleanliness and operability should include the following:

- Excessive moisture
- Oil contamination
- Debris
- Restrictions
- Leaks
- Acceptable air pressure
- General damage

The Rebuild/Replace Accessories task is motivated mostly by the need to address worn-out or degraded soft goods within each accessory device or component. Deterioration of soft goods and mechanical wear both leads to symptoms observable in diagnostics or to some degree by calibration drift. If calibration data are trended, they may serve to show that the rebuild/replace interval should be adjusted.

Wear-out of accessories is expected to be application (for example, vibration), duty cycle, and service condition-related. Therefore, optimal rebuild/replace times can vary significantly from one group of valves to another. Individual accessory items may require different rebuild/replace intervals. These intervals should take into account the date of previous actuator accessory replacements.

Because repair or refurbishment of external air filters (not the filter that may be inside the regulator) is not cost-effective, the PM task is to replace them also. Air supply system quality and cleanliness can also affect valve function and operation. A general air supply system check is prudent in conjunction with this replacement activity; problems in the air supply could result in shorter intervals.

C.3.2.8 Diagnostic Testing

The main intent of diagnostic testing is to check the operability of all the accessories, the actuator, and the valve as a single integrated unit.

Diagnostic testing could include the following:

- Total friction
- Seat load
- Travel
- Available actuator thrust/torque
- Accessory signatures
- Air pressures
- Spring rate
- Spring preload

Diagnostic testing checks the operability of all the accessories, the actuator, and the valve as a single integrated unit. As a minimum, it provides a verification of the calibration data and the calibration process. This verification includes being within overall tolerances for the complete valve as a system.

For example, if valve timing or travel data indicate a problem, the diagnostic testing can usually indicate whether the source is inappropriate friction, possibly from a packing problem or from internal damage, or if it is a result of worn springs.

Key Technical Point

Travel and seat load information on the seating area can raise the likelihood of internal leakage, which can often be confirmed by acoustic or thermographic techniques.

There are limits to these capabilities however. For example, although leakage may be confirmed, the extent of the leakage can be assessed only by an inspection of the seat—that is, an overhaul. The techniques may not always be applicable. For example, a cold water valve in a noisy environment may not be assessable by thermography or acoustics. A control valve that needs to shut off in an emergency may not be able to be tested for leakage in realistic shutoff conditions.

Nevertheless, diagnostic testing can be used to decide whether the source of a problem is the operator or the valve and whether the problem can be corrected without tearing down the whole valve.

Diagnostic test results allow trending of useful valve parameters. These parameters may include travel, total friction, air pressures, spring rate, and seat load and may be used to adjust PM intervals.

Key O&M Cost Point

Because the diagnostic test data can be trended, it is possible to use them, with some qualification, to defer overhauls and replacements when the condition of the equipment appears to be good and stable over time or to decide whether an overhaul is appropriate.

However, there is one major exception to this claim. Diagnostic testing does not provide information on the condition of the diaphragm if there is no leakage. The condition of other soft goods can be inferred from diagnostic information because they typically deteriorate gradually and give signs of progressive leakage. For example, O-ring piston seals degrade this way. Similarly, soft goods in accessories typically show degradation over time through increasing calibration drift.

C.3.2.9 Functional Valve Stroke Test

A Functional Valve Stroke Test is done to verify that the valve operates as a complete unit. A simple stroke test can be done as a failure-finding task to ensure that a valve has not already failed. However, it provides practically no assurance that the valve is not about to fail.

Failure-finding tasks such as stroke tests can be applied to any critical valve that may fail undetected.

C.3.2.10 Seat Leakage Test

This task is intended to reveal internal leakage of the valve.

Methods for detecting seat leakage may include the following:

- Infrared
- Local leak rate testing
- Temperature monitoring
- Acoustic methods

Advanced technologies—that is, temperature profile—and acoustic signature can be used for non-intrusive internal leakage detection.

C.3.2.11 Solenoid-Operated Valve

Task scope objective, content, and related implementation guidance for this subcomponent are not included in this report.

C.3.2.12 Stroke Time Test

A Stroke Time Test is performed to verify that the valve operates as a complete unit, including the solenoid valve.

Stroke Time Tests can include the following:

- Timed stroke
- Limit switch actuations
- Solenoid-operated valve actuations

A timed stroke test, combined with visual external inspection, provides some additional assurance that the valve system is operating within overall tolerance, especially if the data are trended over time. A time response outside tolerance requires further investigation to ascertain whether the problem is in the valve or the actuator.

C.3.3 General PM Activities for Plug-Type Steam Bypass Valves

Table C-4 provides an overview of the PM tasks and frequencies for steam turbine air-operated, plug-type bypass valves.

Table C-4
PM tasks and frequencies for steam turbine plug-type bypass valve components

Valve Component/Assembly	PM Task	Frequency
Nozzles	• Verify that cracking pressure is within specification (using the nozzle test device provided by the manufacturer). • Visually inspect the nozzle to ensure smooth stroke (physical assessment of even motion). • Visually inspect the spring and washer for evidence of physical wear, corrosion. or damage. • Visually inspect seating surfaces for smoothness and to ensure that there are no scratches or dents.	12–18M
Diffusers, desuperheater interior surfaces, and liners	• Perform borescopic inspection of the valve interior body and nozzle studs.	12–18M
Valve internals	• Visually inspect the packing follower, plug/spindle assembly, seat ring, and disk stack/cage for physical damage, wear, or corrosion.	18M
Valve instrumentation	• Check the operation and calibration of valve instruments, control devices, and the actuator.	18M
Spray water valve	• Visually inspect valve for any signs of leakage, such as high heat downstream of seated spray valve, signal calibration, or chattering check valves. • Verify that inlet and outlet pressures are within design specification. • Check valve position and trend flow data to ensure valve operability.	12–18M
Steam valve	• Verify that positioner is providing hard over seat in closed position (no in-valve leakage) in accordance with the manufacturer's recommendations. Check for any indication of high downstream temperatures.	12–18M
Dump device	• Measure inlet pressure to verify that it is within the manufacturer's recommended specifications.	12–18M
Control logic	• Verify the operability of the system interlocks and sequencing. There should be no spray water when steam valve is closed.	12–18M
	• Verify stability of the controls with a detailed operation analysis.	AR
Valve gaskets and seals	• Replace Flexitallic[1] gaskets, balance seals, and metal seal (if damaged).	18M
Packing and spacer	• Replace valve packing and packing spacer.	18M

[1] *Flexitallic* is a registered trademark of The Flexitallic Group.

Valve Component/Assembly	PM Task	Frequency
Actuator elastomeric items	• Replace the actuator bushing, actuator, and manual override O-rings.	3Y
System elastomeric items	• Replace elastomeric items.	4.5Y
System components	• Record surface temperature profile (gradients) of bypass valve, desuperheaters, and adjacent piping during startup and shutdown.	AR
Welds	• Perform visual inspection or liquid penetrant examination of bypass valve, desuperheater outlet, and desuperheaters manifold welds to identify thermal fatigue cracks or pinhole leaks.	AR

Y = years M = months AR = as required

C.4 Attemperators

The primary PM for an attemperator consists of visual inspections of the subcomponents listed in Table C-5. This PM activity is categorized as a minor inspection, and it should be performed about once a year.

Table C-5
Attemperator PM activities

Attemperator Subcomponent	PM Task
Control valve stacked disk, if present	Visually inspect for plugging.
Control valve stacked disk, if present	Visually inspect for wear between valve plug and stacked disks.
Header ring, if present	Visually inspect for cracking.
Liner	Visually inspect for cracking, cracked weld, or damaged/broken liner.
Spray nozzles	Visually inspect for corrosion, physical damage, erosion, or incorrect installation—for example, misaligned, leaking at flanged joint, missing hardware, plugging, warping, or wrong nozzle/incorrect depth.
Spray nozzles—spring type, if present	Visually inspect for broken spring, eroded swirl chamber, leakage, leakage from loss of spring constant, or loose or missing retaining nut.
Steam pipe attachment	Visually inspect for cracking.
Steam pipe flange	Visually inspect for cracking or leakage.
Strainer	Visually inspect for clogging, or erosion/corrosion.
Water pipe attachment	Visually inspect for cracking.
Water pipe flange	Visually inspect for cracking or leakage.

Key Technical Point

Operator walkdowns of attemperators can also include visual inspections detecting bowed pipes, pipe hanger problems, or pipe leaks.

In addition to the visual inspections noted in Table 4-1 that constitute the minor inspection, performing the following PM tasks may also be considered:

- Borescopic inspection of liner assembly and downstream piping
- NDE (ultrasonic testing) of downstream piping and welds for inside diameter initiated crack propagation
- NDE (magnetic particle inspection/liquid penetrant testing) on nozzle assembly

C.5 Piping and Hangers

The primary PM for a hanger consists of visual inspections of the subcomponents listed in Table C-6. The hanger PM activity is categorized as a minor inspection, and it should be performed during the HGP inspection. The piping PM should be performed during the major inspection. Because of the varying degradation mechanisms possible in a piping system, an engineering evaluation needs to be performed to determine the degradation progression and, therefore, the subsequent inspection frequency.

Table C-6
Hanger PM activities

PM Task	Frequency
Visually inspect hanger for signs of physical damage, cracking or excessive wear.	HGP inspection
Visually inspect hanger for excessive corrosion.	HGP inspection
Measure movement of hanger while the unit is online to establish an upper range of motion.	Before or after HGP inspection
Measure movement of hanger while the unit is off-line to establish a lower range of motion.	HGP inspection
Visually inspect piping for cracks, leaks, excessive corrosion, or physical deformation.	Major inspection

C.6 Drain Lines

Drain lines should be visually inspected for signs of leakage, corrosion, and physical damage to the drain lines. A minimum interval for the drain line leak check is prior to a planned extended outage (HGP or major inspection) to test for proper isolation. A more frequent interval could be supported by the site’s performance program.

D
PM TASKS AND FREQUENCIES FOR I&C COMPONENTS

D.1 Introduction

The purpose of this section is to provide PM guidance for I&C components typically installed in a steam bypass system at a CTCC facility. The scope of individual/discrete I&C components covered in this section is summarized in Table D-1.

Table D-1
Scope of I&C components

I&C Component	Sections
Dc power supply	D.2
I/P and E/P transducer	D.3
Pneumatic controller	D.4
Positioner	D.5
Pressure regulator	D.6
Pressure sensor and transmitter	D.7
Pressure switch	D.8
Signal conditioner	D.9
Temperature switch	D.10

Section 4.3 provides technical justifications for variance from the PM tasks and frequencies provided for each discrete I&C component taking into account system design, typical failure history, outage schedules, and operating conditions. Although it is left up to the user to assemble these tasks into a useful craft instruction, sample job plans are provided in Section 5 of this report to assist in this aspect of maintenance planning.

D.2 DC Power Supply

D.2.1 PM Tasks and Frequencies

Table D-2 provides an overview of the PM tasks and frequencies for a direct current (dc) power supply.

Table D-2
PM tasks and frequencies for a DC power supply

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Monitor alternating current (ac) ripple and dc output voltage	D.2.2.1	18M	NA
Refurbishment	D.2.2.2	6Y	NA

M = months Y = years NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following sections.

D.2.2 PM Tasks

D.2.2.1 Monitor AC Ripple and DC Output Voltage

Measuring the ac ripple and dc output voltages is done to provide advance indication of the need to replace the capacitor, especially when random effects cause breakdown earlier than the scheduled replacement interval. The interval is not well determined by the failure mode data, but there does not seem to be opportunity to extend the interval if protection is to be even modestly successful against the random events.

D.2.2.2 Refurbishment

The Refurbishment task is performed to prevent wear-out failures. The intervals are definitely determined by the failure mechanism data.

The Refurbishment task should include the following:

- Checking for any discolored, damaged, or loose connections
- Checking for any discolored (indicative of overheating, overstress, or leakage) or damaged components
- Checking that solder connections appear to be intact and show no evidence of cold soldering or over heating
- Checking that printed circuit lands are intact and that the printed circuit boards (PCBs) shows no signs of overheating or other visual indications of damage
- Inspecting transformers for signs of overheating, usually leakage or discoloration
- Replacing all electrolytic capacitors, if present

- Inspecting, cleaning, and repairing, as necessary, all terminal strips and PCB connectors and connections
- Replacing cooling fans
- Evaluating and considering replacement of regulator circuits
- Performing voltage regulation tests prior to returning to service

D.3 I/P and E/P Transducer

D.3.1 PM Tasks and Frequencies

Table D-3 provides an overview of the PM tasks and frequencies for an I/P and E/P transducer.

Table D-3
PM tasks and frequencies for an I/P and E/P transducer

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Calibration	D.3.2.1	18M	NA
Scheduled Replacement	D.3.2.2	6Y	NA
Functional Testing	D.3.2.3	AR	NA

AS = as required NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.3.2 PM Tasks

D.3.2.1 Calibration

Calibration ensures that the device is performing within specification and confirms traceability to National Institute of Standards and Technology (NIST) standards in demonstrating the absolute accuracy of the output. The interval is clearly determined by the failure timing data.

Calibration should include the following:

- A visual inspection to check for tightness of the connections, general cleanliness, proper mechanical alignments, free movement of the mechanical assembly, evidence of air leaks, damaged tubing, corroded edge connectors, overheated components on printed circuit boards, leaking capacitors, and cracked terminations and cases
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.3.2.2 Scheduled Replacement

Scheduled Replacement is done to prevent failure from the aging of elastomers and, to some degree, failures of other subcomponents. The interval is strictly determined by failure timing data.

D.3.2.3 Functional Testing

The Functional Testing task is performed as a go/no-go test to identify the need for calibration or other action. The interval is not well determined by the failure timing data, but the task needs to be done frequently to be effective.

D.4 Pneumatic Controller

D.4.1 PM Tasks and Frequencies

Table D-4 provides an overview of the PM tasks and frequencies for a pneumatic controller.

Table D-4
PM tasks and frequencies for a pneumatic controller

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Operator Rounds	D.4.2.1	1S	1S
Calibration	D.4.2.2	18M	18M
Channel Check	D.4.2.3	AR	AR
Scheduled Replacement	D.4.2.4	10Y	10Y
Internal Inspection	D.4.2.5	AR	AR

S = shift M = months Y = years AR = as required

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.4.2 PM Tasks

D.4.2.1 Operator Rounds

The Operator Rounds task is done to detect gross failure of the device. Personnel performing the Operator Rounds task generally look and listen for large leaks of air, as well as loose, damaged, or missing fasteners, abnormal pressures, alarms, and mispositioned devices.

For pneumatic controllers, it includes essentially a channel check looking for indication that the setpoint, the process input, and controller output are reasonable compared with a redundant indication.

Additionally, controller knob functions will be exercised during normal use and their correct functioning verified.

D.4.2.2 Calibration

Calibration assures that the device is performing within specification and confirms traceability to NIST standards in demonstrating the absolute accuracy of the output. The interval is determined by the failure timing data.

Calibration should include the following:

- A visual inspection or walkdown, as far as practical, of the instrument's sensing line looking for damaged, crushed, or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors
- Verifying and adjusting, as needed, the device’s zero span
- Verifying and adjusting, as needed, the device’s linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.4.2.3 Channel Check

The purpose of the Channel Check task is to identify any channel that is behaving abnormally. The interval is usually sufficiently frequent to provide protection against random failure mechanisms.

A channel check provides an opportunity make a gross comparison between like instruments monitoring the same process condition and ensures that the output of the device is correct and typically within a few percentage points of the medium channel or has not drifted significantly from previously noted values.

D.4.2.4 Scheduled Replacement

The Scheduled Replacement task prevents long-term wear-out failures. The interval is clearly determined by the failure mode data.

D.4.2.5 Internal Inspection

The Internal Inspection task is performed to prevent failures resulting from mechanical wear and binding and elastomer aging. The task would be effective at a three-year interval.

The Internal Inspection task consists of vendor-specified maintenance to clean, lubricate, and inspect all subcomponents, and it involves a high level of disassembly. It should include the following:

- Inspecting for loose, damaged, or missing parts
- Inspecting the condition of all elastomers for evidence of age-related wear, hardening, and loss of elastic properties (Some or all elastomeric components may be replaced at this time.)
- Inspecting the general condition of all internal parts looking for excessive wear, damage, distortion
- Checking for evidence of corrosion and air leakage
- Cleaning and lubricating all parts as required

Although the instrument is dismantled to the piece-part level, this task is often less than a rebuild, although similar to it, because many of these parts will not automatically be renewed, especially if the task is performed at the same time as calibration.

D.5 Positioner

D.5.1 PM Tasks and Frequencies

Table D-5 provides an overview of the PM tasks and frequencies for a positioner.

Table D-5
PM tasks and frequencies for a positioner

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Calibration	D.5.2.1	18M	18M
Diagnostic Testing	D.5.2.2	18M	18M
Rebuild or Replace	D.5.2.3	5Y	5Y
Functional Testing	D.5.2.4	AR	AR

M = months Y = years AR = as required

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following sections.

D.5.2 PM Tasks

D.5.2.1 Calibration

Calibration ensures that the positioner is performing within specification. The intervals are fairly clearly determined by the underlying failure time data.

Calibration should include the following:

- A visual inspection to check for tightness of the connections, general cleanliness, proper mechanical alignments, free movement of the mechanical assembly, evidence of air leaks, and damaged tubing
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.5.2.2 Diagnostic Testing

Diagnostic Testing provides assurance that the total performance of the valve as a whole (including positioner, booster, actuator, and so forth) is within specifications. The intervals are clearly determined by the failure time data.

Diagnostic Testing (such as Flow Scan) is usually performed as a part of valve testing, which measures characteristics such as the following:

- Total friction, packing drag, and so forth
- Seat load, lift-off, and seating points
- Travel
- Available actuator thrust/torque
- Accessory signatures
- Air pressures
- Spring rate
- Spring preload

This task is performed with the valve off-line, but it is done in place and is relatively nonintrusive.

D.5.2.3 Rebuild or Replace

The Rebuild or Replace task prevents wear-out failures of subcomponents, including elastomers. The intervals are clearly determined by the failure mode data.

The Rebuild or Replace task should consist of inspection for damage, overheating of components, corrosion, evidence of air leakage, tightness and conditional of all electrical and mechanical connections, loose, or missing parts. The entire device may be replaced with a refurbished or new device at this time.

D.5.2.4 Functional Testing

The Functional Testing task is primarily a failure finding task. The interval should be short to enable the testing to address random sources of failure effectively.

D.6 Pressure Regulator

D.6.1 PM Tasks and Frequencies

Table D-6 provides an overview of the PM tasks and frequencies for a pressure regulator.

Table D-6
PM tasks and frequencies for a pressure regulator

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Set-Point Check	D.6.2.1	6Y	NA
Filter Replacement	D.6.2.2	AR	NA
Drain and Blowdown	D.6.2.3	AR	NA
Rebuild or Replace	D.6.2.4	15Y	NA

Y = years AR = as required NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.6.2 PM Tasks

D.6.2.1 Set-Point Check

The Set-Point Check task ensures that the regulator is operating within specifications. The interval is strongly determined by the failure mode data.

Set-point verification should include the following:

- Visually inspecting for loose, damaged, or missing hardware and parts, or corrosion
- Performing set-point verification test at the devices operational setpoints and comparing to historical data
- Making adjustments as required

D.6.2.2 Filter Replacement

The Filter Replacement task is done to prevent clogging of the filter.

D.6.2.3 Drain and Blowdown

The Drain and Blowdown task is done to prevent clogging of the filter. It should include the following:

- Removal of entrapped water from low point drains
- Inspection and cleaning of the strainer and traps, if present
- Inspection for evidence of corrosion and leakage

D.6.2.4 Rebuild or Replace

The Rebuild or Replace task prevents failure from the aging of elastomers. The interval is clearly determined by the failure timing data.

The Rebuild or Replace task should consist of inspection for damage, overheating of components, corrosion, evidence of air leakage, tightness and conditions of all electrical and mechanical connections, and loose or missing parts. The entire device may be replaced with a refurbished or new device at this time.

D.7 Pressure Sensor and Transmitter

D.7.1 PM Tasks and Frequencies

Table D-7 provides an overview of the PM tasks and frequencies for a pressure sensor and transmitter.

Table D-7
PM tasks and frequencies for a pressure sensor and transmitter

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Operator Rounds	D.7.2.1	1S	NA
Calibration	D.7.2.2	18M	NA
Channel Check	D.7.2.3	AR	NA
Scheduled Replacement	D.7.2.4	15Y	NA

S = shift M = months
Y = years AR = as required NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.7.2 PM Tasks

D.7.2.1 Operator Rounds

The Operator Rounds task is mainly focused on detecting air leaks from components associated with the sensing lines.

The Operator Rounds task generally detects large leaks of air, as well as loose, damaged, or missing fasteners, abnormal pressures, and alarms.

D.7.2.2 Calibration

Calibration ensures that the device is performing within specification and confirms traceability to NIST standards in demonstrating the absolute accuracy of the output. The intervals are fairly clearly determined by the underlying failure time data.

Calibration should include the following:

- A visual inspection or walkdown, as far as practical, of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.7.2.3 Channel Check

The purpose of the Channel Check task is to identify any channel that is behaving abnormally. The interval is usually sufficiently frequent to provide protection against random failure mechanisms.

The Channel Check task provides an opportunity to make a gross comparison between like instruments monitoring the same process condition, and it ensures that the output of the device is correct and typically within a few percentage points of the medium channel or has not drifted significantly from previously noted values.

D.7.2.4 Scheduled Replacement

The Scheduled Replacement task is done to prevent failure from the end of life of subcomponents. The interval is fairly closely determined by failure timing data.

The Scheduled Replacement task should replace the entire sensor and transmitter as a complete package.

D.8 Pressure Switch

D.8.1 PM Tasks and Frequencies

Table D-8 provides an overview of the PM tasks and frequencies for a pressure switch.

Table D-8
PM tasks and frequencies for a pressure switch

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Operator Rounds	D.8.2.1	1S	NA
Calibration	D.8.2.2	18M	NA
Scheduled Replacement	D.8.2.3	10Y	NA

S = shift M = months Y = years NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.8.2 PM Tasks

D.8.2.1 Operator Rounds

The Operator Rounds task focuses on detection of leaks and visible damage.

The Operator Rounds task generally detects large leaks of air, as well as loose, damaged or missing fasteners, abnormal pressures, and alarms.

D.8.2.2 Calibration

Calibration ensures that the device is performing within specification, and confirms traceability to NIST standards in demonstrating the absolute accuracy of the output. The intervals are fairly clearly determined by the underlying failure time data.

Calibration should include the following:

- A visual inspection or walkdown, as far as practical, of the instrument's sensing line, looking for evidence of air leaks; damaged, crushed or broken tubing; loose tubing connections; loose or missing tubing clamps; or corroded tubing and connectors
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.8.2.3 Scheduled Replacement

The Scheduled Replacement task is done to prevent failure from the end of life of various subcomponents. The interval is strictly determined by the failure timing data.

D.9 Signal Conditioner

D.9.1 PM Tasks and Frequencies

Table D-9 provides an overview of the PM tasks and frequencies for a signal conditioner.

Table D-9
PM tasks and frequencies for a signal conditioner

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Calibration	D.9.2.1	18M	NA
Channel Check	D.9.2.2	AR	NA
Scheduled Replacement	D.9.2.4	15Y	NA

M = months Y = years AR = as required NA = not applicable

Detailed implementation guidance for each of the PM tasks listed in the template is provided in the following section.

D.9.2 PM Tasks

D.9.2.1 Calibration

Calibration ensures that the device is performing within specification and confirms traceability to NIST standards in demonstrating the absolute accuracy of the output. The intervals are not clearly determined by the underlying failure time data.

Calibration should include the following:

- A visual inspection to check for tightness of the connections, general cleanliness, corroded edge connectors, overheated components on printed circuit boards, leaking capacitors, and cracked terminations and cases
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.9.2.2 Channel Check

The purpose of the Channel Check task is to identify any channel that is behaving abnormally. The interval is usually sufficiently frequent to provide protection against random failure mechanisms.

The Channel Check task provides an opportunity make a gross comparison between like instruments monitoring the same process condition and ensures that the output of the device is correct and typically within a few percentage points of the medium channel or has not drifted significantly from previously noted values.

D.9.2.3 Scheduled Replacement

The Scheduled Replacement task done to minimize late life wear-out failures. The intervals are at the high limit of what is suggested by the failure timing data, providing little room for interval extension.

The Scheduled Replacement task should replace, as a minimum, all electrolytic capacitors. However, consideration may be given to replacing the entire signal conditioner with a completely refurbished or new device, especially if obsolescence is an issue.

D.10 Temperature Switch

D.10.1 PM Tasks and Frequencies

Table D-10 provides an overview of the PM tasks and frequencies for a temperature switch.

Table D-10
PM tasks and frequencies for a temperature switch

Task Name	Section	High-Duty Cycle	Low-Duty Cycle
Operator Rounds	D.10.2.1	1S	NA
Calibration	D.10.2.2	18M	NA
Scheduled Replacement	D.10.2.3	12Y	NA

S = shift M = months Y = years NA = not applicable

Implementation guidance for each of the PM tasks listed in the template is provided in Section D.10.2.

D.10.2 PM Tasks

D.10.2.1 Operator Rounds

The Operator Rounds task focuses on visible detection of loss of fill from the bulb and capillary.

The Operator Rounds task generally detects large leaks of air, as well as loose, damaged or missing fasteners, abnormal pressures, and alarms.

D.10.2.2 Calibration

Calibration ensures that the device is performing within specification and confirms traceability to NIST standards in demonstrating the absolute accuracy of the output. The intervals are fairly clearly determined by the underlying failure time data.

Calibration should include the following:

- A visual inspection to check for tightness of the connections, general cleanliness, overheated components, and cracked terminations and cases
- Verifying and adjusting, as needed, the device's zero span
- Verifying and adjusting, as needed, the device's linearity and hysteresis

It is strongly suggested that a minimum five-point calibration response check be performed; a nine-point check should be considered for more critical devices.

D.10.2.3 Scheduled Replacement

The Scheduled Replacement task is done to prevent failure from the end-of-life of various subcomponents. The interval is strictly determined by the failure timing data.

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