

# Air Preheater Maintenance Guideline

2015 TECHNICAL REPORT



# **Air Preheater Maintenance Guideline**

**3002006035**

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# PRODUCT DESCRIPTION

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## Background

Industry experience suggests that air preheaters have a wide array of maintenance issues that directly affect the thermal efficiency of fossil-fueled power plants. The following factors prompted EPRI member utilities to request the development of this maintenance guide:

- Failures or premature wear of air preheater components
- Lack of documented preventive maintenance practices
- A need to familiarize newer engineers with current industry preventive maintenance practices for air preheaters
- A need to develop the basis for a new template in the *EPRI Preventive Maintenance Basis Database (PMBD)* (3002005428)

## Objectives

The primary purpose of this report is to provide guidance to fossil-fuel power plant owners to properly operate and care for the equipment installed in their regenerative air preheater systems. The guidance will promote safe, efficient, and cost-effective operation and maintenance of major types of equipment that are unique to fossil-fuel power generation facilities. The benefit to the public is enabling fossil-fuel power plants to efficiently produce low-carbon electricity at minimal cost with high reliability.

## Approach

The Electric Power Research Institute (EPRI) worked with plant owners, operators, original equipment manufacturers, and vendors to develop tactical guidance to address common failure mechanisms of air preheaters and to provide guidance for appropriate preventive maintenance, repair, replacement, and troubleshooting of this major component.

## Results

This report provides comprehensive insights for fossil-fuel power plants to effectively address ongoing maintenance issues. The report provides an overview of design parameters and describes air preheaters and their functions. The focus of the report is to provide site personnel with insights into various failure mechanisms and detailed guidelines for performing preventive maintenance on the air preheaters. The report also provides guidance on troubleshooting, the repair or replacement of system components, and those components that are typically repaired or refurbished on site.

### **Applications, Value, and Use**

This report can be used for in-house development of maintenance crews, to provide training for contract maintenance travelers to overcome loss of knowledge caused by turnover, and to provide a consistent maintenance program for air preheaters. By developing a reliability-based program using standard guidelines, owners can use this guide as an added strength in bidding maintenance to a larger resource pool. It can also be used as a basis for specifying reliable long-term maintenance contracts and to provide assistance in stabilizing projected maintenance costs.

### **Keywords**

Air preheater

Preventive maintenance

Repair and replacement

Rotating plate

Troubleshooting

## **ABSTRACT**

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Industry experience suggests that air preheaters have a wide array of maintenance issues that directly affect the thermal efficiency of fossil-fueled power plants. The Electric Power Research Institute (EPRI) worked with plant owners, operators, original equipment manufacturers, and vendors to develop tactical guidance to address common failure mechanisms of air preheaters and to provide guidance for appropriate preventive maintenance, repair, replacement, and troubleshooting of this major component. This report provides comprehensive insights for fossil-fuel power plants to effectively address ongoing maintenance issues.



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# 1

## INTRODUCTION

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This guideline provides component-level information regarding the maintenance of major components associated with the rotary-plate regenerative air preheater typically installed at a fossil-fuel power generating facility. It combines those recommendations offered by major equipment manufacturers with lessons learned from owner/operators of fossil-fuel power plants.

### 1.1 Background and Scope

#### 1.1.1 Background

Industry experience suggests that air preheaters have a wide array of maintenance issues that have a direct effect on the thermal efficiency of fossil-fueled power plants. The following factors prompted EPRI member utilities to request the development of this maintenance guide:

- Failures or premature wear of air preheater components
- Lack of documented PM practices
- A need to familiarize newer engineers with current industry PM practices for air preheaters
- Develop the basis for a new template in the EPRI Preventive Maintenance Basis Database (PMBD)

#### 1.1.2 Scope of Equipment and Boundaries

The guidance provided in this report primarily focuses on rotating-plate regenerative type air preheaters due to their predominance in fossil-fuel power plants. As such, stationary-plate and tubular type air preheaters are not discussed in great detail. The rotating-plate regenerative type air preheater components that are discussed in this report include the following:

- Heat absorbing elements
- Support thrust bearings
- Thrust bearings lubrication system, including lubrication circulation system (pump, instrumentation, electric motor, couplings, cooler, filter, and associated piping)
- Radial guide bearings
- Radial guide bearings lubrication system, including lubrication circulation system (pump, instrumentation, electric motor, couplings, cooler, filter, and associated piping)
- Radial supports, cages and rotor seal plates
- Rotor drive unit, including gearbox/speed reducer, couplings, pin rack, pinion, electric motor, and auxiliary driver (for example, air motor)

- Plate cleaning systems
  - Soot blower, including nozzles
  - Water wash, including nozzles, piping and mechanical traversing mechanisms

Components that are excluded from the scope of this report include the following:

- AC electric power supply systems
- Compressed air supply systems
- Wash water supply systems
- Induced draft or forced draft fans
- Boiler components
- Fly ash collection and removal systems

## **1.2 Purpose**

The primary purpose of this report is to provide guidance to fossil-fuel power plant owners to properly operate and care for the equipment installed in their regenerative air preheater 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 fossil-fuel power generation facilities. The benefits to the public are enabling fossil-fuel power plants to efficiently 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 technical report. The figure identifies key sections in the report that provide guidance to owners to effectively address component maintenance issues.

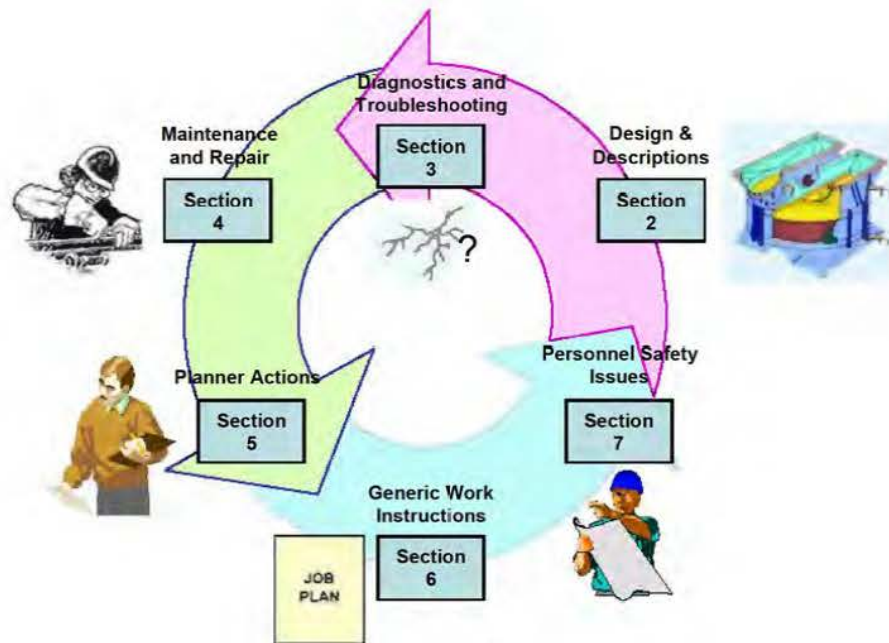


Figure 1-1  
Scope and Content of this EPRI Report

## 1.4 Listing of Key Points

*Appendix C* 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 if 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. Electric Power Research Institute (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, 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 personal injury, prevent equipment damage, and/or improve the efficiency and effectiveness of the task.



**Key O&M Cost Point**

Emphasizes information that will result in overall reduced costs and/or an increase in revenue through additional or restored energy production.



**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

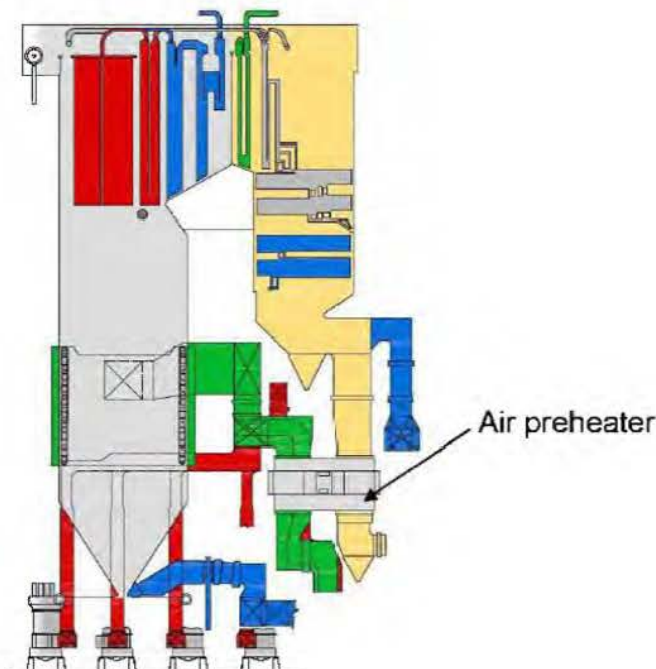
## DESIGN AND DESCRIPTIONS

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The purpose of this section is to provide plant operations, maintenance and engineering personnel with an overview of a typical air preheater installed in a fossil-fuel power plant.

### 2.1 Introduction

An air preheater (APH) is generic terminology used to describe a device designed to preheat combustion air that is used in a fuel-burning furnace. The purpose of the preheater is to increase the thermal efficiency of the furnace. At fossil-fuel power plants, the air preheater increases the steam generator's thermal efficiency by preheating the combustion air with heat recovered from the hot combustion flue gases. Figure 2-1 provides the typical location of the air preheater assembly at a fossil-fuel power plant.



**Figure 2-1**  
**Typical Location of an Air Preheater**

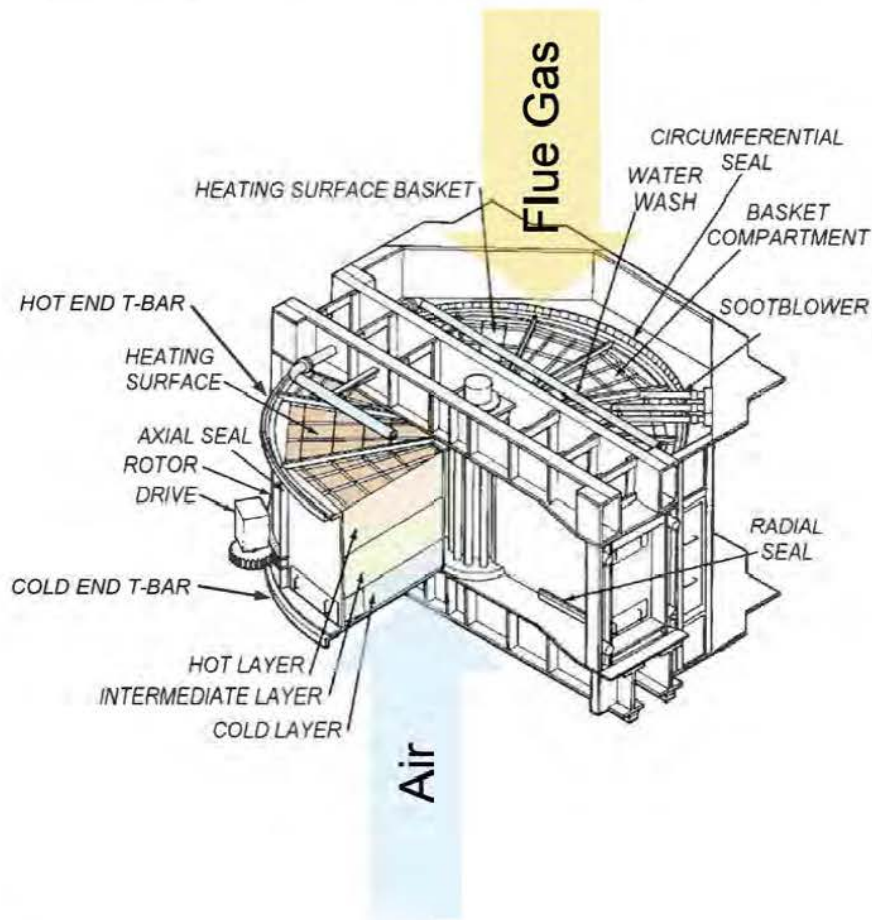
The incoming hot flue gas (shown with the yellow ducts) can transfer some of its heat in the air preheater assembly to preheat combustion air (shown with the green ducts), and to preheat primary air to the coal pulverizers (shown with the red ducts).

The two most common types of regenerative air preheaters installed at fossil-fuel power plants are the rotating-plate regenerative air preheater and the stationary-plate regenerative air preheater. The rotating-plate design was invented by Fredrik Ljungström, a Swedish engineer, and is often referred to as a Ljungström air preheater. The stationary-plate regenerative air preheater design is commonly known as a “Rothemuhl” because Rothemühle is the German city where the original manufacturer produced them for many years.

As noted earlier, the guidance provided in this report primarily focuses on rotating-plate regenerative type air preheaters due to their predominance in fossil-fuel power plants. As such, stationary-plate and tubular type air preheaters are not discussed in great detail.

## 2.2 Rotating-Plate Air Preheater Designs

Figure 2-2 illustrates a typical arrangement and components of a Ljungström air preheater.



**Figure 2-2**  
Typical Arrangement and Components of a Ljungström Air Preheater

A rotating-plate air preheater absorbs waste heat from flue gas, and then transfers this heat to incoming cold air by means of continuously rotating heat transfer elements of specially-formed metal plates. Thousands of these high-efficiency elements are spaced and compactly arranged within sector-shaped compartments of a radially-divided cylindrical shell, often referred to as the rotor. A typical rotating-plate air preheater design consists of a central rotating-plate element installed within a circular casing that is divided into sectors. The number of sectors can vary depending on how the circular rotating element is divided.

The housing surrounding the rotor is provided with duct connections at both ends, and is adequately sealed by radial and circumferential sealing members. These members form an air passage through one half of the preheater, and a gas passage through the other.

As the rotor slowly revolves, the mass of elements alternately through the gas and air passages, heat is absorbed by the element surfaces passing through the hot gas stream. Then, as these same surfaces are carried through the air stream, they release the stored-up heat. This heat transfer greatly increases the temperature of the incoming combustion or process air.

### **2.2.1 Tri-Sector Design**

The tri-sector design has three sectors, and the steam generators hot flue gas flows through the largest sector. This largest sector often encompasses about half of the cross-section of the casing and transfers a portion of its heat into the heat-absorbing material within the rotating wheel element. The cooled flue gas is discharged and often routed to further treatment in dust removal and other equipment before being vented from the flue gas stack. Ambient air is blown through the second, smaller sector by a forced-draft fan. The ambient air absorbs heat from the elements that were heated by the flue gas as it rotates through that smaller sector. This heated air then flows into the steam generating furnace as preheated combustion air. The third sector is often the smallest one, and it is used to heat a portion of the ambient air which is discharged and routed into the coal pulverizers. This is often referred to as primary air flow for the coal pulverizers, and is used to transport the coal-air mixture to the coal burners. In summary, the total air heated provides heated primary combustion air for the boiler, heated air to remove moisture from the pulverized coal, and primary air for transporting the pulverized coal to the coal burners.

Figure 2-3 illustrates an exploded view of a typical rotating-plate preheater design.

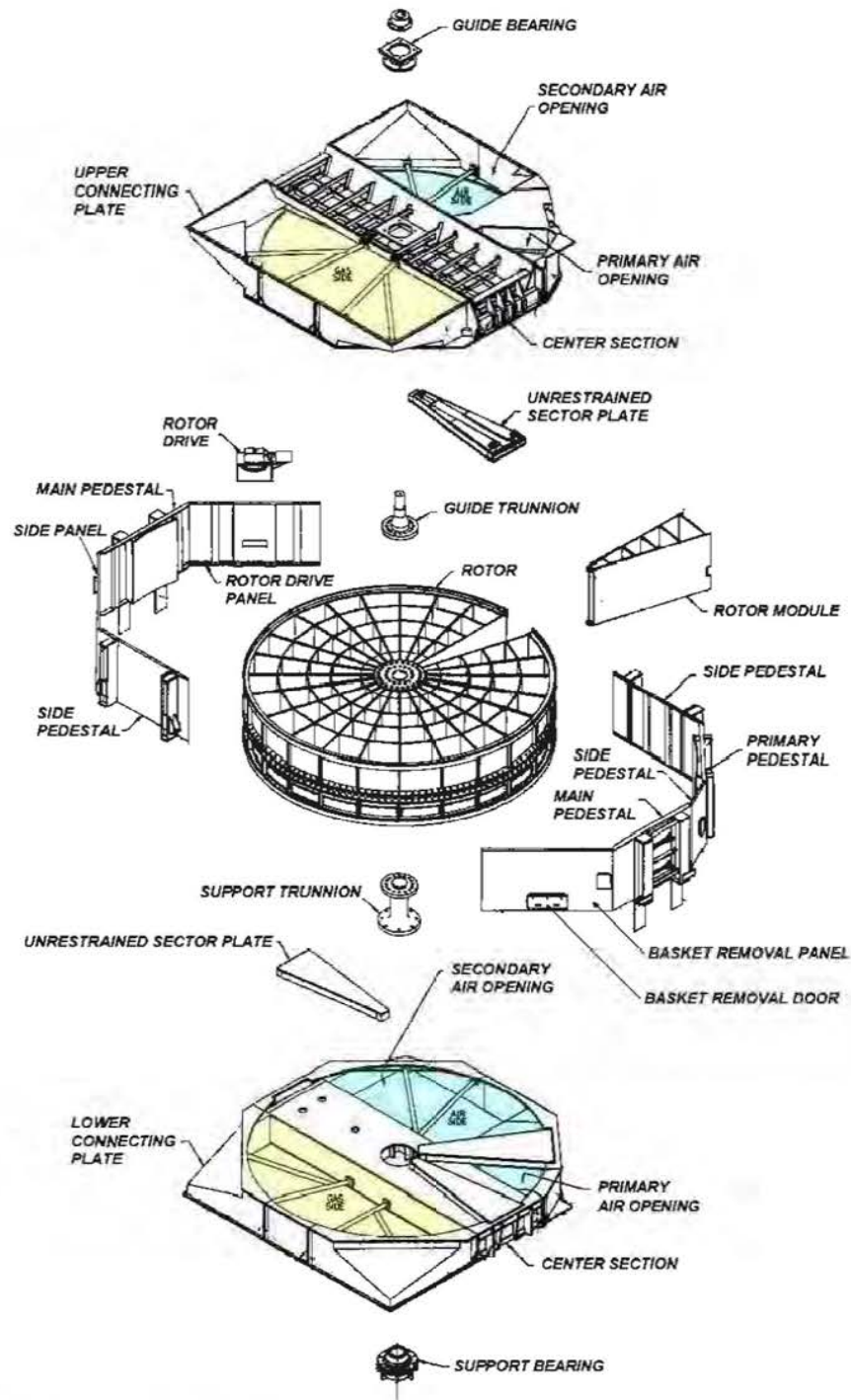


Figure 2-3  
Exploded View of a Ljungström Air Preheater

### **2.2.2 Bi-Sector Design**

The bi-sector design is often used in thermal power plants that burn fuels such as oil or gas that would not require pulverizing or removal of moisture. The bi-sector design air preheater does not include a separate section for extracting primary air to the boiler. Instead, a portion of the secondary air is diverted to a primary air duct and used for that purpose.

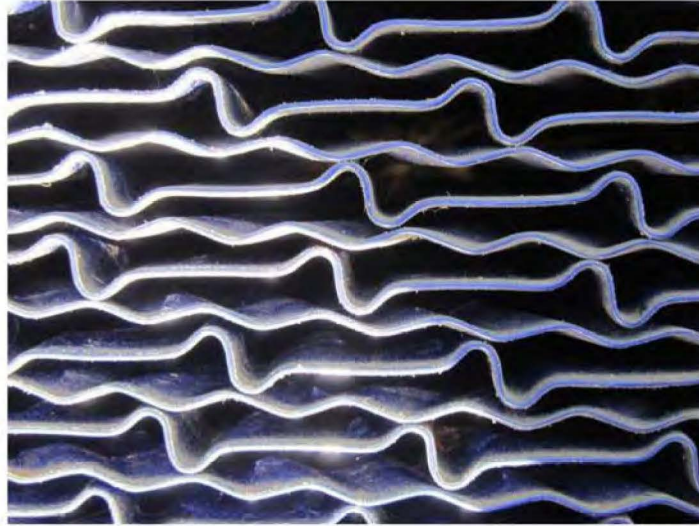
## **2.3 Rotating-Plate Air Preheater Components**

### **2.3.1 Heat Absorbing Elements**

The heat-absorbing elements in the rotating wheel assembly typically consist of vertical corrugated plates pressed into steel baskets. There must be sufficient space between the plates for the hot flue gas to pass through. The plate elements are typically corrugated to provide more surface area for the heat transfer to occur and to provide rigidity. Figures 2-4 through 2-6 illustrate two commonly-used corrugation patterns for the heating elements. The double undulated heating elements are most commonly installed in the hot and intermediate layers of the rotor. The notched flat heating elements are typically installed in the cold layer of the rotor.



**Figure 2-4**  
**Double Undulated Heating Element**



**Figure 2-5**  
**Cross-Sectional Double Undulated Heating Element Pattern**



**Figure 2-6**  
**Notched Flat Heating Element**

Figure 2-7 illustrates how the heating elements are arranged in layers so as to optimize the heat transfer of the rotor. The baskets are typically designed so they can be removed and replaced as needed.

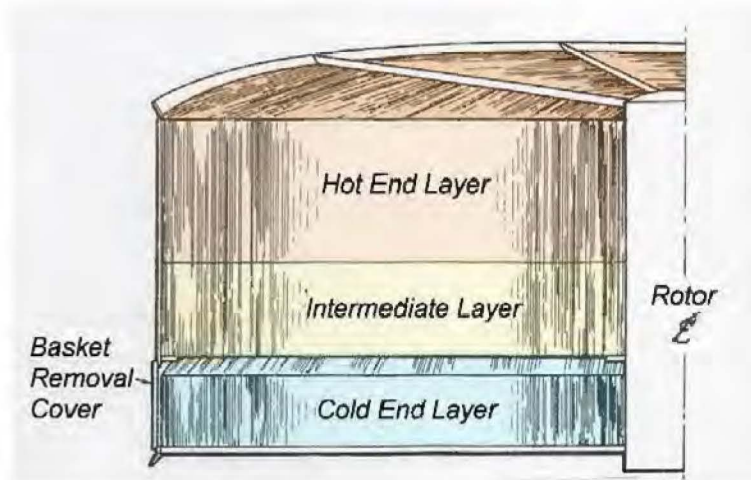


Figure 2-7  
Heating Element Layers



**Key O&M Cost Point**

Industry experience suggests keeping the cold end thick enough to cover all acid condensation but small enough to physically handle. This allows for better soot blowing effectiveness. Basket design is critical in balancing maintenance, replacement, and soot blowing activities.

Figure 2-8 illustrates a double-undulated (hot end layer) basket of heating elements that have undergone significant distortion, erosion and corrosion.



Figure 2-8  
Air Preheater Heating Element Failure

There are many different design profiles for basket heating elements, each with its own designation. For example Alstom designated various basket profiles by DNF, DN7, DL7, FNC, DU2.78, NF6, and so on.



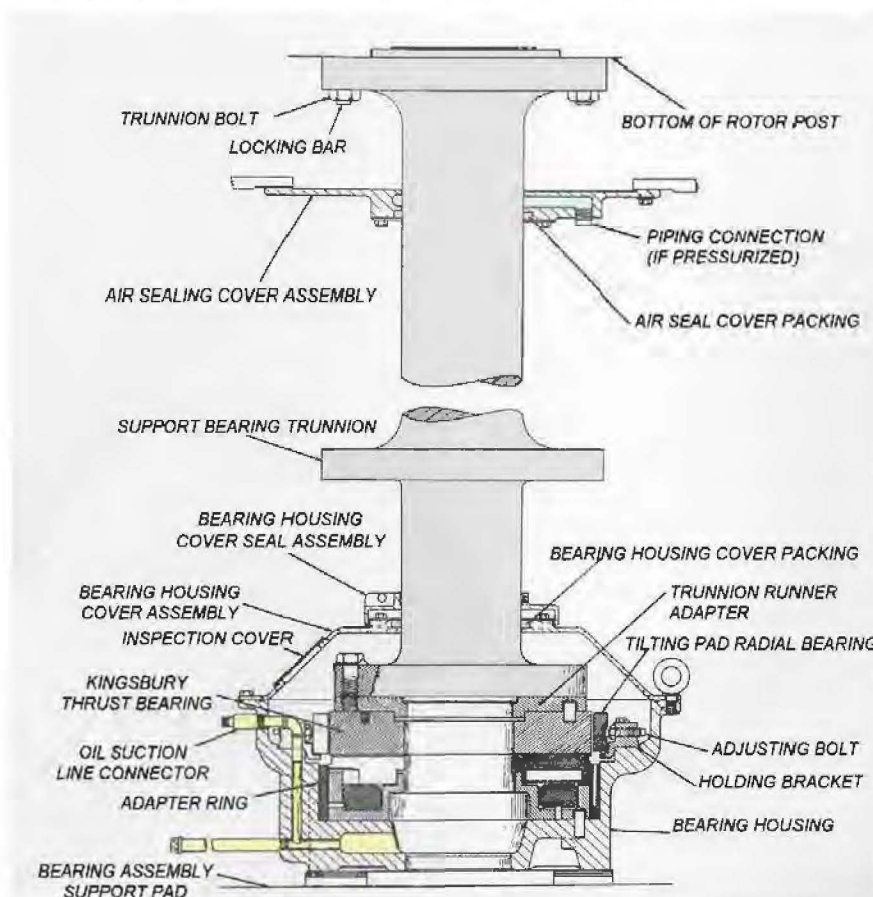
### Key Technical Point

The optimum design profile of the basket heating elements should be selected based on parameters such as the type of fuel, air temperature differential, heat transfer requirements and flue gas particulate composition. Selection of the optimum profile is typically performed during the design phase of the air preheater by the equipment manufacturer.

### 2.3.2 Support Thrust Bearings

The vertical shaft that rotates the heating element rotor assembly is supported on thrust bearings at the lower end. The load is transmitted to the thrust bearing by a trunnion, bolted to the lower end of the rotor post. The bearing assembly is mounted on a support beam.

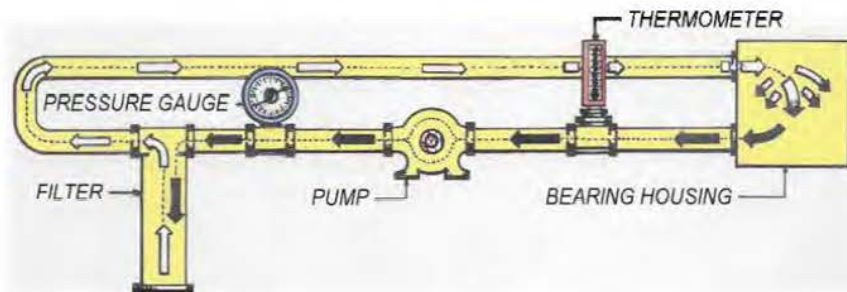
Figure 2-9 illustrates a typical configuration of a support thrust bearing assembly.



**Figure 2-9**  
**Support Thrust Bearing Configuration**

### 2.3.3 Thrust Bearings Lubrication System

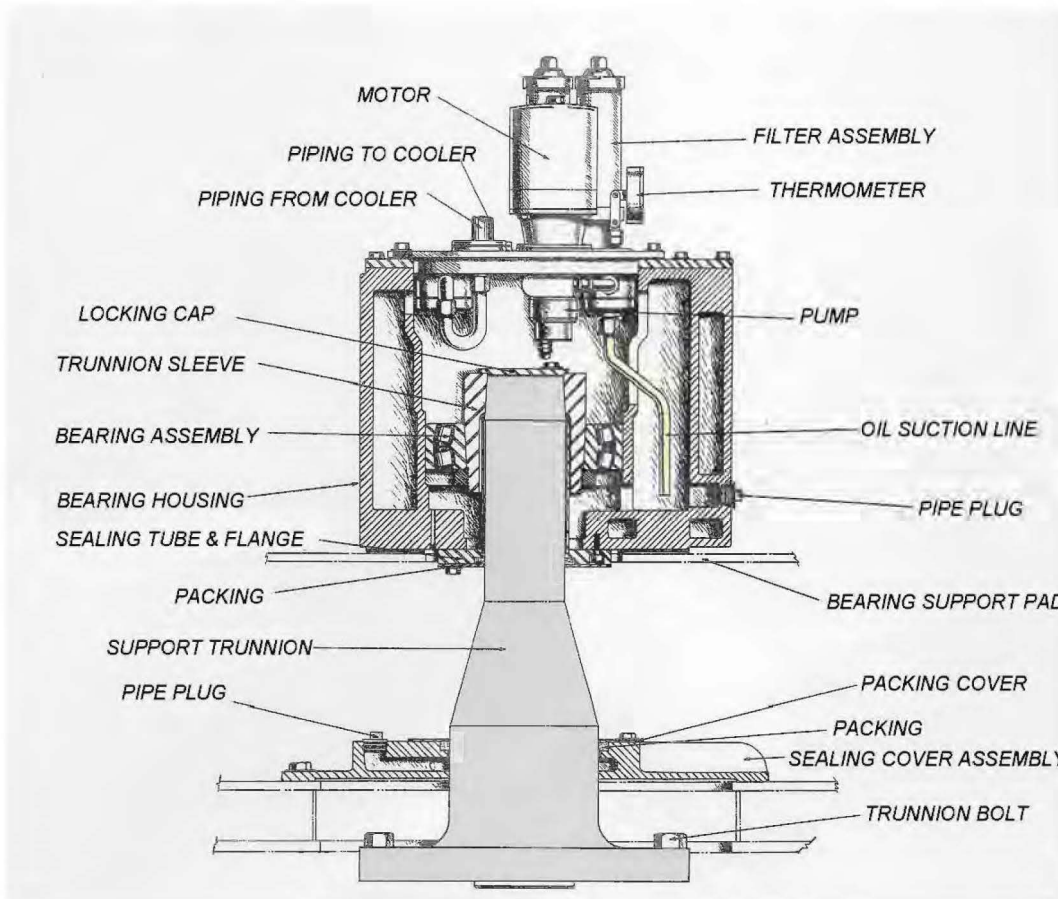
The thrust bearings are typically lubricated with an oil bath that is cooled by water circulating in coils inside the oil bath. Cooling of the bottom end of the shaft is most critical since that is where the hot flue gas enters the air preheater assembly. The oil circulating system is designed to supply the support bearing with a bath of continuously-cleaned oil at the proper viscosity. To accomplish this, the bearing oil supply is circulated by means of a motor-driven pump through an external filtering system. A thermostat may be used to limit the operation of the system to temperatures which will ensure against overloading the pump or motor as a result of high oil viscosity. Figure 2-10 illustrates the path which the oil takes as it passes through this system. Oil is drawn from the bearing housing by the pump, into the filter, and back to the bearing housing.



**Figure 2-10**  
Support Thrust Bearing Lubrication Flow Path

### 2.3.4 Radial Guide Bearings

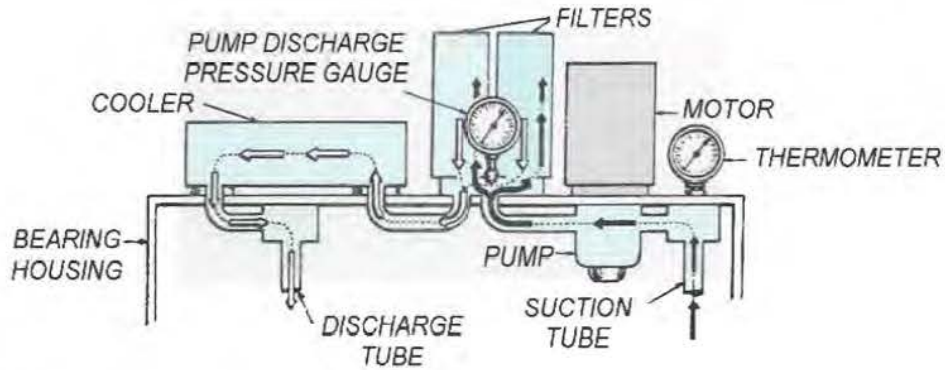
Because the top end of the rotor shaft is cooler, it typically is equipped with a simple roller bearing to hold the shaft in its vertical position. To guide the upper end of the rotor, a guide trunnion is bolted to the face of the rotor post. The position of this trunnion is maintained by the radial guide bearing assembly mounted on a guide beam. Figure 2-11 illustrates a typical configuration of a guide bearing assembly.



**Figure 2-11**  
**Radial Guide Bearing Configuration**

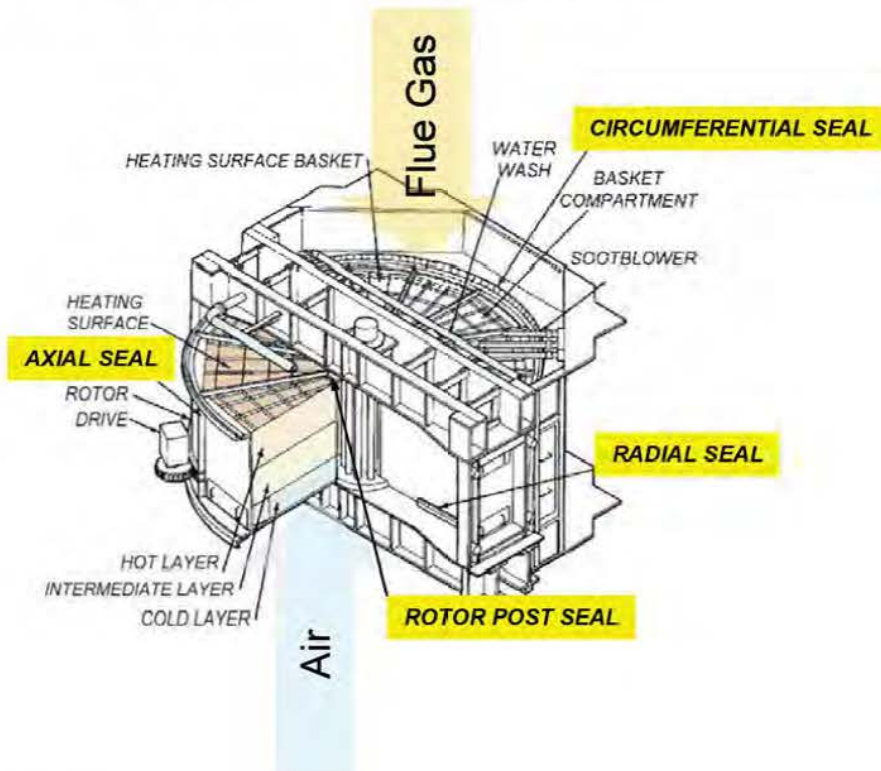
### **2.3.5 Radial Guide Bearings Lubrication System**

The radial guide bearings are typically lubricated using an integral-type oil circulating system that is designed to supply the guide bearing with a bath of clean oil at a satisfactory viscosity. The oil is typically pumped from the bearing housing, through two parallel filters to a cooler, and then discharged to the bearing. A thermostat may be used to limit the operation of the system to temperatures which will ensure no overload of the pump or motor as a result of high oil viscosities. Figure 2-12 illustrates a typical flow path for an integral-type oil circulating system.



**Figure 2-12**  
Radial Guide Bearing Lubrication Flow Path

### 2.3.6 Radial Supports, Cages and Rotor Seal Plates



**Figure 2-13**  
Air Preheater Seal Plate Locations

Attached to the rotating shaft are radial supports and cages. These structural devices provide structural integrity by holding the corrugated plate baskets in position. To minimize leakage of flue gas or air between the sectors and around the rotor, radial, axial, post and circumferential seal plates are typically provided. Figure 2-13 illustrates the typical locations of these three types of seals.

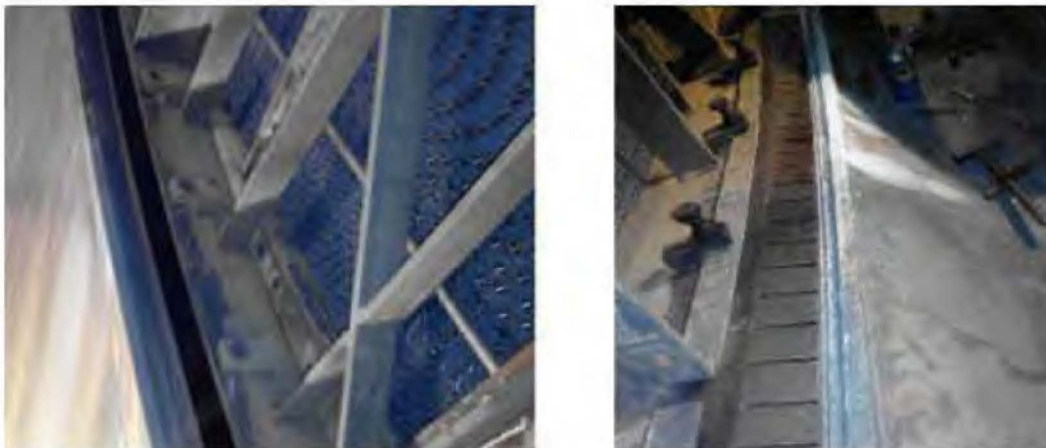
Figure 2-14 illustrates typical configuration for a radial seal plates.



**Figure 2-14**  
**Radial Seal Plates**

Hot and cold end radial seals are typically attached to each diaphragm of the rotor and are set at a specified clearance from the sector plates which separate the air and gas streams. The seals provided at the rotor post are set to operate with minimum clearance with respect to the horizontal sealing surface of the sector plate center section.

The axial and circumferential seals provide sealing between the periphery of the rotor and sealing surface of the connecting plate and/or the preheater housing. Seal designs allow for field adjustment to necessary clearances. Figure 2-15 illustrates a typical configuration for the air preheater axial and circumferential seals.



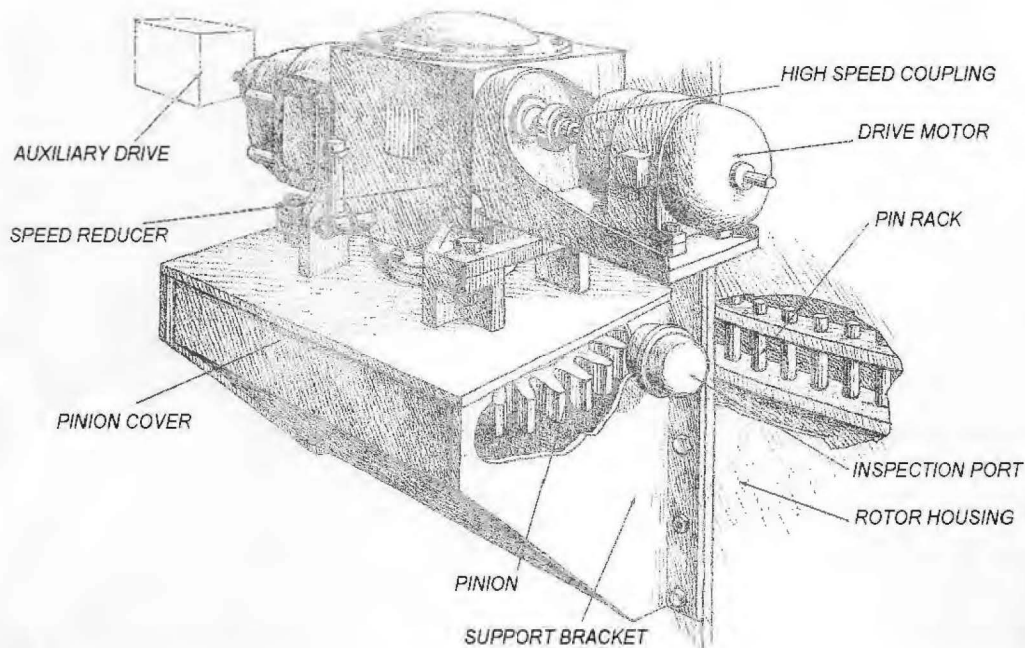
**Figure 2-15**  
**Axial and Circumferential Seal Plates**

A fairly recent development to improve the sealing capability of the air preheater is the installation of moveable sector plates. These moveable plates have the benefit of being able to close up the seal gap created as the rotor heats and droops. Moveable sector plate designs can range from simple two-position design (cold and hot positions) to rotor-position sensing that allows the sector plate to track the rotor as it droops as it heats up. Because of the extreme environmental conditions, the simpler design tends to be more practical and provides more functionality, but it can lead to more air loss during transition periods while the plate remains in the cold position.

Malfunctioning moveable sector plates can wipe out radial seals if they do not retract properly when the heater is shutdown. Actuation systems for the moveable plate can be gear-driven jacks or pneumatic cylinders, but industry experience suggests that the simpler pneumatics tend to be more problem free. Actuating system should be routinely tested for proper function, and the gear drives or cylinders should undergo periodic maintenance in accordance with each manufacturer's recommendations.

### 2.3.7 Rotor Drive Unit

One of the means the driving force for turning the rotor may be applied is by using a rack and pin located at the rotor's periphery. A pin rack mounted on the rotor shell is engaged by a pinion attached to the low-speed shaft of a power-driven speed reducer or gear motor. The rotating shaft in the center of the circular rotor is driven by a motor and gearing. The rotation of the rotor assembly and heating elements must be started before starting the steam generator to avoid uneven thermal expansion and contraction. This could result in damage to the circular rotor assembly, which must also be kept in rotation for some time after the steam generator is shut down. Figure 2-16 illustrates a typical arrangement for a periphery rotor drive assembly.



**Figure 2-16**  
**Typical Periphery Rotor Drive Assembly Arrangement**

An air motor is often furnished as optional equipment to provide an auxiliary drive for the air preheater. This drive ensures the continued operation of the preheater, even if power to the electric motor is interrupted. The air motor or a clutch may also be used to start the preheater, and to control the speed of the rotor during water washing of the heating surfaces. The drive unit is typically furnished with an auxiliary high-speed shaft extension, thus permitting installation of an air motor drive at any time.

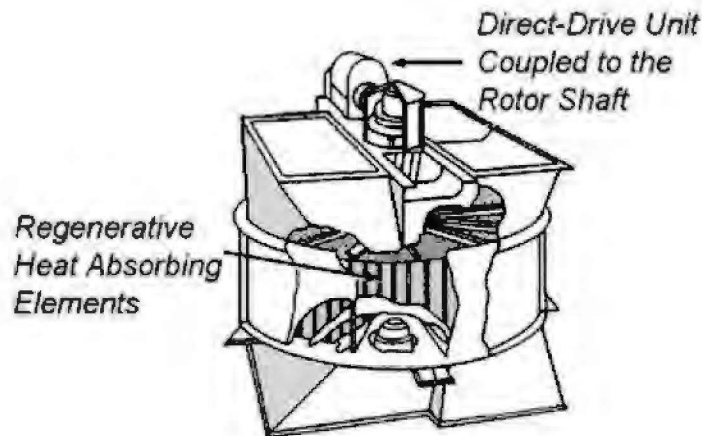


**Key Supervisory Observation Point**

Care should be taken to ensure rotor-stopped alarms and associated proximity probes are functional, so operators can take the necessary actions to secure the unit should the rotor stop.

Another way the driving force for turning the rotor may be applied is at the shaft (hub) of the rotor where the rotor drive assembly is mounted above the rotor. In this arrangement, the motor may be oriented either horizontally or vertically, and is directly coupled and geared to the shaft of the rotor, thus eliminating issues associated with a rack and pinion design.

Figure 2-17 illustrates this alternative rotor drive assembly arrangement.



**Figure 2-17**  
**Rotor Direct-Drive Assembly Arrangement**

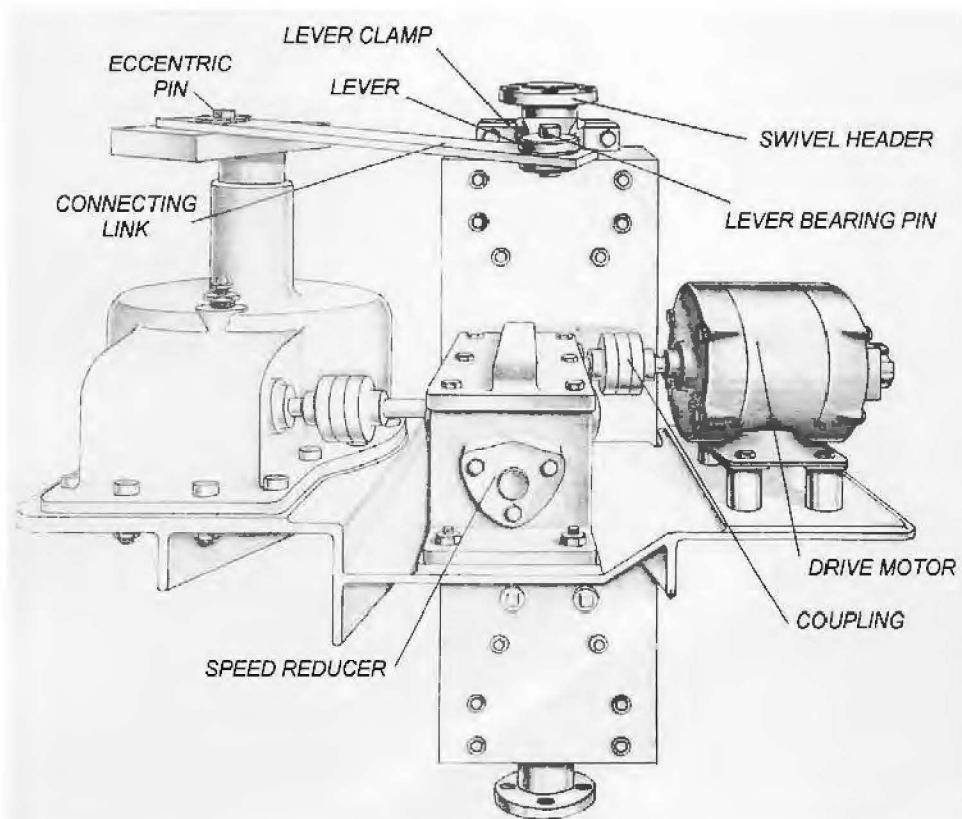
## 2.3.8 Heating Element Cleaning Systems

### 2.3.8.1 Soot Blowing

The baskets of corrugated heating elements are subject to abrasive and corrosive wear from the fly ash and corrosive gases in the flue gas. For cleaning of the baskets while in operation, steam jets or soot blowers are typically provided to blow any fly ash that has been deposited by the flue gas into an ash hopper located directly below the preheater assembly.

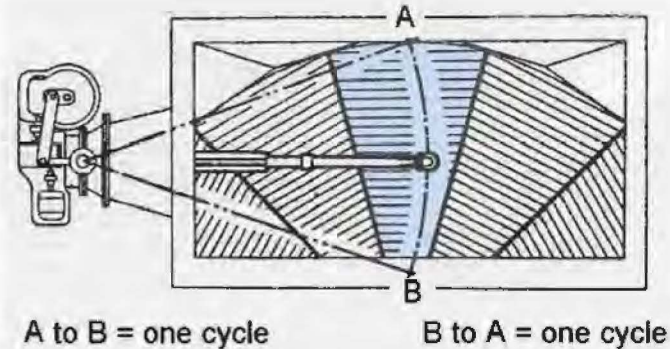
The cleaning device typically consists of an electric motor coupled to a gear-driven crank mechanism that oscillates the swivel header carrying the nozzle pipe or pipes. The cleaning mechanism is conveyed through the swivel header and respective nozzle pipe to the nozzle at the end.

Figure 2-18 illustrates a typical arrangement for an air preheater element cleaning assembly.



**Figure 2-18**  
Typical Air Preheater Element Cleaning Assembly Arrangement

A rotary joint is often provided in the supply line which permits free motion of the swivel header while connected to the source of the supply. The arc traversed by the nozzle and the rotation of the rotor subjects the entire area of the rotor to the action of the cleaning jets, which is illustrated on Figure 2-19.



**Figure 2-19**  
**Air Preheater Cleaning Assembly Traverse**

To maintain the desired air or steam pressure at the nozzle, an orifice plate is provided in the supply line. If steam is used, drain connections are recommended in the steam piping layout for removing condensate from the piping system while the device is idle and just before it is placed in operation.

### 2.3.8.2 Water Washing

Some designs also facilitate water washing of the corrugated plate heating elements. When cleaning the heating elements with water, adequate facilities should be provided to trap and drain the wash water to a sump or sewer. Drain lines must have sufficient pitch to prevent settling of the deposits in the wash water drainage line.

Regenerative air heaters can be washed with any of three approaches:

- Low pressure, high volume: 75 psi (5.1 bar), with variable volume
- Intermediate pressure, high volume: 600 psia (41 bar) and ~300 gpm (~1140 lpm)
- High pressure, low volume: 2,000-10,000 psia (136-680 bar) and ~30 gpm (~115 lpm)

Most air heaters are not equipped with intermediate- or high-pressure washing equipment; accordingly, this discussion focuses on low-pressure, high-volume washing.



#### **Key O&M Cost Point**

Due to inadequate water pressure at the facility, some owners have found it more beneficial to use the services of a commercial vendor if water washing of the heating elements and baskets are needed.

Washing is normally conducted off-line, although some plants have the capability to isolate one or two air heaters and wash at reduced load. With low-load, on-line washing, vendors caution operators to be aware of thermal deformation of the rotor, impacts of water on downstream equipment, and possible reactions with ash constituents (calcium and magnesium oxides).



#### Key Human Performance Point

Operators should also be aware of the need to properly dry the air heater before it is returned to service.

Washing devices are normally installed at both the hot and cold ends of the air heater. Each device typically consists of a header pipe and spaced nozzles designed to provide complete surface coverage. The amount of water consumed depends on unit capacity; a 600-MW unit with two air heaters (utilizing four cleaning pipes, two per air heater) consumes approximately 5300 gpm (20,060 lpm). Some air heaters also employ special fire suppression nozzles; these nozzles can be used for cleaning and almost double the volume of water for cleaning.

Neither cold-end nor hot-end nozzles are optimized for water washing of ABS material. Where such equipment is not effective, the intermediate-pressure and high-pressure systems can be used.

Cleaning time with low-pressure, high-volume equipment varies with the degree of fouling, element type, layer configuration, and available water quantity and pressure. Cleaning time typically varies from 6 to 30 hours and is minimized by maximizing flow quantities and using both hot-end and cold-end nozzles. A key aspect of cleaning is monitoring wash effluent, preferably at approximately 30-minute intervals, for variables such as pH and turbidity. These data provide indication of cleaning effectiveness. Visual inspections are critical to ensure that all surfaces are wetted and clean, and sample baskets should be pulled and inspected to confirm deposit removal.



#### Key O&M Cost Point

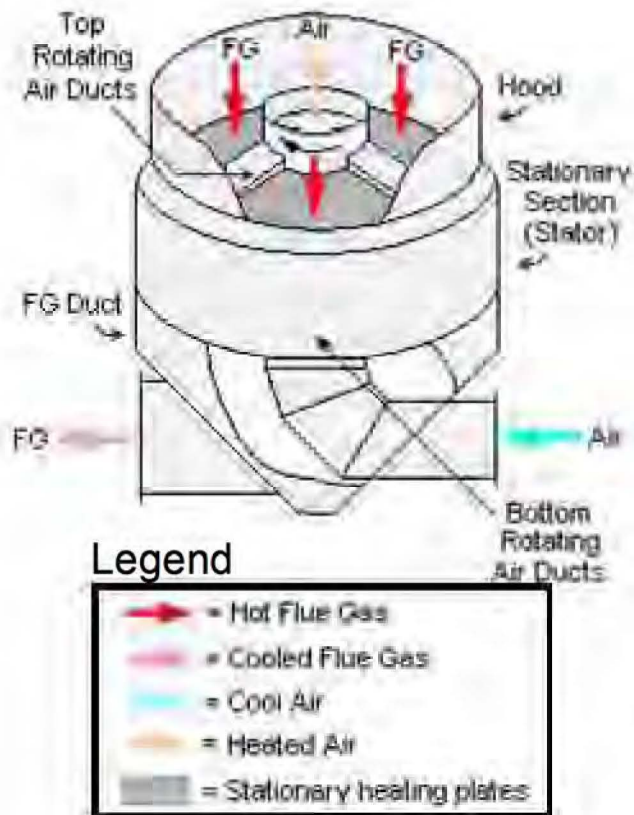
Air heater washing should be performed only when deemed necessary to reduce flue gas pressure drop (that cannot be corrected with soot blowing).

## 2.4 Stationary-Plate Air Preheater Designs

The primary difference in this type of air preheater is the heat absorbing element in this type of regenerative air preheater is stationary rather than rotational. Instead of the heat absorbing elements rotating, the air ducts in the preheater are rotated so as to alternately expose sections of the heating absorbing element to the up-flowing air.

In most designs, the hot flue gas enters at the top of the preheater and flows down through the exposed sections of the stationary heat-absorbing element that are not blocked-off by one or more of the rotating air outlet ducts. This flow of the hot flue gas heats those particular sections of the stationary element. As the air ducts slowly rotate around, they pass over the stationary heated sections, and the incoming air is heated as it flows upward through those stationary heated sections.

As illustrated in Figure 2-20, there are rotating inlet air ducts (inside the outer casing) at the bottom of the stationary heat absorbing element as well as the rotating outlet air ducts at the top of the stationary element.



**Figure 2-20**  
**Typical Stationary Plate Air Preheater Design**

The basic heat transfer principals of the stationary-plate regenerative preheater are the same as for the rotating-plate regenerative preheater. Typically the rotating plates will move at approximately 1.5 to 4.0 revolutions per minute (rpm), whereas the air ducts will rotate at approximately 0.7 to 1.4 rpm for a stationary-plate design air preheater. The air flow area is about 35 to 45% of the total circular area for both of the two designs. The gas flow area for the stationary-plate design can be slightly larger than for the rotating-plate design and can account for up to 60% of the total circular area.

Because this type of air preheater is not as predominant as the rotating-plate regenerative preheater at fossil-fuel power plants, component-specific guidance for this type of equipment is not provided in this report.

# 3

## DIAGNOSTICS AND TROUBLESHOOTING

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### 3.1 Scope of Air Preheater Components

The boundary of an air preheater vertical design, which is primarily for newer (after 1970) coal fired plants and should also be useful for other fossil fuel plants, is described below. The major elements of this device consist of the following:

- Air preheater cleaner soot blower
- Air preheater housing
- Auxiliary drive air motor
- Drive gearbox
- Drive motor - electric (main or auxiliary)
- Drive pin rack
- Drive pinion gear
- Guide bearing (rolling element)
- Guide bearing air seal cover
- Guide bearing housing
- Heating elements (baskets) - hot, cold, intermediate
- Instrumentation - pressure and temperature (local, DCS, control room)
- Lube oil systems (guide, support bearing rotor drive with cooler, motor, pump, filters, valves, piping, nozzles, oil)
- Radial stub shaft
- Rotor assembly (diaphragm, stay plates, shell, post, trunnions)
- Seal plates (hot radial, cold radial, axial, sector, and adjusters)
- Seals (axial, radial, bypass/circumferential, post)
- Support bearing (radial - rolling element)
- Support bearing (runner type with pads)
- Support bearing housing
- T-bars

The following components are excluded:

- Power feed, controls, and switchgear

## **3.2 Air Preheater Degradation Mechanisms**

### **3.2.1 Overview of Common Degradation Mechanisms for Air Preheaters**

#### **3.2.1.1 Pinion/Pin Rack Drive**

A common failure mechanism experienced with rotating air preheaters is excessive wear on both the pinion gear and the pins on the pin rack. Excessive wear on these components can cause binding of the drive system, or can actually wear the pins away if left to go too long. These points should be inspected regularly.

Another common pin rack failure occurs where the anchor points of the pin rack to the rotor shell fail. The pin rack is in segments. If the anchor point on the trailing end of the rack segment fails, it may go un-noticed for quite some time. However, if the leading end anchor point fails, it will become free to swing away from rotor circumference and jam against some stationary component, causing the air preheater to stop completely. The integrity of the pin rack and its anchor points should be inspected regularly.

#### **3.2.1.2 Lower Bearing Oil Level Indication**

The lower bearing can be the guide bearing or the support bearing, depending on the make and configuration of the air preheater. These bearings are physically located in a most inaccessible area, and because of this, there is no good way to check the oil level in that bearing. Normally, an external oil level indicator is furnished that is comprised of piping from the bearing that runs horizontally to somewhere around the outer circumference of the air heater, and connected to a float mechanism. The oil will seek a level that matches what is in the bearing housing, and the float is adjusted so that an operator can see what the oil level is. This works pretty well under normal plant conditions, but in some cases the horizontal pipe becomes plugged from sediment. This causes the external float mechanism to give the appearance that the oil level is sufficient, while in actuality the bearing has run dry and failed. The piping arrangement should be disassembled and cleaned regularly to prevent this kind of failure.

### 3.2.2 Detailed Failure Mechanisms for Air Preheater Components

Table 3-1 lists the various degradation mechanisms exhibited by the major components of an air preheaters installed at a fossil-fuel power plant.

**Table 3-1  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Air Preheater Housing	Door and manway leakage	Improper maintenance, gasket damage
	External corrosion or rust	Outdoor units with inadequate shielding from rain water
	Internal corrosion	Cold end gas side from acid attack
	Warpage or cracking	Duct loading, contact interference from platforms, and so on (expansion restraint on the housing)
	Worn bracing (gas side only)	Erosion on the hot end, corrosion on the cold end
Auxiliary Drive	Air line leak	Vibration, erosion, improper installation
Auxiliary Drive Air Compressor, Tank, Air Filter, Oiler, and Solenoid Valve	Air filter fouled	Oil contamination, excess moisture, pipe scale
	Air compressor failure	Age
	Oiler leakage	Broke glass bulb or improper maintenance
	Solenoid valve stuck or failed	Coil failure, rust and moisture in air line
Auxiliary Drive Air Motor	Bearing wear	Failure of the over-running clutch in the gearbox (air motor runs dry)
	Failure or seizure	Supply air quality issues, for example, moisture, lubrication, flow, pressure
	Loose mounting	Improper installation
	Loss of torque	Supply air line leakage, inadequate air supply, for example, close isolation valve
Drive Gearbox	Gasket or shaft seal leakage	Age
	Gear wear	Contaminated or wrong lubricant
		Degraded lubricant, age of the oil, loss of oil lubricity
		Normal use
Gear wear or damaged	Inadequate lubrication	

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Drive Gearbox	Over-running clutch stuck	Oil varnish buildup causing the clutch to stay engaged driving the air motor or fails to engage air motor
	Plugged oil breather	Contamination, dirt, paint
	Wear - bearings output shaft	Lack of lubrication (grease)
	Wear - bearings rolling element	Degraded lubricant, contamination, for example, water ingress
		Incorrect, mixed, or inadequate lubricant
	Normal use or wear	
Drive Gearbox Frame	Cracked or deformed	Misalignment, impact damage, loose hardware, improper installation or maintenance
Drive Gearbox oil cooler, if present	Shell side plugging	Fouling
	Tube side leak	Poor water chemistry
Drive Motor - Electric (Main or Auxiliary)	Bearing wear	Degraded or dry or incorrect or excessive/insufficient lubricant - Grease - temperatures above 140 °F or very long idle periods may allow the lubricant to separate, shortening bearing life
Drive Motor - Electric (Main or Auxiliary)	Bearing wear	Improper installation, alignment
		Normal wear
	Blocked fan and cover loose	Dirt, debris, dust, normal operation
	Breakdown of lead and connection insulation	Age, operation in temperatures above rated
	Breakdown of stator laminations insulation	Contamination usually from excessive lubrication, operation in temperatures above rated
	Breakdown of winding insulation	Contamination usually from excessive lubrication, operation in temperatures above rated
	Cracked or deformed frame	Misalignment, impact damage, loose hardware, improper installation or maintenance
	External fan and cover loose	Vibration, personnel error
	Open, cracked or deformed rotor	Age, cyclic or thermal fatigue, large number of starts, manufacturing issue, especially in older motors

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Drive Motor - Electric (Main or Auxiliary)	Shaft seal leakage	Excessive lubricant, shaft misalignment, failed bearing, shaft misalignment, dust, lack of lubrication
Drive Motor - Electric (Main or Auxiliary)	Shaft seal wear	Normal wear, duty cycle (Note that very long idle periods may allow the seal to harden, shortening its useful life.)
Drive Motor and Gearbox Couplings	Misalignment	Improper installation, broken key or keyway
	Wear	Lack of lubrication
Drive Pinion Gear	Damage	Contact with pin rack rails due to loosening of the hub
	Wear	Normal use
Guide Bearing (Rolling Element)	Wear	Degraded oil, temperature, contamination, moisture
		Improper installation, alignment, improper maintenance (misapplication of welding grounds)
		Incorrect, mixed types, or insufficient oil
		Normal use
Guide Bearing Air Seal Cover	Leakage	Failed packing due to age
		Loose bolting
Guide Bearing Housing	Leakage	Misalignment creating wear of the sealing tube
	Loose	Fastener failure housing to structure
Heating Elements (Baskets) - Cold	Corrosion	Acid (HBr) attack caused by metal temperatures approaching 120 to 140 °F impacted by load with low air inlet temperatures to the pre-heater
	Fracturing	Improper soot blowing or wash washing (can cause a missing or lost element by destroying the elements)
	Plugging	Ammonium bisulfate fouling with a low exit gas temperature or excess ammonia slip and can be as short as 1 month
	Wear	Thinning due to corrosive attack of H <sub>2</sub> SO <sub>4</sub> , or particle ash impingement

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Heating Elements (Baskets) - Hot	Erosion	High ash fuel, improper or incomplete combustion
	Fracturing	Improper soot blowing or wash washing (can cause a missing or lost element by destroying the elements)
Heating Elements (Baskets) – Hot Heating Elements (Baskets) - Hot	Plugging	Ammonium bisulfate fouling with a low exit gas temperature or excess ammonia slip and can be as short as 1 month
	Plugging	Large particle ash from combustion practices, failure of upstream trapping (for example slag screen), fuel quality
	Wear	Erosion or thinning from soot blowing
Heating Elements (Baskets) - Intermediate, if present	Erosion	High ash fuel, improper or incomplete combustion
	Failed	Acid dew point corrosion compounded by low exit gas temperature or low load operation
	Fracturing	Improper soot blowing or wash washing (can cause a missing or lost element by destroying the elements)
	Plugging	Ammonium bisulfate fouling with a low exit gas temperature or excess ammonia slip and can be as short as 1 month
	Wear	Erosion or thinning from soot blowing or corrosive attack
Heating Elements (Baskets) - Supports	Wear	Thinning due to corrosive attack of H <sub>2</sub> SO <sub>4</sub> , or particle ash impingement
Instrumentation - Pressure and Temperature (Local, DCS, Control Room)	Failed or improper indication	Age, drift
Lube Oil (Guide Bearing, Support Bearing, Rotor Drive)	Loss of lubricating properties	Contamination, biological growth, debris, sludge, or water
		Normal wear
		Temperature
Lube Oil Cooling Heat Exchanger (Guide Bearing, Support Bearing, Rotor Drive)	Shell side plugging	Fouling
	Tube side leak	Poor water chemistry

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Lube Oil Metering Orifice, if present	Clogged	Contaminated oil, debris, sludge
Lube Oil System (Guide Bearing, Support Bearing, Rotor Drive)	Clogged filters	Contamination - wear particles
	Gear drive oil pump failure	Improper assembly
		Normal wear of gears, bushings, seals, housing, end plate
	Leaking pressure relief valve	Inadvertent operation
Lube Oil System (Guide Bearing, Support Bearing, Rotor Drive)	Leaks - piping, fittings, or valves	Improper assembly
	Oil pump motor failure	Normal wear (bearing and winding insulation degradation)
	Oil pump temperature switch failure	Drift
Pin Rack	Failed welds on pin rack to rotor shell leading to detachment	Improper welding techniques
	Wear	Normal use
Pinion Shaft Seal	Leakage	Age, improper installation (Can lead to over heating of the gearbox.)
Rotor Assembly (Diaphragm, Stay Plates, Shell, Post, Trunnions)	Diaphragm thinning	Corrosion from condensing acid at cold end aggravated by chemical additions to control emissions
		Erosion from fly ash, poor fuel quality
		Normal use
		Soot blower impingement
	Post separation from the diaphragm	Duty cycle (welded rotors are more susceptible)
	Shell corrosion	Corrosion from condensing acid at cold end aggravated by chemical additions to control emissions
	Shell droop	Post-to-diaphragm separation
Stay plates corrosion	Corrosion from condensing acid at cold end aggravated by chemical additions to control emissions	

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Rotor Assembly (Diaphragm, Stay Plates, Shell, Post, Trunnions)	Stay plates cracks or diaphragm interface weld cracking	Thermal cycling or stress
	Stay plates warpage	Improper maintenance usually from water washing with out pre-cooling
	Trunnions bolting loose or failed	Improper maintenance or torquing of bolting especially in the guide bearing area, higher pressure operation
Rotor Assembly (Diaphragm, Stay Plates, Shell, Post, Trunnions)	Trunnions loose or failed	Corrosion from condensing acid at cold end aggravated by chemical additions to control emissions
Seal Plates (Hot Radial, Cold Radial, Axial, Sector) Seal Plates (Hot Radial, Cold Radial, Axial, Sector)	Adjuster failure	Corrosion, excessive load due to high operating pressure, cold end washing
	Erosion	Higher operating pressure, fuel quality
	Misalignment	Improper maintenance, duct loading
	Static seal failure	Erosion due to contact with fly ash, cold end corrosion due to acid attack
	Wear	Rotational contact with seals from improper seal settings, creep, improper maintenance
Seals (Axial, Radial, Bypass/Circumferential, Post)	Corrosion from H <sub>2</sub> SO <sub>4</sub>	Cold end acid attack
	Corrosion from HBr	Acid attack caused by metal temperatures approaching 120 to 140 °F impacted by load with low air inlet temperatures to the pre-heater
	Cracking (mostly in contact seals)	Interference tolerances, especially at low loads
	Leakage	Debris entering the air pre-heater
		Misalignment, loose, improper seal settings, deformation
	Loose hardware	Improper maintenance (can lead to complete failure, for example, falling out of place)
	Wear	Improper installation, high temperature gas flow, bottle up (gas flow without adequate air flow)
Normal use, age		

**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Soot Blower	Drive failure	Motor or gearbox failure, broken linkages, limit switches
	Erosion to lance or nozzle	Normal wear (leads to improper cleaning of or damage to the heating elements)
	Improper indexing or movement	Improper setup or failed limit switches (leads to improper cleaning of or damage to the heating elements)
	Ineffective cleaning	Inadequate steam or air supply media quality (low pressure, high moisture, low temperature)
	Leaking hose, packing, and piping connections	Normal use, age
	Misaligned lance	Improper maintenance (leads to improper cleaning of or damage to the heating elements)
	Missing or worn nozzles	Normal wear (leads to improper cleaning of or damage to the heating elements)
Support Bearing (Tilt Pad Type) Support Bearing (Tilt Pad Type)	Wear	Babbitt imperfection (for example, cold spot, hydrogen porosity, loss of bond, etc)
		Degraded lubricant due to contamination, entry of wash water
		Failure of pad support components (leveling ring), normal wear
	Wear	Insufficient lubricant
		Maintenance induced errors such as improper clearances, handling, installation, welding
		Normal wear
		Rough runner
Support Bearing Air Seal Cover	Leakage (flue gas, hot air)	Failed packing due to age
Support Bearing Cover Shield	Damaged or missing	Improper maintenance
Support Bearing Housing	Loose	Fastener failure housing to structure

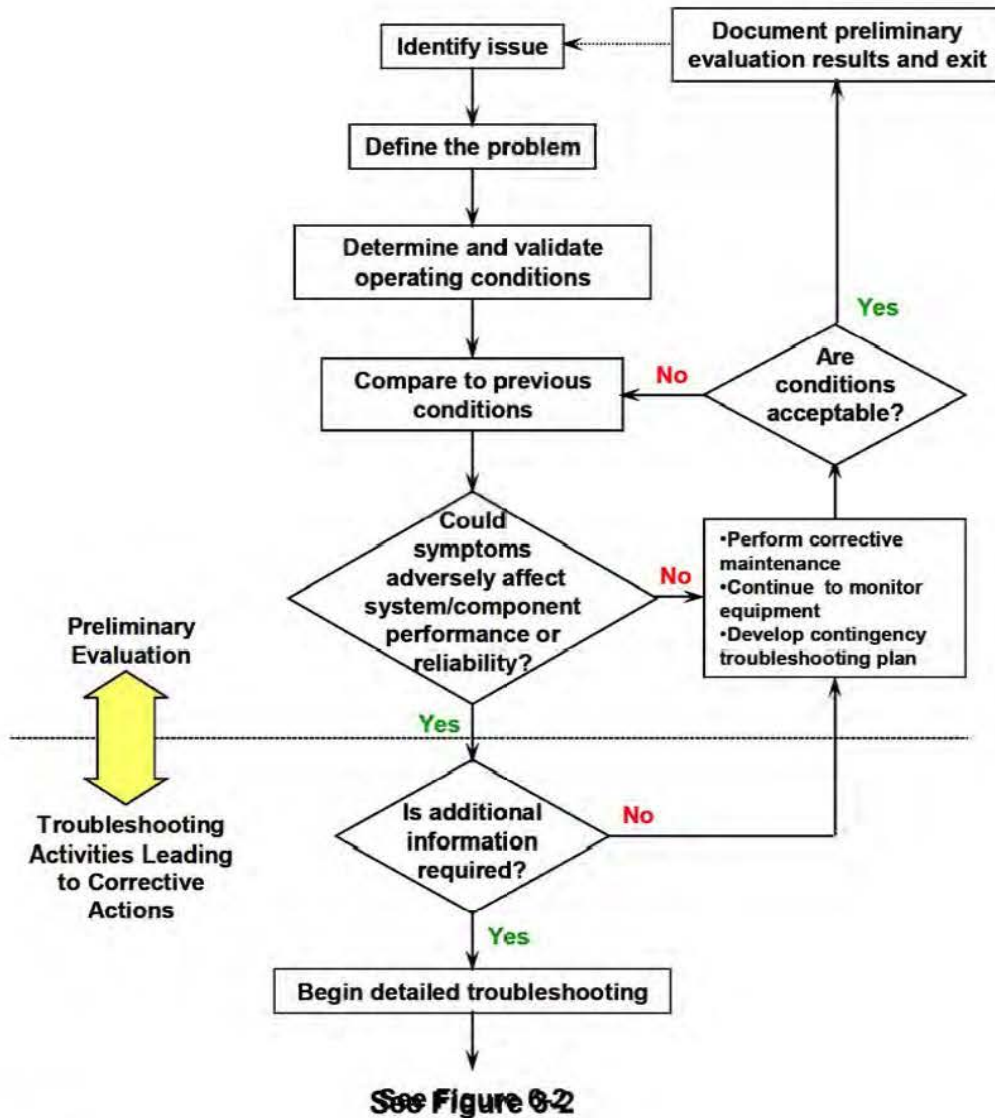
**Table 3-1 (continued)  
Failure Mechanisms for Major Air Preheater Components**

Failure Location	Degradation Mechanism	Degradation Influence
Support Radial Bearing (Rolling Element)	Wear	Degraded oil, temperature, contamination, moisture
		Improper installation, alignment, improper maintenance (misapplication of welding grounds)
		Incorrect, mixed types, or insufficient oil
		Normal use
Support Radial Bearing Stub Shaft	Fastener failure	Operational stress, overturning moment due to draft loss
T-Bars	Contact wear	Improper setup, high temperature operation
	Corrosion (cold end)	Cold end acid attack
	Fastener failure	Erosion, corrosion
	Wear	Normal use, age

The EPRI PMBD should be referenced if additional failure mechanism data is required for the electric motors, mechanical couplings, gearbox, and lubrication circulation pumps associated with the air preheater.

### 3.3 System Troubleshooting

Figure 3-1 illustrates the generic process for performing preliminary troubleshooting for a given power-generation system, like an air preheater installed in a fossil-fuel power plant. 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 3-1**  
**Generic Process for System Troubleshooting (Preliminary Evaluation)**

Figure 3-2 illustrates the detailed system troubleshooting process that may be undertaken to investigate the symptoms and performance problems being experienced. The figure emphasizes the need to identify failure modes, develop a troubleshooting plan (especially if the system is evaluated while on-line), 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*.

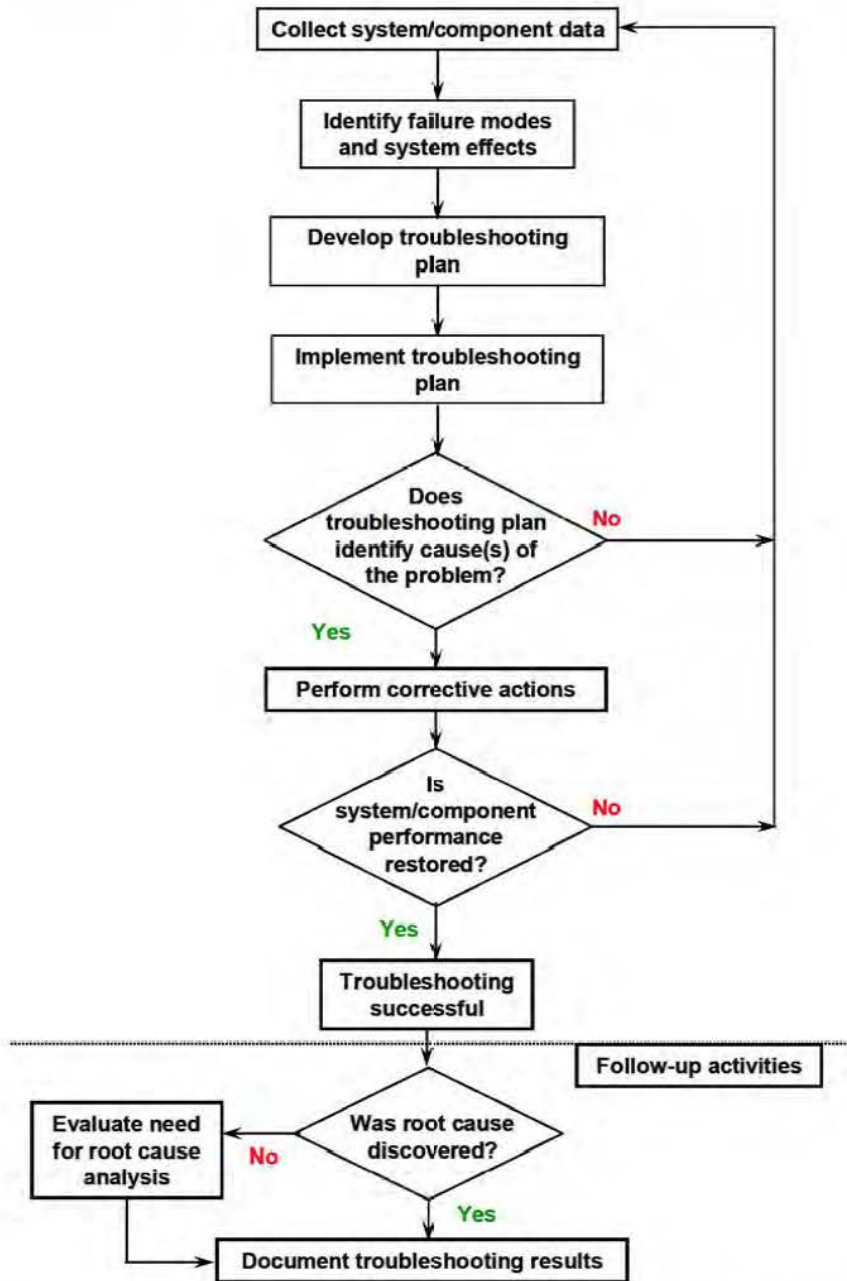


Figure 3-2  
Generic Process for System Troubleshooting (Detailed System Troubleshooting)

### 3.4 Troubleshooting the Air Preheater System

Given that the primary function of the air preheater is to transfer heat from flue gas to ambient air, Table 3-2 provides an overview of causes for experiencing inadequate thermal performance. The user of this report should keep in mind that the most common causes of air preheater failures are:

- Acid dew point corrosion
- Fly ash impingement
- Soot blower operation
- Contaminated oil

**Table 3-2**  
**System Troubleshooting for Air Preheaters**

Component	Performance Anomaly	Possible Cause	Corrective Action
Baskets	Inadequate heat transfer	Damaged, corroded or physical deformation	Replace baskets as needed
	High pressure drop	Fouling, swelling, baskets at end of life, fuel combustion issues	Adjust cold end temperature (steam coils, etc). Replace basket elements
	Inadequate heat transfer	Basket plugged	Clean basket (soot blower or water wash)
Drive motor	Motor overheating	Seals too tight, inadequate rotor speed	Adjust seal clearances, repair, or replace seals as needed
Expansion joints	Inadequate heat transfer	Air in-leakage	Repair/replace expansion joints
Heating elements	Inadequate heat transfer	Heating elements plugged or dirty	Clean heating elements with blower or water wash
Rotor	Inadequate rotational speed	Electrical motor breaker is open	Check motor circuit breaker
		Electrical motor is shorted	Eliminate short circuit
		Electrical motor insulation breakdown	Repair/refurbish motor
		Mechanical failure of gearbox components	Replace damaged gearbox components
		Inadequate lubrication of bearings	Check oil levels, replenish as needed. Perform oil analysis and replace if needed

**Table 3-2 (continued)**  
**System Troubleshooting for Air Preheaters**

Component	Performance Anomaly	Possible Cause	Corrective Action
Rotor	Inadequate rotational speed	Misalignment and excessive vibration of the rotor	Repair/replace rotor structural members causing vibration and misalignment
		Seal clearance is too tight causing undue friction	Adjust seals to reduce friction
Rotor seals	Inadequate heat transfer	Seal leakage, wear, improper installation, loose	Adjust seal clearances, repair, or replace seals as needed
	Loss of air flow because air is short-circuited from air to flue gas	Degraded sector plates between the air and gas sides.	Repair or replace sector plates
Rotor bearing	Bearing wear or failure	Inadequate lubrication	Check circulation pump and supply piping valves
		Contaminated lubrication	Conduct oil analysis and replace if needed
		Oil cooler leakage, plugging or failure	Repair/replace oil cooler
		Oil circulation pump leakage or failure	Repair/refurbish circulation pump
		Oil recirculation pump motor failure	Check motor circuit breaker
		External forces – misalignment of the rotor and excessive vibration of the rotor	Repair/replace rotor structural members causing vibration and misalignment
Soot blowing system	Inadequate heat transfer	Inadequate air supply	Check air supply line valves
		Inadequate air pressure	Check operation of air compressor

### 3.5 Effects of Seal Leakage

Seal leakage is a failure mechanism of an air preheater system that can have a direct and significant impact on the heat transfer capability of the air preheater system and subsequently on the thermal efficiency of the boiler. Radial and circumferential seals are needed to maximize the flow of hot flue gas through the air preheater, and to ensure as much heated air as possible flows back to the boiler. Any leakage away from the air preheater and these two primary flow paths can significantly affect the temperature and amount of hot air exiting the air preheater and entering the boiler. Leakage can occur both at the radial seals and the circumferential seals, on both the hot and cold sides of the air preheater rotor, as shown on Figures 3-3 and 3-4.

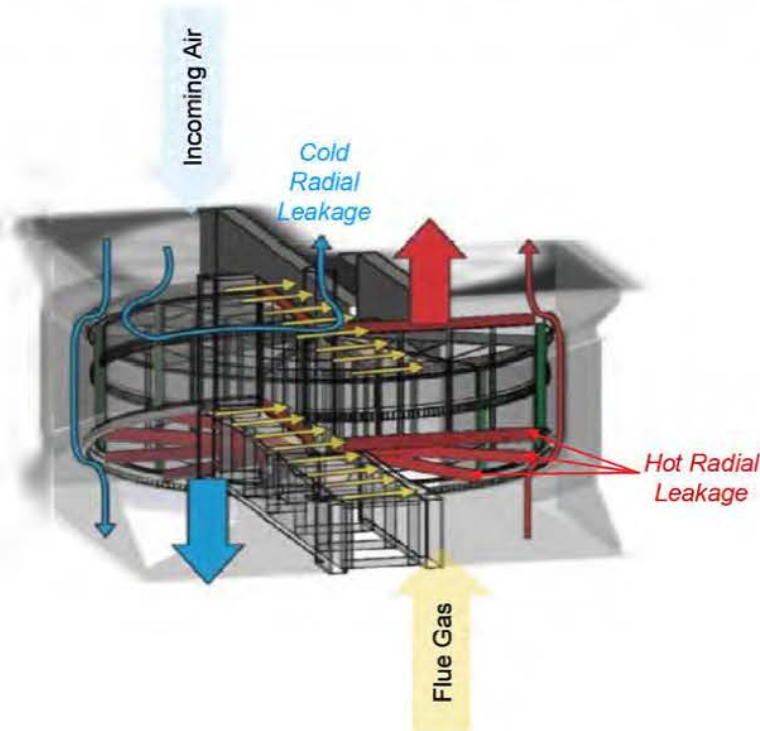
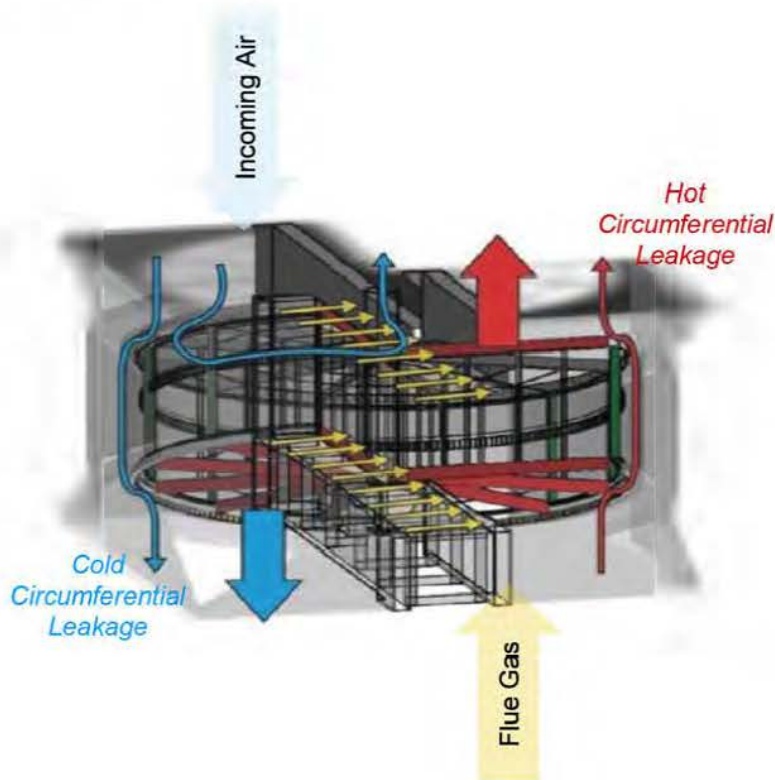


Figure 3-3  
Hot and Cold Radial Air Leakage Paths



#### Key Technical Point

Seal leakage can also result in inadequate fan capacity or the inability to supply enough air for full-load operation, that is, running out of air.



**Figure 3-4**  
**Hot and Cold Circumferential Air Leakage Paths**

One of the primary causes of leakage from an air preheater is the large temperature differential between its hot and cold end elements. These opposing temperature gradients produce a significant radial thermal expansion difference between the hot and cold sides of the air heater's rotor after unit start up. Due to this inherent thermal distortion, it's not uncommon for the outer edges of a large air heater at operating temperature to experience a significant "droop" (or "turn down"). The physical distortion caused by this thermal turndown can be as much as 4 inches on some rotors. This distortion changes the gaps between the seals and the sealing surfaces as the rotor warms to operating temperature. This thermal expansion phenomenon should be accounted for when setting the seals at a cold state.



**Key Technical Point**

Sector plate damage can also result in air leakage issues, because if sector plates warp or degrade, the seals may not be able to isolate the flows of air and flue gas.

## **3.6 Managing Deposits of Ammonia/Sulfur Compounds**

Ammonium Bisulfate (ABS) deposition is problematic for all types of air heaters, including regenerative air heaters supplied by both major equipment manufacturers and tubular-type air heaters employed on cyclone-fired and other types of boilers. In Europe, Rothemühle regenerative air heaters are frequently utilized, and deposition of ammonium compounds on these units has been well documented. Rothemühle air heaters are also used in the United States.

Increased flue gas pressure drop resulting from deposition of ABS on heating surfaces is perhaps the most significant balance-of-plant impact.

### **3.6.1 Soot Blowing**

The most effective means of removing air heater deposits is cold-side soot blowing. Soot blowing from the hot side can augment cleaning, but alone is generally inadequate to maintain clean surfaces and minimize deposit accumulation. Regardless of the soot blowing media – either steam or compressed air – moisture should be minimized, because it can damage surfaces. Also, aggressive soot blowing alone – for example, use of high-pressure and frequent cleaning – may not be enough to maintain a clean surface. Further, aggressive soot blowing may damage and erode air heater surfaces.

### **3.6.2 Water Washing**

EPRI conducted an informal survey of selected utility operators to determine experience with higher flue gas pressure drop and the need for air heater washing, and the results show that a higher incidence of air heater washing occurs on SCR- and SNCR-equipped facilities, with the wash frequency dependent on the level of residual  $\text{NH}_3$  in flue gas, as well as coal sulfur (and presumably flue gas sulfur trioxide ( $\text{SO}_3$ ) content).

Although water washing is not recommended by air heater suppliers as a usual maintenance practice, this cleaning methodology can be applied during scheduled outages to assist in maintaining clean surfaces and to minimize corrosion damage to surfaces from SCR byproducts during the downtime. Major air preheater manufacturers suggest that to avoid corrosion, the surfaces be washed immediately after the unit is removed from service, to minimize potential corrosion damage.

### **3.6.3 Air Heater Pressure Drop**

Monitoring the air heater pressure drop provides an indirect measure of the ammonium bisulfate (ABS) deposition within the air heater baskets, and thus residual  $\text{NH}_3$  levels. Air heater pressure drop trends are evaluated over long time periods - that is, on the order of months or years.

Evaluating the pressure drop at a consistent boiler operating point, such as full load, and with comparable levels of excess air, will provide a reference for long-term comparison. An increase in full-load pressure drop signifies that deposition in the baskets has increased. Long-term trends will indicate if increased deposition and potentially higher residual  $\text{NH}_3$  are occurring.

The introduction of residual  $\text{NH}_3$  into the flue gas with  $\text{SO}_3$  will lead to the deposition of ABS within either or both the intermediate and/or cold-end sections of an air heater. The formation of these compounds is inevitable; what is not known is the propensity for these compounds to be successfully removed by soot blowing or to remain on the surface, increasing pressure resistance. Prior to operation with SCR, it is advisable to define “normal” or baseline flue gas pressure drop across the air heater. Ideally, plant operators will characterize flue gas pressure drop across the air heater as a function of load, noting the role of soot blowing or water washing in restoring flue gas pressure drop to baseline values. Once SCR is installed, any deviations in the trends of flue gas pressure drop with load, or restoration with soot blowing, will suggest a net accumulation of ammonium bisulfate and, thus, production of residual  $\text{NH}_3$ . Monitoring air heater pressure drop may, in fact, provide the best indicator of residual  $\text{NH}_3$ , because extremely low concentrations (< 1 ppm) that may be difficult to detect analytically will react and can deposit in the air heater. Unless removed by soot blowing, these deposits are indicative of residual  $\text{NH}_3$  concentration.



**Key Technical Point**

In addition to ABS, pressure drop can increase as a result of fouling. Most air preheater vendor manuals have a recommended minimum average cold end temperature (ACET). Weather, operating load, sulfur content of fuel can all impact fouling.

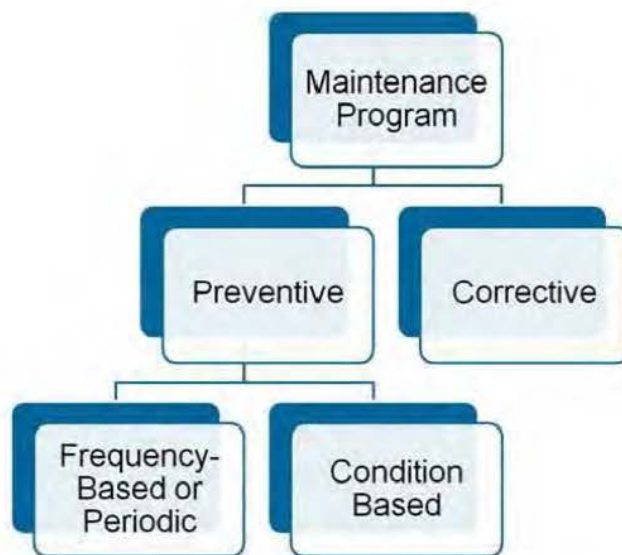
# 4

## MAINTENANCE AND REPAIR

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### 4.1 General Guidance

The following sections provide an overview of the various types of maintenance activities that can be performed on air preheaters. The four types or categories of maintenance are shown on Figure 4-1.



**Figure 4-1**  
Types or Categories of Maintenance

### **4.1.1 Preventive Maintenance**

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 below.

#### **4.1.1.1 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 may 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. Examples of periodic maintenance are shown below.

- Scheduled valve re-packing 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

#### **4.1.1.2 Condition-Based Maintenance**

Condition-based maintenance (CBM) is a methodology for performing preventative-maintenance activities based on the actual condition of the equipment rather than on the basis of fixed intervals or hours of operation. Examples of condition monitoring are shown below.

- 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
- Air preheater leakage testing
- Monitoring differential pressure during operator rounds

Condition-based maintenance would constitute the work triggered by condition monitoring as listed in the examples above.

### **4.1.2 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 such that failure is imminent (within its operating cycle/preventive maintenance 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.

### **4.1.3 Initial Basis for PM Tasks and Frequencies**

The following information provides insight into how an air preheater manufacturer might develop initial PM tasks and frequencies. However, the user of this report should recognize that the PM tasks and frequencies recommended in Section 4.2 of this report were developed with input from fossil-fuel power plant 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 air preheater manufacturer's initial recommendations for scheduled PM activities.

## **4.2 Background and Definitions of PM Terminology**

### **4.2.1 Background for Establishing a PM Program**

Many owners of fossil-fuel power plants are in the process of reducing PM costs and improving equipment performance by matching PM tasks with the functional importance of the equipment. For this process to succeed, owners require information on the most appropriate tasks and task intervals for the important equipment types, while accounting for the influences of functional importance, duty cycle, and service conditions.

An early approach to optimizing PM activities was the use of reliability centered maintenance (RCM). RCM was developed in the 1960s by the commercial airline industry to apply reliability concepts to maintenance and the design of maintenance programs. The RCM approach to preventing equipment failure is to perform maintenance tasks that are specifically aimed at preventing component-failure mechanisms from occurring.

Initially, PM tasks were assigned based on vendor recommendations and plant experience. In modifying or optimizing the PM tasks, one vital piece of information was missing: the time-to-failure for the components. Because the time-to-failure was not known, it was difficult to justify the PM task intervals. Also missing was the understanding of the factors that influence the progression of the degradation mechanisms for the component.

Although fossil-fuel power plants do not have the same regulatory requirements as nuclear or fossil-power plants, the establishment of the PM Basis for critical components provides valuable information for optimizing maintenance programs.

The information used in the development of the PM Basis was gathered from the manufacturer, the industry literature, and input from owner maintenance personnel. The following is a description of the tables generated by the PM Basis document.

#### **4.2.2 Definition of Duty Cycles and Service Conditions**

The following are definitions used to establish functional importance, duty cycles and service conditions. This information was the basis for determining the frequencies for the tasks described in Section 4 of this report.

##### Functional Importance:

**Critical** – Functionally is important, for example, required for power production or other regulatory requirements.

**Non-Critical** – Functionally is not critical, but important, for example, for any of the following reasons: high frequency of corrective maintenance, more expensive to replace or repair than to do preventive maintenance, 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 template.

##### Duty Cycle:

**High** – Frequently cycled

**Low** – Continuously run (Units that are maintained in a prolonged standby mode with no fire in the boiler can be considered to be low duty cycle, since most of the operating service conditions that generally affect degradation timing are not present.)

##### Service Conditions:

**Severe** – High or excessive humidity, excessively high or low temperatures, excessive temperature variations, excessive environmental conditions (such as dust, salt, corrosive spray), low fuel quality (high amounts of fly ash), ammonia slip from the SCRs, or low loads for extended periods.

**Mild** – Absence of the above conditions.

#### **4.2.3 Significant Risks Associated with Intrusive Maintenance Activities**

Significant risks that arise from performing intrusive maintenance on this equipment are:

- Foreign material (FME)
- Improper grounding during welding
- Attention to details, especially alignments

#### **4.3 PM Program Tasks for Air Preheaters**

Table 4-1 provides an overview of the PM activities for major air preheater components. Job plans have been developed for the tasks that must be performed during an outage, and those job plans are provided in Section 6 of this report. PM activities that can be performed while the unit is on-line are described in this section.

**Table 4-1**  
**Recommended PM Tasks and Frequencies for Air Preheaters**

Task Name	CHS	CLS	CHM	CLM	MHS	MLS	Section
Operator Rounds	1S	1S	1S	1S	NA	NA	Section 4.3.1
System Owner Inspection	3M	3M	3M	3M	NA	NA	Section 4.3.2
Oil Analysis	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.3
Vibration Analysis	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.4
Thermography	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.5
Performance Monitoring	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.6
Auxiliary Air Drive Functional Test	1M	1M	1M	1M	NA	NA	Section 4.3.7
Oil Filter Replacement	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.8
Maintenance Inspection	1Y	1Y	1Y	1Y	NA	NA	Section 4.3.9

### 4.3.1 Operator Rounds

The objective of Operator Rounds is to determine the current health and serviceability of equipment through systematic monitoring and inspection. Operator rounds should occur once per shift. This task is focused on the discovery of leaks from all sources, and listening for unusual noises indicative of equipment wear or damage.

PM tasks that may be considered during operator rounds include the following:

- Check the air preheater housing for door and manway leakage, external corrosion or rust, and warpage or cracking.
- Check the auxiliary drive air compressor, tank, filter, oiler, and solenoid valve for oiler leakage.
- Check the drive gearbox for gasket or shaft seal leakage, gear wear, damage, a stuck over-running clutch, and wear of the bearings rolling element.
- Check the drive gearbox frame for cracking or deformation.
- Check the drive gearbox oil cooler, if present, for shell-side plugging and tube-side leaks.
- Check the drive motor - electric (main or auxiliary) for bearing wear, blocked fan and cover looseness, cracked or deformed frame, external fan and cover looseness, shaft seal leakage, and shaft seal wear.
- Check the drive motor and gearbox couplings for misalignment and wear.
- Check the drive pinion gear for damage and wear.
- Check the guide bearing air seal cover for leakage.
- Check the guide bearing housing for leakage and looseness.

- Check the instrumentation – pressure and temperature (local, DCS, control room) for failed or improper indication.
- Check the lube oil cooling heat exchanger (guide bearing, support bearing, rotor drive) for shell side plugging and tube side leakage.
- Check the lube oil metering orifice, if present for clogging.
- Check the lube oil system (guide bearing, support bearing, rotor drive) for clogged filters, gear drive oil pump failure, leaking pressure relief valve, piping/fittings/valve leaks, oil pump motor failure and failure of the oil pump temperature switch.
- Check the pin rack for failed welds (for example, pin rack to rotor shell) leading to detachment, and for wear.
- Check the rotor assembly (diaphragm, stay plates, shell, post, trunnions) for post separation from the diaphragm and for shell droop.
- Check the seal plates (hot radial, cold radial, axial, sector) for adjuster failure.
- Check the soot blower for drive failure, improper indexing or movement, and leaking hose/packing/piping connections.
- Check the support radial bearing (rolling element) for wear.
- Check the support radial bearing stub shaft for fastener failure.
- Check the T-bars for fastener failure.

#### **4.3.2 System Owner Inspection**

The objective of the System Owner Inspection task is to discover abnormalities or changes from normal operating conditions that would have an adverse effect on reliability, by performing a detailed visual inspection, and evaluating reported data from sources such as operator logs and maintenance reports to identify trends that suggest the relative "health" or serviceability of the component.

PM tasks that should be considered during operator rounds include the following:

- Inspect the air preheater housing for door and manway leakage, external corrosion or rust, and warpage or cracking.
- Inspect the auxiliary drive air compressor, tank, filter, oiler, and solenoid valve for oiler leakage.
- Inspect the drive gearbox for gasket or shaft seal leakage, gear wear, damage, a stuck over-running clutch, and wear of the bearings rolling element.
- Inspect the drive gearbox frame for cracking or deformation.
- Inspect the drive gearbox oil cooler, if present, for shell-side plugging and tube-side leaks.
- Inspect the drive motor – electric (main or auxiliary) for bearing wear, blocked fan and cover looseness, cracked or deformed frame, external fan and cover looseness, shaft seal leakage, and shaft seal wear .

- Inspect the drive motor and gearbox couplings for misalignment and wear.
- Inspect the drive pinion gear for damage and wear.
- Inspect the guide bearing air seal cover for leakage.
- Inspect the guide bearing housing for leakage and looseness.
- Inspect the instrumentation - pressure and temperature (local, DCS, control room) for failed or improper indication.
- Inspect the lube oil cooling heat exchanger (guide bearing, support bearing, rotor drive) for shell side plugging and tube side leakage.
- Inspect the lube oil metering orifice, if present for clogging.
- Inspect the lube oil system (guide bearing, support bearing, rotor drive) for clogged filters, gear drive oil pump failure, leaking pressure relief valve, piping/fittings/valve leaks, oil pump motor failure and failure of the oil pump temperature switch.
- Inspect the pin rack for failed welds pin rack to rotor shell leading to detachment Inspect the pin rack for wear.
- Inspect the rotor assembly (diaphragm, stay plates, shell, post, trunnions) for post separation from the diaphragm and for shell droop.
- Inspect the seal plates (hot radial, cold radial, axial, sector) for adjuster failure.
- Inspect the soot blower for drive failure, improper indexing or movement, and leaking hose/packing/piping connections.
- Inspect the support radial bearing (rolling element) for wear.
- Inspect the support radial bearing stub shaft for fastener failure.
- Inspect the T-bars for fastener failure.

The System Owner should also inspect the instrumentation associated with the air preheater, such as pressure and temperature instruments (local, DCS, control room) for failed or improper indication. Pressure gauges, temperate gauges, thermometers and other instrumentation should be visually inspected for operability every three months. Calibration of instrumentation should be conducted approximately every 18 months. The following general inspection activities should be considered:

- Follow ISA guidelines in calibrating 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
- Qualified personnel should only perform this task

Task content should include the following activities:

Instrument	Preventive Maintenance Task
Pressure Sensor and Transmitter	<p>Calibration:</p> <ul style="list-style-type: none"> <li>• 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.</li> <li>• Verify and adjust, as needed, the device's zero span</li> <li>• Verify and adjust, as needed, the device's linearity and hysteresis</li> <li>• It is strongly suggested that a minimum 5 point calibration response check be performed, a 9 point check should be considered for more critical devices.</li> </ul>
Temperature Switch	<p>Calibration:</p> <ul style="list-style-type: none"> <li>• A visual inspection should be performed to check for tightness of the connections, general cleanliness, over heated components, and cracked terminations and cases.</li> <li>• Verify and adjust, as needed, the device's zero span.</li> <li>• Verify and adjust, as needed, the device's linearity and hysteresis.</li> <li>• It is strongly suggested that a minimum 5 point calibration response check be performed, a 9 point check should be considered for more critical devices.</li> </ul>
Pressure Switch	<p>Calibration:</p> <ul style="list-style-type: none"> <li>• 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.</li> <li>• Verify and adjust, as needed, the device's zero span.</li> <li>• Verify and adjust, as needed, the device's linearity and hysteresis.</li> <li>• It is strongly suggested that a minimum 5 point calibration response check be performed, a 9 point check should be considered for more critical devices.</li> </ul>
Pressure Regulator	<p>Set Point Verification should include the following:</p> <ul style="list-style-type: none"> <li>• Visually inspect for loose, damaged, or missing hardware and parts, or corrosion.</li> <li>• Perform set point verification test at the devices operational set points and compare to historical</li> <li>• Make adjustments as required.</li> </ul>
Rotor Stop Alarm	<p>Inspection and testing of the rotor stop alarm should include the following:</p> <ul style="list-style-type: none"> <li>• Visually inspect for loose, damaged, or missing hardware and parts, or corrosion.</li> <li>• Verify the functionality of the alarm upon rotor stoppage in accordance with the original equipment manufacturer's recommendations and procedure (if provided).</li> <li>• Make adjustments as required.</li> </ul>

### 4.3.3 Example Worksheets

Calibration Worksheet		
Calibration Point	As-Found	As-Left

Measurement Worksheet		
Measurement	As-Found	Notes on Remediation

As-Found Worksheet for a Temperature Switch (Check-off any unacceptable conditions)		
	Sensing device (Other types)	Cannot be calibrated
	Sensing device (Other types)	Out of tolerance
	Electrical switch	Cannot be calibrated
	Electrical switch	Out of tolerance
	Electrical switch	Loose connections
	Sensing device (Temperature bulb and capillary)	Cannot be calibrated
	Sensing device (Temperature bulb and capillary)	Out of tolerance
	Mechanical linkage	Cannot be calibrated
	Mechanical linkage	Out of tolerance

As-Found Worksheet for a Pressure Switch (Check-off any unacceptable conditions)		
	Sensing line and tube fittings	Broken or cracked line, or loose fitting
	Sensing line and tube fittings	Fitting and/or tubing leak
	Sensing line and tube fittings	Leaking valves
	Sensing device	Cannot be calibrated
	Sensing device	Out of tolerance
	Elastomers, gaskets, and O-rings	Cannot be calibrated
	Elastomers, gaskets, and O-rings	Out of tolerance

<b>As-Found Worksheet for a Pressure Switch (Check-off any unacceptable conditions)</b>		
	Electrical switch	Cannot be calibrated
	Electrical switch	Out of tolerance
	Mechanical linkage	Cannot be calibrated
	Mechanical linkage	Out of tolerance

<b>As-Found Worksheet for a Pressure Sensor and Transmitter (Check-off any unacceptable conditions)</b>		
	Transmitter Electronics	Cannot be calibrated
	Transmitter Electronics	Out of tolerance
	Sensing lines and associated components, for example, condensate pot, sealed reference legs, bellows, manifold, root valves and isolation valves.	Cracked or broken
	Sensing lines and associated components, for example, condensate pot, sealed reference legs, bellows, manifold, root valves and isolation valves	Damaged bellows
	Sensing lines and associated components, for example, condensate pot, sealed reference legs, bellows, manifold, root valves and isolation valves	Fitting or tubing leak
	Sensing lines and associated components, for example, condensate pot, sealed reference legs, bellows, manifold, root valves and isolation valves	Leaking bellows
	Sensing lines and associated components, for example, condensate pot, sealed reference legs, bellows, manifold, root valves and isolation valves	Leaking valves
	Sensor, for example, capacitance cell, Bourdon tube, Piezo electric, strain gauge	Cannot be calibrated
	Sensor, for example, capacitance cell, Bourdon tube, Piezo electric, strain gauge	Out of tolerance
	Internal wiring and connections	Cannot be calibrated
	Internal wiring and connections	Out of tolerance
	Sensor, capacitance cell	Cannot be calibrated
	Sensor, capacitance cell	Out of tolerance

<b>As-Found Worksheet for a Pressure Regulator (Check-off any unacceptable conditions)</b>		
	Regulator	Cannot be calibrated
	Regulator	Out of tolerance
	Elastomer	Failed
	Pneumatic connections	Loose

In addition, the System Owner should consider evaluating all data and data trends gathered from recorded monitoring points and from any other condition monitoring activities performed on this equipment.

#### **4.3.4 Oil Analysis**

The objective of the Oil Analysis task is to ensure equipment reliability and operability by maintaining high quality lubrication, and detecting the wear of rotating components, and to ensure that the oil remains clean and free of contamination. Oil analysis, as a minimum, should test and trend the following using a spectro-chemical analysis consisting of:

- Particle count
- Viscosity
- Total acid/base measure
- Condition of oil additives
- Air release properties
- Water content
- Solid debris and wear metals

The following failure mechanisms may be identified while taking oil samples for analysis:

- Check the drive gearbox for gear wear
- Check the drive gearbox for gear wear or damage
- Check the drive gearbox for wear - bearings output shaft
- Check the drive gearbox for wear - bearings rolling element
- Check the drive gearbox oil cooler, if present for tube side leak
- Check the guide bearing (rolling element) for wear
- Check the lube oil (guide bearing, support bearing, rotor drive) for loss of lubricating properties
- Check the lube oil cooling heat exchanger (guide bearing, support bearing, rotor drive) for shell side plugging
- Check the lube oil cooling heat exchanger (guide bearing, support bearing, rotor drive) for tube side leak

- Check the support bearing (tilt pad type) for wear
- Check the support bearing cover shield for damage or missing
- Check the support radial bearing (rolling element) for wear

The results of this task may be used to determine when the oil has reached the end of its useful life and requires changing, thus reducing the need for a time-based oil change. Trends of the wear and contaminants in the oil can help to establish when filters require replacement; again, reducing the need for a time-based filter change. A comprehensive oil analysis program can reduce cost and extend the operational life of the components lubricated by the oil systems.

Oil levels should be checked on a weekly basis. Lubrication types should be in accordance with each equipment manufacturer's recommendations. Replacement of lubricant with an alternate type/grade/manufacturer is not recommended and could have an adverse affect on the equipment.

Table 4-2 provides a listing of lubricated air preheater components and the type of lubricant often used in this plant application. The types of lubricants noted in the table may not be suitable for all preheater applications, and the user of this report should refer first to the maintenance guidance provided by each original equipment manufacturer.

**Table 4-2  
Typical Air Preheater Component Lubricants**

Air Preheater Component	Lubricant and Frequency
Air motor and gearbox ball bearings	Mobilux™ No. 2 or equal
Air motor and gearbox	SAE 10 or 10W oil
Cleaning device speed reduction unit	High-grade EP oil (non-corrosive type)
Cleaning device swivel joint and sleeve bearings	Lubrication is typically not required for these devices.
Cleaning device worm gear housing	Sinclair Litholene™ #2 or equal
Falk-type couplings operating between 0 – 150°F	Replace lubricant once a year with Mobilux™ No. 2 or equal
Fractional horsepower motors	Ball bearing motors are packed with sufficient grease for approximately five years of operation under normal conditions. After this time, the bearings and housings should be cleaned and repacked with the grease recommended by the motor manufacturer
Oil circulation pump ball bearings	These bearings are typically factory-sealed and the grease does not need to be replaced.
Pre-lubricated ball bearings for squirrel-cage electric motors	These bearings are factory-sealed and the grease does not need to be replaced.
Rotor drive gearbox	SAE 30 mineral oil with a viscosity of 450 – 600 for ambient temperatures between 15 – 60 °F SAE 40 mineral oil with a viscosity of 850 – 1000 for ambient temperatures between 50 – 125 °F

**Table 4-2 (continued)**  
**Typical Air Preheater Component Lubricants**

Air Preheater Component	Lubricant and Frequency
Rotor drive gearbox low-speed shaft bearings (upper and lower)	Replace grease once a year with a No. 2 ball and roller bearing grease
Rotor drive gearbox over-running clutch coupling	This coupling is typically an integral part of the unit and is lubricated with oil splashed up by the gearbox gears
Rotor radial guide bearing	Typically the same oil that is determined to be suitable for the thrust bearing will also be acceptable for use on the rotor radial guide bearing
Rotor support thrust bearing	Refer to the manufacturer's recommendations based on the type of lubrication method (that is, bath-lubricated or filtered circulation system) and the operating temperature (typically below 160 °F)

#### 4.3.5 Vibration Analysis

The objective of the Vibration Analysis task is to ensure continued equipment operation by detecting wear in bearings and other rotating components before failure occurs. Vibration analysis should be performed on the electric motors, pumps, and gearboxes. It may also be performed on the support and guide bearings, if accessible, and if the pickup is capable of handling the slow rotational speed of the rotor. Vibration analysis should be reasonably effective for detecting the following failure mechanisms:

- Detecting gear wear, damage, wear of the bearings output shaft, or wear of the bearings rolling element of the air preheater drive gearbox
- Detecting bearing wear of the electric drive motor (main or auxiliary)
- Detecting misalignment or wear of the drive motor and gearbox couplings

#### 4.3.6 Thermography

Thermography has the objective of detecting abnormal thermal conditions that may be indicative of component degradation, and exhibit themselves as localized heating (that is, hot spots), or differential temperatures between similar subcomponents or locations, for example, wiring connections, poor heater element heat transfer, overheated support or guide bearings. This task may require the use of the more technically-advanced imagers, but can still be effective if only the simpler handheld devices are employed. Thermography should be reasonably effective for detecting the following failure mechanisms:

- Door and manway leakage, external corrosion or rust, and warpage or cracking of the air preheater housing
- A blocked fan and loose cover, and a breakdown of lead and connection insulation of the electric drive motor (main or auxiliary)

### 4.3.7 Performance Monitoring

Performance Monitoring has the objective of ensuring continued equipment and system operation, especially with respect to the air preheater's thermal performance and the integrity of its sealing components. This task is expected to determine if the air preheater's thermal performance is acceptable, and as a consequence of this testing, the owner may opt to also perform a seal leakage test. This is not the extensive ASME acceptance test PTC 4.3, but making use of the information provided by the plant's data systems and monitoring devices.

Performance monitoring should be reasonably effective for attributing any the following failure mechanisms for a loss in air preheater thermal performance:

- Corrosion, fracturing, plugging and wear of cold heating elements (baskets)
- Erosion, fracturing, plugging and wear of hot heating elements (baskets)
- Erosion, failure, fracturing, plugging or wear of intermediate heating elements (baskets), if present
- Adjuster failure, erosion, misalignment, static seal failure or wear of seal plates (hot radial, cold radial, axial, sector)
- Corrosion of H<sub>2</sub>SO<sub>4</sub>, corrosion from HBr, cracking (mostly in contact seals, leakage, loose hardware or wear of seals (axial, radial, bypass/circumferential, post)
- Lance or nozzle erosion, improper indexing or movement, misalignment of lance, missing or worn nozzles of soot blower for: erosion to lance or nozzle
- Contact wear, cold end corrosion, fastener failure or wear of T-bars

The user of this report should note that the purpose of the ASME PTC 4.3 is to establish procedures for conducting performance tests to determine and measure the following operating parameters associated with an air preheater:

- Gas side efficiency
- Air leakage
- X-Ratio (ratio of the heat capacity of the air passing through the air preheater to the heat capacity of the gas passing through the air preheater)
- Gas and air pressure loss
- Gas and air inlet and outlet temperatures

A determination of any or all of the performance characteristics noted may be necessary for:

- Checking the actual performance against the manufacturer's guarantee
- Comparing these performance characteristics with a standard of operation
- Comparing performance when firing different fuels
- Determining the effect of changes to equipment

Determining corrections to air preheater exit gas temperature caused by variations in inlet air temperature in an efficiency test of a steam generator.

Seal leakage tests should be conducted prior to an outage to determine the extent of leakage, its locations within the air preheater, and possible causes for the seals not functioning properly. Testing should be conducted in accordance with the original equipment manufacturer's recommendations and procedure (if provided).

#### **4.3.8 Auxiliary Air Drive Functional Test**

In some air preheater systems, an air motor is provided as an auxiliary back-up for instances of electrical drive motor failure, and for the rotor maintenance. If this is the case, a functional test of the air motor should be conducted monthly to assure its reliability as an emergency back-up. The objective of the auxiliary drive functional test is to ensure the operability of auxiliary air drive motor that is used only occasionally or upon demand. There is no need to test electric auxiliary drive motors to an extent beyond that described in this report for electric drive motors.

Because of the various types and sizes of air motors that may be provided as an auxiliary drive, the test should be conducted in accordance in the manufacturer's recommendations. In general, the auxiliary air drive functional test should verify the following performance characteristics against the curves provided by the original equipment manufacturer:

- Horsepower of the air motor
- Torque of the air motor
- Air consumption
- Maximum allowable shaft radial load

Prior to conducting the functional test, it is important to ensure that the desired air pressure is available at the motor, while the motor is operating. A pressure reading at the compressor does not necessarily mean that the same pressure will be available to an operating air motor, because of possible restrictions and friction losses in the air system. Exhaust restrictions can also affect air motor operation, and are often the cause of performance problems.

In many air supply systems, a four-way valve or two three-way valves may be installed to prevent blockage of the secondary exhaust port. These valves should also be inspected and tested for operability and any signs of physical damage, corrosion or leaks.

The auxiliary air drive functional test should be reasonably effective for detecting the following failure mechanisms:

- Fouled air filter, air compressor failure, oiler leakage or a stuck/failed solenoid valve of auxiliary drive air compressor, tank, air filter, oiler, and solenoid valve
- Bearing wear, failure/seizure, loose mounting, or loss of torque of auxiliary drive air motor
- A stuck over-running clutch of drive gearbox

### 4.3.9 Oil Filter Replacement

The objective of the Oil Filter Replacement task is to maintain clean oil. Oil filters that may need yearly changing are the oil breather on the drive gearbox and the filters integral to the guide bearing, support bearing and rotor drive lubricating oil systems.

Oil changes should occur at least once a year, but may occur more often if done in conjunction with an oil filter cartridge replacement, and may occur less frequently if oil analysis is routinely performed. Oil should be replaced with an identical lubricant, as specified by each equipment manufacturer's maintenance manual. Care should be taken to ensure the oil reservoirs are not overfilled, and that there are no leaks once the equipment has been returned to service.



#### Key Technical Point

When replacing the lubricant in the rotor thrust bearing, the oil level should be checked after the lubricant has been able to heat up and circulate through the system. Failure to do this may result in a false oil level reading, which could lead to the bearing being insufficiently lubricated during service.

Oil filter cartridges are typically provided in the rotor thrust bearing oil lubrication system and the radial guide bearing oil lubrication system. A typical process for changing the filter cartridges includes the following steps:

- Remove the caps on the drain lines (typically two) and the vent plug in each filter cap to allow the oil to drain from the filter.
- Remove the filter shell from the base. This is often accomplished by simply unscrewing the single center post nut at the top of each filter and sliding the shell upward off of the cartridge. This will allow the cartridge centering clip and the cartridge to be slid off of the center post.



#### Key Technical Point

At this point in the process, the cartridge should be inspected to identify the amount and type of debris found inside the assembly.

- Clean the shell and base thoroughly, and remove/replace the old gaskets with new ones. The filter may be removed from the filter shell to facilitate cleaning. The gasket in the filter cap may be also be removed and replaced, if necessary.
- Install the new cartridges by sliding each one gently over the center post. Then slide the centering clip down flush with the top of the new cartridge. Then reassemble the shell and cap to the filter base.
- Tighten cap nuts and drain line caps. Add oil to refill filter shells and replace vent plugs, as needed.
- The system should then be restarted to check for leaks. Excess air should be bled through the vents.

### 4.3.10 Maintenance Inspection

The objective of the Maintenance Inspection task is ensure the continued safe and reliable operation of the air preheater, and to correct those degradations whose repair cannot be delayed. For the purposes of this report, the Maintenance Inspection should consist of the off-line maintenance activities described in Table 4-3.

The Maintenance Inspection should be considered on an annual basis or when the unit is off-line. Owners may consider performing only those Maintenance Inspection tasks that are needed, based on the condition of the air preheater components at the time the unit is taken off-line. A job plan is provided for each of these major activities.

**Table 4-3**  
**Recommended Maintenance Inspection Tasks for Air Preheaters**

Maintenance Inspection Tasks	Reference Section
Heating element inspection	Job Plan #1
Rotor support and guide bearing inspection	Job Plan #2
Rotor bearing oil circulation systems inspections	Job Plan #3
Motor off-line test and inspection	Job Plan #4
Rotor drive assembly including gearbox and couplings inspection	Job Plan #5
Rotor and rotor seals inspections	Job Plan #6
Cleaning system inspection and functional test	Job Plan #7
Heating element water wash	Job Plan #8

#### 4.4 General Guidance for Repairs

Figure 4-2 illustrates a generic process for determining whether to repair or replace a system component that is no longer performing in accordance with design requirements.

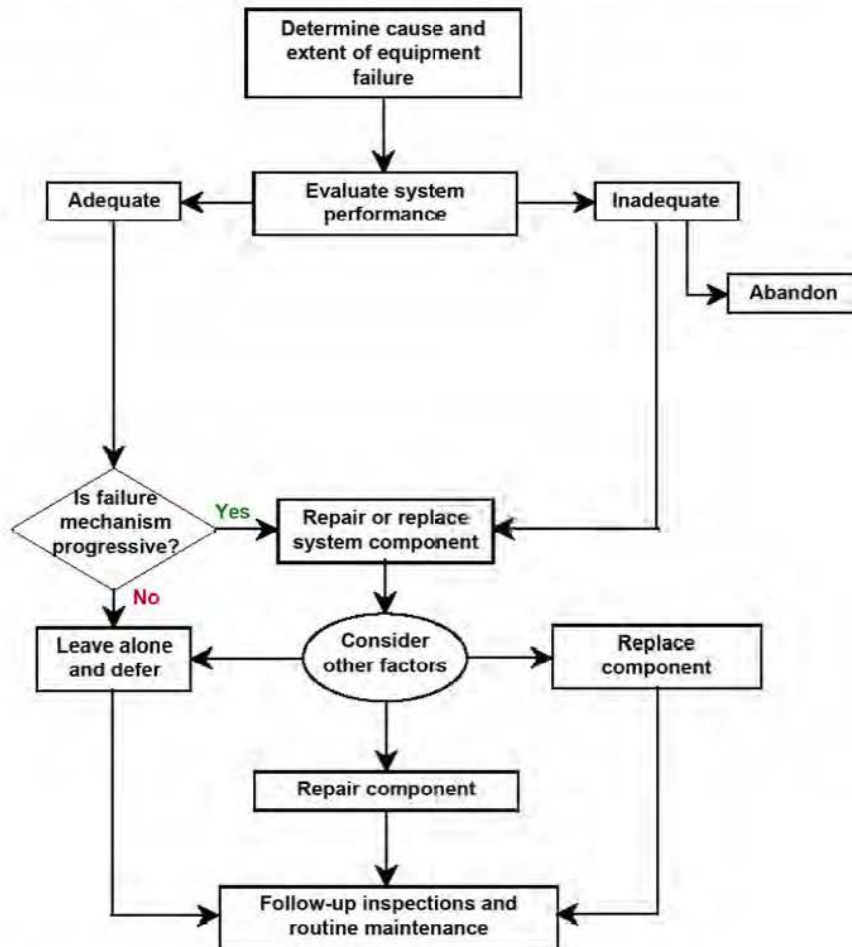


Figure 4-2  
Generic Repair vs. Replace Evaluation (Based on EPRI 1009670)

The question of whether to repair, replace or defer maintenance on a system component is often a complicated one to answer. The issue is further complicated depending upon whether the analysis is performed for an entire system or simply a particular component of an existing Coal Handling conveying system. In most cases, thorough economic cost study is the only effective way of attaining a quantified answer.

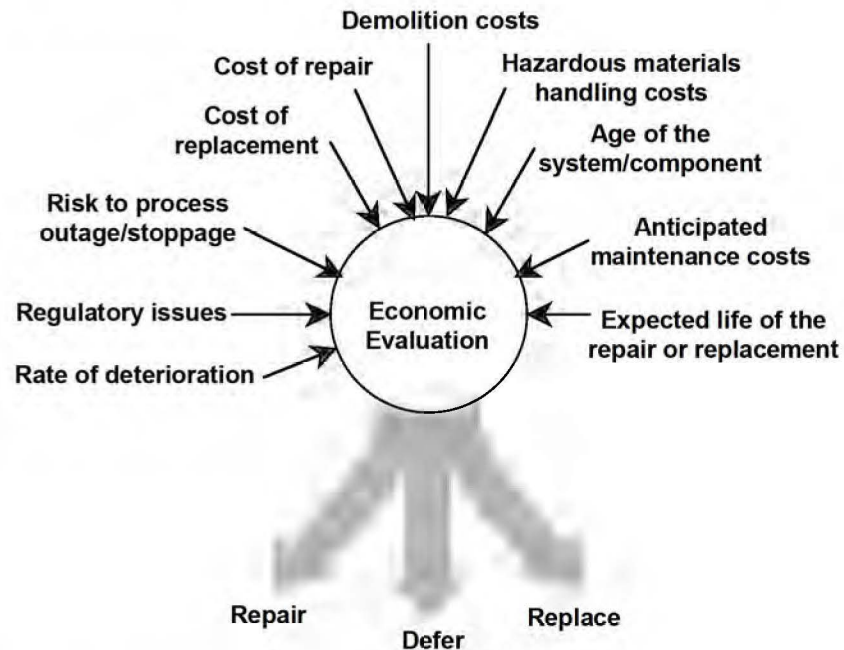


#### Key O&M Cost Point

As a general rule of thumb, if the repair costs 50% or less of the replacement cost, then repair should be considered. If the percentage is greater, then replacement is generally the best option.

This rule of thumb is generally effective if the system can be put out of service during replacement construction. Of course, one option is to do nothing or defer the maintenance.

Figure 4-3 illustrates a number of factors that should be considered when performing a comprehensive analysis. Some of the factors are easier to quantify than other factors, and in some cases actual costs can be estimated. To quantify the results of the analysis, some factors may be weighted as to its relative importance in the calculation.



**Figure 4-3**  
**Factors Considered During the Decision Making Process**

Because of the complexity of the analysis and the varying relevancy of each factor, this report does not attempt to provide a mathematical equation for performing such a calculation. The reader should also note that some of the factors are more qualitative in nature and as such tend to be more difficult to quantify in those cases where an economic cost study is desired.

Each of the factors illustrated in Figure 4-2 is discussed in more detail below. The reader should recognize that this list of factors is not all-inclusive, and is provided for illustrative purposes only.

#### **4.4.1 Quantifiable Factors for Economic Cost Study**

As noted in the previous section, some factors are easier to quantify than other factors, and as such in some cases costs can be estimated for each course of action. A brief discussion of the quantifiable factors and costs is provided below.

- **Cost of the Repair** – One of primary factors that should be considered is the cost of the repair. This cost is typically comprised of the costs for materials, equipment, labor and preparation needed to perform the repair. For the purposes of this report, this cost would not include follow-on maintenance costs associated with maintaining the repaired components over the life of the operating system.

- **Cost of Replacement** – Another primary factor that should be considered is the cost of replacement. This may apply to either the entire system or a particular component under evaluation. Similar to estimating the cost of a repair, replacement costs should include the costs for materials, equipment, labor and preparation needed to replace the existing component(s). Likewise, for the purposes of this report, this cost would not include follow-on maintenance costs associated with maintaining the replaced components over the life of the operating system.
- **Anticipated Maintenance Costs** – When making the decision to replace or repair a particular component, the manager should consider the anticipated maintenance costs associated with either action. Whether an item is replaced or repaired, there will be costs associated with maintaining it for some period of time. An estimation of projected maintenance costs should include the following components:
  - Maintenance Equipment Costs – Special equipment and/or tools are often required to perform a repair or to replace a given item. The costs of using these items should be factored into the decision as to whether replace it or repair it.
  - Labor Costs – The labor costs associated with projected or anticipated maintenance are important to consider because they may constitute a significant component if the life expectancy of the operating system or component is high. Labor costs can be effected by the availability of maintenance personnel, whether special or unique skills are required, and/or whether the maintenance personnel are in-house or contracted.
- **Demolition Costs** – In many cases, there are significant demolition costs associated with a replacement that are not necessarily as important when performing a repair. Demolition costs should include costs associated with preparing the system or structure for the replacement, removal of the components that have been replaced, and disposal of the waste.
- **Hazardous Materials Handling Costs** – In some cases there are costs associated with handling certain hazardous materials such as asbestos, lead paint, and hazardous chemicals that should be factored into the overall cost of performing maintenance and/or repair on existing operating systems and their components. These costs may be so significant that the most economical option is to defer the maintenance or repair until the end of the service life of the facility.

#### **4.4.2 Key Qualitative Factors in the Decision Making Process**

Several key qualitative factors that should be considered in the analysis are discussed in more detail below:

- **Rate of Deterioration** – The rate of deterioration is another factor that should be considered when evaluating the cost benefits of either repairing or replacing a system component. The rate of deterioration primarily impacts the urgency with which the item needs to be addressed. For an item failing at a slow rate, the system owner is afforded additional time to decide what course of action to take. In some cases, the rate of deterioration may be so slow that the best course of action is to defer any action until the component's condition gets more severe. Items failing at a faster rate require that more prompt action be taken.

- **Age of the System/Component** – The age of the operating system and its components should be factored in the evaluation for a number of reasons. First, the older the system is, the less likely repairs will be feasible. Conversely, the newer the system, the less likely it would be beneficial to replace the entire system and the more likely it would be to perform repairs of needed components. Secondly, older systems may have a number of maintenance issues that need to be considered simultaneously. As such the repair costs of these multiple issues should be considered together and not separately.
- **Risk to Process Outage/Stoppage** – The risks associated with inadvertently interrupting the process(es) should be considered from two perspectives – short term and long term. In the short-term perspective, the system owner should consider which action, repair or replacement, would present the least risk to interrupting the processes. In some cases, a repair can be performed without any disruption to the processes, whereas a replacement may require the process equipment shut down until the replacement is complete. When this is the case, the system owner may also consider the cost of lost production necessitated by the replacement.
- **Expected Life of the Replacement or Repair** – Other factors that should be considered are the expected life of the replaced or repaired component. Regardless of what action is taken, the restored condition will not last forever. In time, the item will either have to be initially repaired, repeatedly repaired, or replaced again. The length of time until one of these follow-on activities will vary depending on the maintenance decisions taken now.
- **Regulatory Issues** – Regulatory issues that may have arisen or new regulations that may have been enacted since the original construction of the system should also be considered when deciding the optimum maintenance action to take.

## 4.5 Air Preheater Repair Activities

Because of the complexity of many of the system components integral to an air preheater, most are repaired if needed, or until they have reached the end of their service life. Depending on the extent of the repair and the skill of the craft within the maintenance organization, assistance from an authorized service representative recommended by the original equipment manufacturer may be warranted.

The maintenance activities recommended in this section are generic in nature and may not be applicable, in whole or in part, to all air preheater components installed in a fossil-fuel power plant. The user of this report should apply the guidance in this report in conjunction with the equipment-specific guidance and repair instructions provided by each particular manufacturer when performing corrective maintenance on air preheater components.

### 4.5.1 Repair and Replacement of Air Preheater Gearboxes

The repair and replacement guidance provided in this section may be applicable to the following gearboxes typically associated with an air preheater system:

- Rotor drive assembly gearbox
- Rotor rack and pinion (if provided)
- Rotor bearing oil lubrication pump gearboxes (if provided)

#### 4.5.1.1 Typical Procedure for Gearbox Disassembly

##### *General Guidance*

The following disassembly sequence is provided in this report for information purposes only, and should not be used without reference to the manufacturer's instructions that are specific to the actual gearbox being maintained. Note that any work done on equipment during the manufacturer's warranty period without the written approval of an authorized manufacturer's representative could void the warranty.

**Lock Out/Tag Out Procedure** – These steps should be followed to complete lock out/tag out:

1. Identify the energy sources used and all control devices.
2. Notify all affected personnel.
3. Turn OFF all operating controls.
4. Lock out or tag out all switches and energy controls in "OFF" or "SAFE" positions.
5. Test all operating controls to ensure no power is getting to equipment.
6. Perform required maintenance.

**Visual Inspection** – The following sequence is for complete disassembly. Visual inspection of the gearing through the inspection cover may provide the information necessary to determine the cause of a problem without complete disassembly.

##### *Tools Required*

For disassembly and reassembly, several commonly available tools may be required. No special tools or fixtures are required for the housing and gears, and oftentimes no tools for assembly/disassembly are provided by the manufacturer. Following is a list of some tools that may be useful:

- Crane or hoist, along with soft slings or chains.
- Eyebolts
- Dial indicator
- Pry bar
- Crocus cloth or fine steel wool
- Wrenches, screwdrivers, torque-wrench
- Prussian blue or similar dye for tooth contact check
- LocTite™ No. 49-31 Plastic Gasket, or equivalent plastic gasket material

##### *Spare Parts*

Parts such as gaskets should be replaced when disassembly is performed. The manufacturer should be contacted to obtain a list of recommended spare parts, as they vary from one manufacturer to another and from one mode to another.

### *Removal of Gear Cover*

Inspections typically performed prior to gear cover removal include the following:

- As-found alignment conditions
- Various end-play checks and verifications

Throughout the disassembly sequence, observe carefully what may have occurred inside the unit and record the position and condition of any failed parts. Note any parts, bolts, nuts, or holes that are numbered or match marked; they must be reassembled as matched for correct assembly.

1. Remove any deflectors, baffles, or coupling guards.
2. Disconnect the high speed and low speed couplings.
3. Disconnect any piping, conduit, or wiring that joins the housing sections.
4. Remove any bearing temperature sensor service heads, probes, or other auxiliary instruments that could be damaged by removal of the cover.
5. Remove the cap screws in the upper half of the seals, end caps, and thrust bearing housing; if lock-wiring is supplied, cut where necessary.
6. Remove end caps, seals, and gaskets.
7. Carefully loosen the thrust bearing housing. (Use the jacking screw holes to loosen from gear housing.)
8. Remove all cap screws and nuts on the parting line. Leave studs in place to serve as guides for cover removal.
9. Break the parting line seal by using jacking screws in the jacking screw holes located on each end of the gear unit. Some sharp raps with a rawhide hammer at the corner positions and prying with a large screwdriver may be needed to loosen the parting line joint.
10. Attach a crane or hoist to the lifting provisions in the cover and carefully lift the cover by lifting both ends equally about ¼ inch (6 mm). Check that bearings remain seated and no conduit or wiring that crosses the parting line is still connected.
11. Check the upper lower speed bearing halves to see if they are stuck in the cover. If they are, carefully pry them out or push them out with a rod inserted through the bearing thermometer holes.
12. Carefully lift the cover straight up, until it clears the gearing. The cover will need enough clearance above the gear and studs for the cover to be removed. CAUTION: Do not bump gear assembly with the raised cover.
13. Place the cover on wood blocks so that the machined split line will not be damaged. Care should be taken to ensure internal lubrication lines are not damaged.

### Removal of Pinion, Gear and Bearings

Removal of gearing from housing is not required if only the rotating element inspection is needed. Radial bearings can be removed and replaced by rolling shells out of housing, one bearing at a time (replace the bearing after inspecting it and prior to inspecting other bearings). The thrust bearing is typically more difficult to remove and reinstall than the radial bearings, and detailed guidance is provided in the following section.

1. Mark the location of each bearing in the housing so that it can be reassembled correctly.
2. Remove the pinion with the bearings in place using a soft sling on each side of the mesh. Place the shaft on a soft material such as wood or rubber or a padded V-rack, taking care not to damage the gear teeth.
3. Remove the upper half of the low speed bearings.
4. Remove the low speed gear and shaft assembly with a chain inserted through a lifting hole or eyebolts inserted into the gear. Care should be taken to protect the teeth by placing wood blocks between the chain and the sides of the gear.
5. Place the gear on a soft surface such as wood taking care not to damage the teeth. Block each side to prevent the gear from rolling.
6. Gears may be inspected at this time in accordance with the guidance provided in this report.



#### Key Technical Point

It is advisable to pour a small amount of oil on each bearing or journal surface to ensure rotation of an oil film whenever rolling gear elements in their fluid film bearings, as the lubrication system is inoperable.

### Thrust Bearing Removal

The thrust bearing might contain temperature sensors, and the lead wires exit the bearing housing through the oil fitting. Following is a sequence for removal of the thrust bearing:

1. Remove the temperature sensors from the thrust bearing shoes with a small hooked probe to pull out the star washer through the access cover adjacent to the sensor connection heads.
2. Remove the thrust bearing end cap bolts.
3. Remove the end cap and shims from the thrust bearing housing.
4. Use wide jaw pliers to pull the outer backing ring a short distance out of the thrust bearing housing.
5. Remove the outer backing ring and thrust pads. Mark the position of pads containing embedded temperature sensors so they can be returned to their original location.
6. Remove the axial probe target plate.
7. Loosen the set screws or locking tabs in the thrust collar lock nut. Note that some thrust collars are integral to the shaft.
8. Remove the lock nut by turning it counterclockwise. Use a spanner wrench or a small punch inserted into the spanner holes to loosen the nut.

9. Insert cap screws into the threaded puller holes in the thrust collar.
10. Carefully remove the thrust collar. Do not allow the collar to drop down and damage the lock nut threads as it is being removed.
11. Mark the position of the inner thrust pads containing embedded temperature sensors so they can be returned to their original position. Remove the shoes and inner backing ring.

**Oil Sample Collection** – If needed, an oil sample (typically a full quart or liter) can be collected at this time for later analysis.

#### 4.5.1.2 Inspection and Maintenance of Gears

##### *Introduction*

The purpose of this section is to describe why gear tooth contact should be checked regularly, how the actual check is made, and how to interpret the tooth contact check on power transmission gearing with involute double helical teeth and parallel input and output shafts.

##### *Purpose of Checking Tooth Contact*

Gear teeth must have an even load across the entire face width to minimize stress on the teeth. The contact between gear teeth is line contact; therefore, the alignment between the rotating elements (pinion and gear) is critical. Tooth alignment is controlled by the accuracy of the rotating elements, the housing, and the bearings assembly.

##### *When to Check Tooth Contact*

Tooth contact should be checked on all new installations, after any disassembly of the gear unit, and after any major housing-to-foundation change. It may also be checked as part of routine annual maintenance or when a problem related to alignment is suspected. Contact should be checked on the foundation being replaced, to be sure the unit will operate properly.

##### *How to Check Tooth Contact*

The contact can be checked two ways:

- **Soft Blue** – Apply soft machinist’s bluing or transfer bluing to the teeth of one gear and roll that gear by hand through mesh with its mating gear. (The terms “blue” or “bluing” are used for convenience; the dye is available in other colors. A soft blue check is usually run across another element that is coated with another color such as soft yellow. This contrast results in a more distinct, representative contact pattern.) The transfer of the blue from one gear to the other gear is read as the contact.
- **Hard Blue** – Paint the gear teeth with hard or layout blue, run the gear unit, and observe the pattern of “wear off” of the bluing.

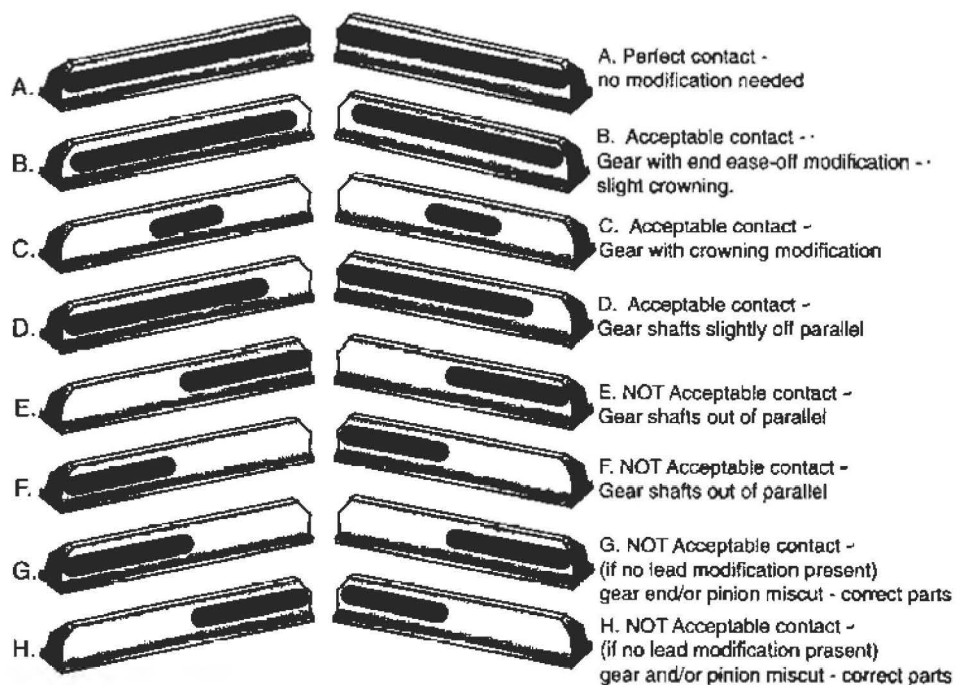
Contact checking may usually be accomplished through the inspection cover port. Occasionally, soft blue checking is done with the housing cover removed, such as during the reassembly process.

### Interpretation of Tooth Contact

The following is information to be used only for guidance in deciding if tooth contact is adequate. In most cases, the gearbox manufacturer should be consulted on how to correct poor contact. Assuming properly manufactured parts, minor corrections can be made to the tooth contact by shimming the gear housing. Exactly what contact should be acceptable should be based on the manufacturer's recommendations and experience.

Maintenance personnel should remember that tip or root relief modifications are designed to improve load distribution when a unit is operating under load, but they can make the contact appear quite bad under no load, as in a soft blue check. Generally, with a soft blue check, one is looking for some blue to transfer, usually in a line that covers at least 80% of the face width, a centralized 60% coverage, or acceptable contact patterns consistent with those illustrated in Figure 4-4. Do not be alarmed by a lack of blue covering the flank of the tooth; flank contact should normally not extend entirely to the tip of the tooth.

Figure 4-4 illustrates various examples of tooth contact patterns. Keep in mind that a soft blue contact will not produce such dark impressions – look for the same pattern in a “sketchy” impression.



**Figure 4-4**  
**Tooth Contact Patterns**

The hard blue operational/running tooth contact check can be done from no load to full load, and the results will vary with the load condition. If the unit is run at no load, the test will usually appear similar to a soft blue check. More blue will wear off the pinion than the gear due to the higher number of cycles the pinion sees. As the load increases, blue will wear off more of the tooth flank. Look for evidence of even load across as much of the gear tooth, both flank and face with, as possible.

### 4.5.1.3 Maintenance of Bearings

#### *Bearing Clearance*

Measurement of bearing clearances may be accomplished while the gear is stopped by lifting the shaft and measuring the distance traveled with a dial indicator or by using feeler gauges, carefully sliding a feeler gauge between the top of the bearing bore and the shaft.

Some wear should be expected, especially on a gear that is stopped and started frequently. The bearing may be considered operational as long as the measured clearance does not exceed the design clearance by more than 0.004 inches (101.6 microns). Note that if shaft vibration is excessive, this clearance increase may not be acceptable, especially on large or small bearings. For instance, a small 3" (10.16 cm) diameter high-speed bearing, with a design clearance of 0.003 – 0.005 inch (76.2 – 127 microns) clearance, could not withstand a clearance increase of 0.004 inches (101.6 microns). The clearance on the tilt pad bearings are difficult to check accurately and can normally be classified as acceptable if they show no signs of distress, damage, or excessive wear.

#### *Bearing Contact Correction*

After bearing contact is satisfactory, it may be possible to improve gear tooth contact by adjusting the shims under the unit. Do not attempt to modify the bearing contact of the tilt pad journal bearing in any manner except the removal of any localized nicks or dings (high spots).

Sometimes gear tooth contact may be corrected by scraping and polishing one of the bearings loaded in the bottom section to spread the contact along the face width. If this is necessary, the manufacturer should be contacted.

After correcting bearing and tooth contact and before putting the cover on the gearbox unit, the bearings should be liberally lubricated with clean oil to provide for initial start-up lubrication.

#### *Correcting Bearing High Spots*

Bearing high (bright) spots should be lightly scraped and polished with fine steel wool or crocus cloth until they blend in with the rest of the bearing.

#### *Flaking of Babbitt*

If flaking is caught in the early stages, the bearing may be repaired by scraping and polishing. The cause of vibration or hammering should be corrected before the gearbox unit is put back in service. In the advanced stages of flaking, the load carrying area of the bearing is typically destroyed and the bearing must be replaced.

#### *Correcting Bearing Scoring*

A little scoring is not serious, and the bearing may be polished with fine steel wool to remove any rough edges caused by scoring. Any foreign particles embedded in the Babbitt, which could score the journal should be carefully picked out, and that area should then be polished smooth. Scoring becomes serious when it significantly reduces the bearing area. In this case, the bearing should be replaced and the gearbox unit drained and flushed out with a solvent.

### Correcting Bearing Wiping

If wiping is localized in a small spot, the bearing may be repaired by scraping and polishing the spot until it blends in with the remainder of the bearing. Otherwise, the bearing must be replaced. Bearing scraping requires experience and expertise however, as well as sound judgment when deciding whether to dress or replace the item.



#### Key Technical Point

Before replacing a wiped bearing, determine and correct the cause of the failure.

### Replacement Bearings

The manufacturer's parts list should be referenced if it is determined that bearings need to be replaced. If new bearings are used, the following precautions should be taken:

- Remove all nicks and burrs from the housing and bearing shell.
- Ensure that journals are free of nicks and high spots. These can be removed using a fine hone and polishing with crocus cloth.
- Obtain the proper bearing contact as described in the manufacturer's technical literature.
- After bearings are fitted and lower halves are installed in the housing, check the radial clearance using feeler gauge or plastic gauge material. Check end-play by barring the shaft axially.

#### 4.5.1.4 Typical Procedure for Gearbox Reassembly

##### Preparation

The following reassembly sequence is provided for information purposes only, and should not be used without reference to the manufacturer's instructions that are specific to the actual gearbox installed at the site. Note that any work done on equipment during the manufacturer's warranty period without the written approval of an authorized manufacturer's representative could void the warranty. This procedure assumes that the gear housing is not removed from its foundation/support and that the original shaft alignment was correct. Additional information regarding shaft alignment techniques is provided in EPRI Technical Report TR-112449, *Shaft Alignment Guide*.

The following is the reassembly sequence for the gearbox:

1. Clean all interior surfaces of the housing, the housing cover, and all components that will be reused. Parting line surfaces must be clean and smooth; use a spray-on paint and gasket remover fluid and/or carefully scrape the surfaces if necessary. Corroded spots can be cleaned by using a fine emery cloth, rubbing shafts in a rotary or circumferential direction. Do not rub shafts in a lengthwise direction as it may cause seal leaks.
2. Check the bearing shells, the parting line, and the housing bores for any burrs or nicks: remove with a fine file.

3. Put a coat of light oil on all parts to help assembly and to prevent rust during reassembly. Use fresh oil from the gearbox supply for this. Do not use special oils, such as STP® because their separate additives may cause operational problems.

The guidance in the following sections is provided assuming that the entire unit must be reassembled.



#### Key Technical Point

Tighten connectors uniformly; when tightening bolts, studs, or screws on an assembled portion with three or more holes, always partially tighten connectors equally in a “cross” pattern to avoid torquing, binding, or warping the section.



#### Key Technical Point

When reassembling, manufacturer torque limits should be followed. Over-torquing can lead to damage and issues with equipment after reassembly and being placed back into service.

#### Typical Reassembly Sequence

Although instructions include using sealer between housing sections, this should actually be done on the final assembly, only after checking tooth contact and ascertaining that the unit is aligned properly. Following is the procedure for reassembling the bearing, gear, and pinion assembly.

1. Install Journal Bearings – Before installing journal bearings, note that pressure dam bearings are match marked and are not interchangeable.
  - Install the lower half of the low speed journal bearings (the half with the slot for the roll pin if there is one) in the housing in the position for which they were marked at disassembly, keeping parting lines on bearing and housing even.
  - Check with a 0.0015” (38.1 microns) feeler gauge to see that lower halves are seated. Consideration may be given to measuring bearing clearance by direct measurement of the ID and the shaft journal OD. Another alternative is to use a commercially available plastic gage, (for example, Perfect Circle Plastigage®).
  - Ensure that the pressure dam is seated in the correct location.
  - Check bearing contact as described in the instructions specific to the size, type, and model bearing in use. Do not attempt to install shafts with lower halves of thrust bearing in housing or Babbitt-faced thrust faces may be damaged.
  - Rethread any temperature sensor wires from bearing through housing.
2. Install Gear – Lift the low speed gear and carefully place the assembly in its correct location in the gear housing and bearings. Use care to avoid bumping housing or edges of bearings.
3. Set the top of the gear bearings in place and secure (bolts or bearing straps if supplied). Turn bearings in bore if necessary.

4. Install Pinion – Install the pinion bearings on the pinion, ensuring that the pinion is level and line it up in mesh with the gear.
5. Carefully set the pinion and its bearings in mesh with the gear, and roll along gear until bearings are seated in the housing.
6. Line up the pins in the housing grooves and rotate bearings until seated.

Following is a typical procedure for assembling the gear cover:

1. Lower the cover over the studs carefully to prevent damage to gearing. Leave it suspended high enough to reach RTD holes.
2. Thread the temperature sensor wires from the bearings as necessary to retain the leads extending into the housing.
3. Coat the split line with a small bead of sealer, such as LocTite™ No. 49-31 Plastic Gasket, or an equivalent plastic gasket material. Circle all studs to ensure sealing of oil, but avoid feeder groove areas.
4. Seat the cover onto the bottom section and install the cylindrical dowel pins. CAUTION: Do not assume doweling is accurate. Straight dowels have clearance, which over time may become out of tolerance. Consideration may be given to using tapered dowels if dowel clearances prevent the proper seating and positioning of the gearbox cover.
5. Tighten all cap screws and studs in accordance with the manufacturer’s recommended instructions. Typical torque values for Grade 5 bolts and studs are provided below in Table 4-2.
6. Perform a soft blue gear tooth contact check in accordance with the guidance contained in this report.

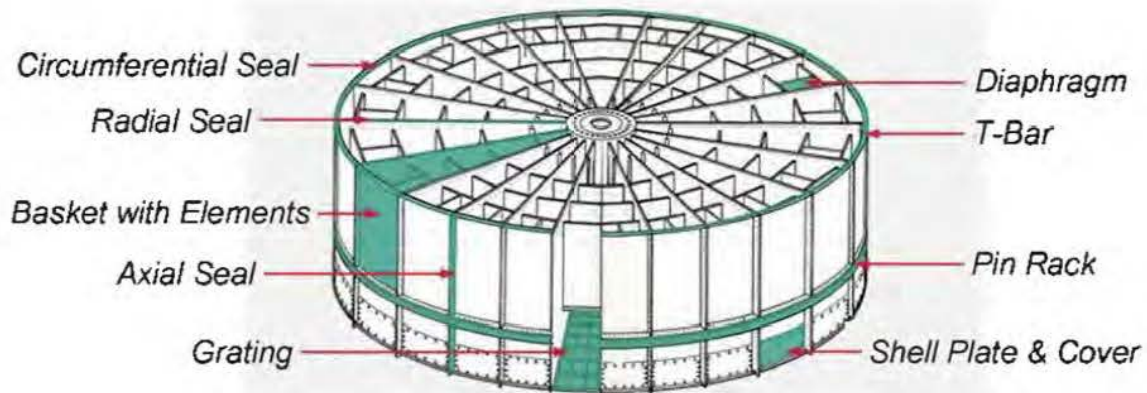
**Table 4-4  
Recommended Tightening Torques**

Nominal Size		Tightening Torque for Bolts		Tightening Torque for Studs	
Inches	mm	Ft. Lbs.	N-m	Ft. Lbs.	N-m
1/2	12.7	75	102	87	117
5/8	15.9	150	203	173	234
3/4	19.0	266	360	307	416
1	25.4	644	873	742	1006
1¼	28.8	1120	1519	1484	2012
1½	38.1	1949	2643	2582	3501
1¾	44.5	2286	3100	4073	5522

7. If the contact is not acceptable, check for improperly meshed gears, burrs on shafts or housing bores, or twisted housing. If no satisfactory explanation can be found, contact the manufacturer.
8. Install Thrust Bearing
  - Replace the inner backing ring. It must be firmly seated against the wall of the housing.
  - Thoroughly clean each thrust bearing shoe.
  - Apply a liberal quantity of thick grease to the back side of each thrust shoe. The grease will serve as a temporary adhesive to keep the shoes positioned in the backing ring as they are installed.
  - Install the inner thrust shoes, taking care to place each shoe having an embedded temperature sensor in its original position.
  - Install and tighten the thrust collar lock nut and tighten the two thrust collar set screws.
  - Install the axial probe target plate.
  - Place the outer backing ring on a flat surface. Apply a liberal quantity of grease to the back side of each outer thrust pad and position the thrust shoes on the backing ring. Ensure that the shoes with embedded temperature sensors are located in their original position.
  - Lift the outer backing ring assembly and install it into the thrust bearing housing.
  - Install the adjusting shims and thrust bearing end cap and tighten securely. Be very careful while handling and installing the shims, since torn or crimped shims can cause incorrect adjustments.
  - Install temperature sensors in their shoes through the access covers.
9. Measure to ensure that the low speed shaft has specified axial movement. (Use a pry bar to move gear from side to side if necessary.) Also check that the high speed pinion can float axially.
10. Mount the shaft seals, end plates, and other auxiliary equipment which may have been disconnected during disassembly.
11. Reconnect any junction box plate and wiring as necessary.
12. Reconnect any instrumentation and lubrication lines as necessary.
13. Couple unit to driver and driven machines.
14. Install inspection covers with gaskets and sealers.
15. Align the unit.
16. Spin the unit slowly with no load, if possible, to verify correct reassembly. Ensure that the unit rotates freely and quietly.
17. Confirm proper shaft alignment and tooth contact.
18. Follow the manufacturer's start-up procedures.

### 4.5.2 Standard Replacement Parts of an Air Preheater Rotor Assembly

Figure 4-5 illustrates a common array of replacement parts that are provided for the air preheater rotor assembly.



**Figure 4-5**  
**Air Preheater Rotor Assembly Replacement Parts**

#### 4.5.2.1 Structural Members

As shown on the figure, the most common structural members of the rotor assembly that are replaced are the following:

- Diaphragm – This element is also referred to as a stay splitter.
- T-Bar Assembly – Inspection and replacement of the T-bars should consider the following process:
  - Inspect the T-bar sealing face around the full perimeter as wear is not always obvious without close inspection.
  - Look for damaged circumferential/bypass seals that can be an indicator of wear on T-bar face and/or an indication of an out-of-concentricity issue.
  - Ensure the cold end is also inspected.
  - Remove old circumferential/bypass seals and old T-bar segments per the manufacturer’s guidance.
  - Ensure concentricity of both the T-bar and circumferential/bypass mounting surface is maintained.
  - Set T-bar segments temporarily in place and set appropriate gap against a fixed point on the heater shell by rotating rotor past this point for each segment.
  - Check at several locations around the heater that the gap remains consistent at a fixed point on the shell while the rotor is being rotated.
  - Make adjustments as necessary.

- Once the T-bar is set secure, weld in place.
- Confirm circumferential seal mounting surface is equal gap to the T-bar around the full circumference, and then adjust mounting surface as necessary.
- Install new circumferential/bypass seals.
- Pin Racks – In many cases replacement pins are heat treated throughout their thickness for an extended life improvement over past induction surface hardening techniques.
- Shell Plates and Covers – Most manufacturers can provide a partial or complete shell plate replacement specific to the particular air preheater being serviced, with each shell plate being rolled to an exact radius for ease of replacement and fit. Inspection and replacement of the shell plates and covers should consider the following process:
  - Inspect shell/sector plate surface for wear or distortion.
  - Thinning of the surface can be repaired with weld buildup. Remove heating element baskets and rotate emptied area partially under the sector plate to gain access for repairs.
  - Excessive thinning or distortion of the plate may require replacement.



#### Key Human Performance Point

Plate replacement commonly requires significant pre-planning and the development of a safe rigging plan both within the air preheater heater and externally to the equipment.

- If replacing a sector plate, consideration should be given to modifying the plate design that allows for removal and replacement of the sector plate face area that typically wears out to avoid full sector plate replacement in the future.
- Mildly distorted plate surfaces (<1/2” distortion between high and lows) can often be straightened. Plate straightening involves mapping the distortion of the plate surface by rotating leveled pointers attached to the rotor underneath the plate surface and measuring the clearance at multiple locations. Once the surface is mapped, a plan can be made to cut desired supports and re-weld in relieved or newly forced positions. Care should be taken because further welding can cause more distortion. The objective is to have the plate straightened with <1/16” distortion.
- Consideration for mildly distorted plate surfaces is to install contact/brush type seals.
- Gratings – Support gratings are a major structural steel member for rotor compartments in horizontal or vertical design air preheaters.

#### 4.5.2.2 Heating Element Replacement

There are a number of original air preheater equipment manufacturers and replacement part suppliers who provide modular-constructed air preheater rotor frames and heating element baskets. These units typically bolt to the center post for field erection. These modular designs may include any of the following configurations:

- Complete frames
- Sub-component assemblies
- Modules with basket heating elements that are pre-installed

Figure 4-6 illustrates two rotor frame and basket element replacements.



**Figure 4-6**  
**Air Preheater Replacement Rotor Frames and Basket Assemblies**

Replacement of basket elements is a very time-consuming process. Extensive preplanning of issues such as rigging, lay-down areas and repair plans for damage found in the rotor structure is required. Inspect stay plate and support frames closely for cracks in welds and distortion before attempting to install any new baskets.

Baskets should be staged as close to the heater as possible as sufficient floor space will be required, including room for the old baskets coming out too. Old baskets should be removed from the work area and disposed of as quickly as possible. Consideration should be given to dedicating an elevator to keep the flow of new and old baskets moving.

When replacing cold end baskets, keep in mind that many preheater designs do not provide for safe and ready access to the cold end of the rotor assembly. Scaffolding costs can be high as there can be limited locations from which to base and support the scaffold. Flanged ports can be added to the ducting below the air preheater that aluminum scaffolding support beams can be slid into and across the duct onto which a scaffold deck can be secured. The spacing and number of ports should be reviewed by the owner's engineering organization to ensure the scaffolding arrangement is adequate. For confined spaces, bolted-segment beams can be inserted as needed.



#### Key O&M Cost Point

Because there are hundreds of baskets in an air preheater rotor assembly, the timing to remove and replace each one must be well choreographed to ensure a timely completion at minimal cost.

When removing cold end baskets, a quick attachment method to pull the baskets out horizontally using a tugging or cable winch should be designed that allows the basket to land directly onto a cart. This arrangement may require a custom-designed cart to accommodate the height of the basket(s). Consideration should also be given to converting the pulling device into a pushing device to install new baskets by using a bidirectional pulley.

When removing hot end baskets, a lifting beam/monorail system is typically needed to lift each basket and transport them in and out of the air preheater. The use of an electric hoist is most common for this work. Similar to the cold end basket replacement, consideration should be given to devising a method or lifting device that quickly attaches to the baskets so they are lifted vertically. Engine hoists or A-frames make a good way to get baskets off the floor and onto a cart for transporting. Ensure the flooring is rated for the combined weight of both the basket and the cart.



#### Key Technical Point

Care should be taken to ensure the rotor remains balanced as baskets are removed. To do this, remove a “pie of baskets” and then rotate the rotor assembly 180 °F to remove the “pie of baskets” from the opposite side of the rotor.

#### 4.5.2.3 Air Preheater Seal Replacement

The replacement of seals is necessary when the seals can no longer prevent leakage around or from the air preheater. Seals can cause leakage due to wear, corrosion, looseness or inability to maintain clearances established by the original equipment manufacturer or the after-market replacement seal supplier.

As shown on the figure illustrating common replacement parts, radial seals are used to minimize the direct air to gas leakage that occurs across the sector plates that separate the air and gas sides of the air preheater. The seals are attached to each diaphragm of the rotor to maintain close contact with the sealing surface that separates the air and gas streams. For larger air preheater units, a seal straight edge is often furnished, which should be used to align and assist in setting the clearances of the replacement radial seal plates. The following procedure is typically used for replacing radial seals and setting clearances:

1. Attach the seal straight-edge to the support channels welded inside the connecting plate. This straight edge can be a temporary beam placed between rotor and sector plates.
2. Set the seal straight-edge to the trailing edge of an existing radial seal, and then remove the seal.
3. Install the new seal so it touches across the full length of the seal straight-edge or beam. Tighten the inner and outer bolts of each seal section first, and then tighten the remaining bolts.

4. Check the seal clearance at both sector plates by referencing the seal clearance chart included in the original manufacturer's maintenance manual. Rotate the baskets one segment at a time and set the seals to the desired clearance of the beam. The beam should be straight and represent the sector plates in terms of elevation.



#### Key Technical Point

When checking seal clearances, both sector plates should be checked at multiple points along the plates, such as at the leading edge, the clearing edge, and at the center to find any high spots that may result in air or flue gas leakage.

If clearance is not correct, adjust the seal to the surface offering the most clearance. If adjustments are necessary, return the seal to the straight-edge and rest the straight-edge.

5. Set the remaining radial seals to the straight-edge as described in Step 2 above.

The original equipment manufacturer should be consulted if replacement of axial or circumferential seals is required. As shown on the figure above, axial seals are used to minimize air leakage that can travel around the circumference of the rotor. Many larger air preheaters are equipped with axial seal adjustment plates, which can prolong the life of the seals and maintain adequate clearances.

Also illustrated on the figure are the circumferential seals (sometimes referred to as by-pass seals) that prevent air and gas from bypassing the heating element through the space between the rotor and the housing shell. They are retained by mounting angles bolted to the circumference of the rotor. The circumferential seals wear against the sealing rings, which are welded to the housing of the air preheater. The bypass seals are mounted on the housing and seal against the rotor mounted T-bar.

Adjusting seal clearances on an air preheater with a horizontal shaft may be accomplished by mounting a soap stone to the inner and outer parts of the rotor assembly. The baskets are rotated until the stone wears from rubbing on the sector plate. By knowing the location of the sector plate, the seals are set accordingly.

The user of this report should also be aware of several "after-market" replacement seals that provide adequate sealing and extended service life. One such product is commonly referred to as an adaptive air preheater brush seal. The unique design of these patented brush seals is inherently flexible and adaptable. They naturally conform to variances in gap size and surface irregularities, like a warped sector plate, providing more continuous sealing over a greater percentage of the rotation. The brush is inherently elastic because each filament can move independently; dissipating stress, reducing drag and wear to extend functional service life providing consistent sealing over multiple outage cycles. In aggregate, the thousands of filaments nestle together to make a very tight seal. The brush's impermeable, malleable membrane enhances sealing an additional 70-80%.

Many APH seals suffer from improper gap settings at installation, resulting in inadequate sealing, seal breakage, and even rotor stoppage. The adaptive brush seal is forgiving of typical setting variances, and allows for closer settings for more continuous and consistent sealing. Plus, brush seals are not prone to the breakaway failures common with strip or fin-type seals. Adaptive air preheater brush seals have been designed to replace radial, axial and circumferential seals.

Figure 4-7 provides an illustration of a typical adaptive air preheater brush seal with an impermeable malleable membrane incorporated between the bristles.



**Figure 4-7**  
**Adaptive Brush Seal with Impermeable Malleable Membrane (Courtesy of Sealeze® Power)**

Figure 4-8 illustrates replacement radial and circumferential adaptive brush seals installed on an air preheater.



**Figure 4-8**  
**Installed Adaptive Brush Radial and Circumferential Seals (Courtesy of Sealeze® Power)**



**Key Technical Point**

Care should be taken to ensure the preheater is rotated during start-up to avoid damage due to uneven thermal expansion of the rotor assembly.

### **4.5.3 Repair and Replacement of Rotor Bearing Lubrication Circulation Pumps**

Manufacturers of these rotary/positive displacement pumps typically provide kits for minor and major repairs. A minor repair kit commonly includes the following parts:

- Mechanical seal
- Oil seal
- Gasket(s) and o-ring(s)
- Ball bearing
- Snap ring(s)

A major repair kit typically includes all of the items in the minor repair kit plus the following parts:

- Rotor housing
- Rotors (power and idler)
- Woodruff key
- Spacer(s)

### **4.5.4 Replacement of Rotor Drive Motor Coupling**

#### **4.5.4.1 Installation of Gear and Grid Couplings**

When couplings are installed on shafts a sequence of events should take place to ensure the couplings are installed properly.

For close coupled applications, either one of the machines must be moved to make room for installation or the rotor must be removed to facilitate installation. If the rotor is removed, an opportunity arises to install one-half of the coupling on the removed rotor at this point in time. The other half is installed on the machine left in place.

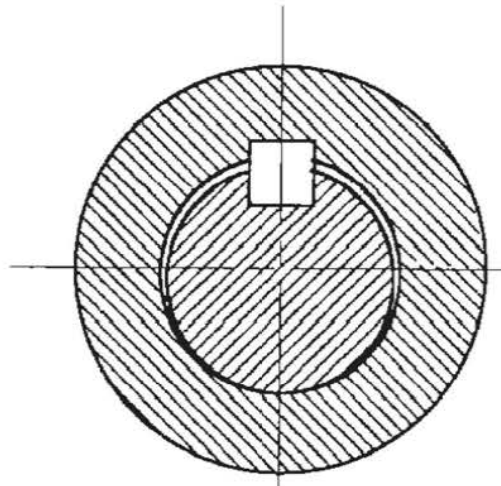
With spacer type couplings, this problem is avoided, as typically there is room to install both halves without removing component parts such as rotors, or moving one machine out of the way.

If the coupling that was removed from the shaft(s) is the one being reinstalled, the processes of installation are usually streamlined as follows by ensuring:

- Coupling halves are installed in the correct position on the shaft
- Shaft separation is correct
- Gaskets are in good condition and in place
- Bolts are torqued properly
- Shaft alignment is performed to align the two machines within specifications for the running position (operating conditions such as pipe strain and temperature)

If the coupling installation is utilizing a new coupling, the installation becomes more involved to include the following:

- Ensure the coupling hub(s) are bored to the proper dimension without run-out.
- The keyway is broached properly and is on centerline and is not skewed off of centerline in one direction.
- The keyway depth is correct to ensure the hub will travel across the key during installation and the key size (height and width) is correct.
- If the coupling is heated for installation to facilitate an interference fit, the hub will stand off the shaft at the key location after cooling. Figure 4-9 illustrates how this can create eccentricity and imbalance in the couplings, and also create stresses in the coupling (which may cause it to fail).



**Figure 4-9**  
Coupling Stand-Off Creating Eccentricity and Imbalance



#### Key Technical Point

The hub will stand off the shaft at the key location after cooling, if the coupling is heated for installation to facilitate an interference fit.

- Ensure the shaft to shaft (hub to hub) dimension is correct after installation.
- The coupling should be lubricated if grease is used while the coupling is apart.
- Manufacturer's specifications should be followed closely when greasing a coupling.
- After the coupling is bolted together, shaft alignment should be performed to align the two machines within specifications for the running position (operating conditions such as pipe strain and temperature).

#### 4.5.4.2 Installation of Disc and Diaphragm Couplings

The installation process described above for gear coupling hubs typically applies to disc or non-lubricated coupling hubs. The difference is that disc and diaphragm couplings are more restricted in the amount of axial movement they can accommodate. For this reason the shaft to shaft spacing is critical. The discs or diaphragm must be in a neutral position when shafts are in their running position. The spring rate (stiffness) of a disc or diaphragm coupling dictates how much tolerance from neutral the disc or diaphragm can be as a result of shaft separation.

#### 4.5.4.3 Installation of Magnetic Couplings



##### Key Technical Point

Due to unacceptable vibration between the rotor drive motor and the gearbox, some owners have replaced the original gear-type coupling with a magnetic coupling.

A magnetic coupling is a non-contact coupling that uses a magnetic field to transmit torque from one rotating member to another. This design tends to minimize the effects of wear and misalignment that can lead to noise and vibration in the drive train. The installation of magnetic couplings should be in accordance with the procedure provided by the coupling supplier/manufacturer.

#### 4.5.5 Replacement of Rotor Thrust Bearings

The replacement of the rotor support thrust bearings should be performed in accordance with the air preheater and bearing manufacturer's recommendations as provided in their respective maintenance instructions. Typically, the process described below should be followed:

- Drain oil from support bearing housing.
- Disconnect all piping and instrumentation.
- Remove plates, cladding and insulation to expose the base of the air heater rotor.
- The rotor must be lifted up to get the weight off the support bearing. The manufacturer may specify specific points from which to lift. If this information is not provided, then an engineering review should be completed to identify lift points that will not damage the equipment.
- Determine the weight of the rotor. A heavy-rigging company with experience lifting such a massive structure may be used for this activity, both to supply the equipment and to perform the lift.
- Rotor should be jacked up a visible amount (~1/8") which can be observed using a dial gauge.



##### Key Human Performance Point

Do not rely on the jacks to hold the rotor. The jacks should be left in position, but the rotor should be blocked by using heavy-steel shaft material cut to specific lengths that can be placed between the jacks and prevent the rotor from falling.

- Before doing any further work, lock the rotor from being able to move or rotate by welding steel plate between the rotor and housing in at least two different and opposing locations.
- Lower the bearing housing. This can first be done by replacing some of the bolts with long lengths of threaded rods, and lower by threading down the nuts. Lower the housing evenly. Once low enough, it may be possible to attach lugs and lower the housing more quickly by using chain-falls.
- Ensure the floor where it is set down can support the weight of the bearing housing.
- Replace bearing and use the reverse procedure for installation and reassembly.

#### **4.5.6 Replacement of Rotor Guide Bearings**

Although the replacement of the rotor support thrust bearings is much simpler than replacing the thrust bearing, it should still be performed in accordance with the air preheater and bearing manufacturer's recommendations as provided in their respective maintenance instructions. Care should be taken to adequately lock the rotor in position to prevent any movement or rotation once the guide bearing is removed. Once the guide bearing is replaced, confirm the rotor rotates freely without any contact with any of the circumferential/bypass seals. This will confirm that nothing has shifted in the position of the bearing housing.

#### **4.5.7 Replacement of Soot Blower System Nozzles**

Measurements should be taken to quantify the degree of wear and erosion on the inside of the nozzles prior to replacing them.



#### **Key Technical Point**

However, due to the erosive nature of particulates that may be present in the air supply for the soot blowing system, it is common to replace the nozzles every outage.

Nozzle replacements should be performed in accordance with the procedure provided by the soot blowing system manufacturer.



# 5

## PLANNER ACTIONS

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### 5.1 Planning Objectives

The work management process is one of the core business processes for the operation and maintenance of conventional power plants. The preparation of work packages is a key element of this overall process. The work planning provides guidance to power plant personnel regarding a consistent approach for administrative control, achieving an appropriate level of maintenance precision, and ensuring an acceptable level of use, work package format, and application.

### 5.2 Lock Out Tag Out (Energy Control) Information

The planner should consider including record clearance or tagging information as necessary. Typically, this information is needed for preventive maintenance work orders, but it can be included on any work order for which it is deemed appropriate. In some cases, the planner might be required by station procedures to prepare and submit a detailed clearance request. In other cases, the planner might be required to simply provide a summary of the clearance needs. If a clearance request is required, it should contain sufficient details to allow the clearance developer to prepare the clearance order. In some cases, the planner might be required to provide the specific scope of work and reference drawings and to enable the clearance order to provide safety to the worker and equipment.



#### Key Human Performance Point

Always consider sources of energy input to a component. Double feeds for electrical and for water present special concerns for isolation. Isolation of one does not ensure the other feed is isolated. Consult drawings and walk downs to ensure isolated.

Typically, the planner should consider including the following information:

- Clearance boundary scope (electrical, fluid, air, and so on).
- Specific tagging order (if important to the maintenance or work activity).
- Components that should not be tagged (that is, the component must be manipulated or removed).
- Components that will need position verification following the maintenance activity (due to work instructions that manipulate the component).
- Boundary extension needs, if known.
- Special precautions or instructions for the clearance developer, such as “hang when requested”.

- If applicable, a P&ID of the system should be included with highlighted components to be tagged on clearance and also show points of energy isolation.
- If applicable, an attachment of the breaker panel or motor control center with specific breakers identified for work and that are to be de-energized should be included. This attachment should also show all breakers in the panel or on the MCC.

At some plants, the operations organization builds clearances and defines clearance boundaries based on work scope, present plant conditions, and past work experience.

### **5.3 Perform Initial Review of the Work Request**

The work planner should typically validate the needs of the work request to allow a work plan to be developed. As plant conditions allow, this validation might include a walk down of the field condition to ensure that the conditions are confirmed prior to disposition as appropriate. This walk down should verify the following:

- Equipment tag number.
- Nameplate data of the component.
- Conditions found in the work area.
- Identification of needed parts.
- Any applicable comments.
- Identification of observable deficiencies.
- Scaffold and insulation requirements.
- During the walk down, the work planner should verify equipment problems and collect work methodology information for planning complex jobs.
- During the walk down, the work planner should identify potential safety hazards.
- During the walk down, the work planner should verify the installed model number of the component for validation against the approved model.
- If assistance is required to perform a walk down, the work planner should notify the respective group that support will be needed.
- If the walk down reveals that an energy release might be necessary, the work planner should take a note in the precautions/prerequisites section, referencing the appropriate plant procedure. (Implementation of the energy release would typically be the responsibility of operations personnel and not the work planner.)
- A work order planning field walk down checklist (for example, a planning form) should be considered as a means of ensuring consistency, and should be used to assist in planning the work order.
- Photographs or digital images to be included in the work package for clarity and pre-job briefs should be considered.

## 5.4 Tools and Equipment Planning Checklist

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 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. Table 5-1 provides a listing of tools most commonly used for the maintenance activities described in this report.

**Table 5-1**  
**List of Commonly Used Tools for Air Preheater Maintenance**

Crane, chain fall, hoist, other lifting device rated to perform work complete with rigging	Torque wrenches: a 50 to 250 feet-lbs. Or equivalent, a 120 to 600 feet-lbs. Or equivalent	Thread sealant, LocTite™ PST-580, or other approved sealant
Drop light	Three-ton chain hoist (2)	Bearing heater
Slings and shackles as required	Bearing puller	Alignment tools
Gantry, (aluminum 1000 lb. capacity or equivalent)	Two 3" x 6" nylon slings or equivalent	Jacking device for thrusting pump shaft
Oxy-acetylene torch with rosebud tip or equivalent	Three 3/8" x 3' wire slings or equivalent	Mobilux™ EP-111, or approved equivalent
V-blocks or rollers	Three 1/2" shackles	Allen wrench set
Personal safety harness	Two 1" x 6" jackscrews	3/8" Allen socket
Assorted cribbing	Bearing heater	5/8" Allen socket
Anti-seize, lubricant	1-1/4" combo wrench and socket	4x4, 24" long
Molykote	1-1/8" combo wrench and socket	Feeler gauges
Aviation form-a-gasket #3	15/16" combo wrench and socket	Glycerin, or approved equivalent
Grease, silicone	7/8" combo wrench and socket	Gasket, coupling, (two required)
Tempstick, 375 to 400°F	3/4" combo wrench and socket	1/8" Allen wrench and socket
Outside micrometers of suitable ranges for 2" - 8"	Inside micrometer of suitable ranges for 2" - 8"	Thread locker LocTite™ 242, or other approved sealant
Laser alignment equipment	5/32" Allen wrench and socket	Primer-N
Gasket (high-density), or other approved gasket	Oil, (type as per work order/equipment database)	Replacement setscrews as identified on parts list
Two 18" pipe wrenches	Heating torch	Standard mechanics tool box
Dial indicators (need 3 to 5)	Strong back	Grease, Dow #4
3/16" Allen wrench and socket	Clam shell	Drop cord

## **5.5 Develop the Detailed Work Instructions**

Guidance regarding the recommended scope and content of detailed work instructions is provided in Section 6, Generic Work Instructions. In general, the work planner should determine the availability and applicability of existing work instructions before developing new ones. If they exist, the work package can be developed with the instructions attached. If they do not exist they need to be developed, reviewed and approved in the work package.



### **Key Supervisory Observation Point**

Crew supervisors should take the opportunity on critical work to review the planner's work on instructions and parts selection. Provide coaching as needed.

# 6

## GENERIC WORK INSTRUCTIONS

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### 6.1 Content and Format for Job Plans

#### 6.1.1 General Guidance and Considerations

##### 6.1.1.1 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.

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:

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

#### 6.1.1.2 Inclusion of Maintenance Experience

The work planner should consider 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**

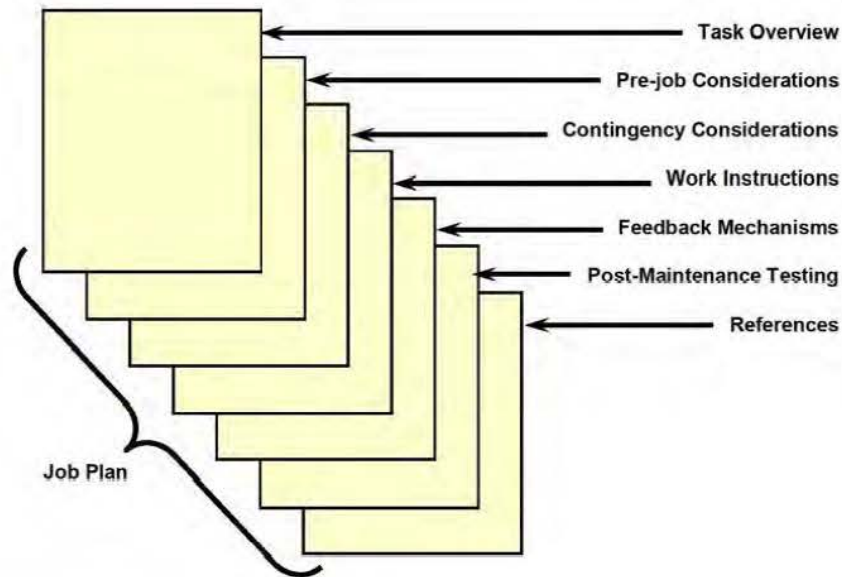
When planning a job plan or maintenance work package, the planner should search for relevant maintenance experience, and if such information is identified that is relative to the work being performed, then it should be placed in the work package.

#### 6.1.1.3 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.

### 6.1.2 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 6-1 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 6-1**  
Typical Elements of a Maintenance Job Plan

#### 6.1.2.1 Task Overview

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

- 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 on)
- 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.

### 6.1.2.2 Pre-Job Considerations



#### 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 may be a specific activity incorporated within the work instructions, or may 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.

In developing the pre-job traveler, the planner should consider the following:

- Critical job steps
- Job safety analysis
- Potential adverse outcomes



#### Key Technical Point

When doing welding on the air preheater, care should be taken to ensure the ground is made from the rotor structure to the rotor frame and not grounded through the support thrust bearings or radial guide bearings.

- Contingency or compensatory actions
- Error-likely situations and defenses
- Relevant maintenance experience
- Review/discussion of the following maintenance procedures:
  - Lock-Out-Tag-Out (LOTO)



#### Key Technical Point

LOTO procedures may require special allowances due to the need to rotate the rotor while certain maintenance activities are on-going such as basket replacements and air seal leakage testing.

- Calibration
- Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Need for foreign material exclusion

- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space).

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

### 6.1.2.3 Contingency Considerations



#### **Key Human Performance Point**

The work planner should review bill-of-materials, 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 the correct parts/replacement items are installed in the plant for the work being prescribed and planned. Care should also be taken to ensure 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 an alternate replacement item has been determined to be a suitable equivalent.

The planners 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 issue and use of required parts/services, as necessary. If the planner has reason to believe the needed parts will not be available by the preparation milestone, then they 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:

1. 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, or
2. 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, they 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.

#### 6.1.2.4 Detailed Work Instructions

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

#### 6.1.2.5 Post-Maintenance Testing

This section of the work package provides post maintenance tests as well as activities that should be performed post-maintenance to return the work location to pre-work conditions or better. Post-maintenance testing is performed to verify that all components and systems are capable of performing their intended functions following maintenance activities. It will also verify that original deficiencies have been corrected and that no new deficiencies were introduced during the maintenance activity. The tests performed should be commensurate with the maintenance work performed and the importance of the equipment to facility safety and reliability. Post-maintenance testing may be specified in the current work order package, a procedure or a subsequent work order package.

Post-maintenance testing may be performed with the equipment operating under normal operating conditions or specific test conditions. Post-maintenance testing provides an initial break-in or run-in period for adjustments, calibrations and/or monitoring of equipment performance characteristics (for example, vibration, temperature, flow, and so on). Post-maintenance testing should include documentation of results for future reference and trending.

### 6.1.2.6 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.

### 6.1.2.7 References

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

- Existing maintenance work instructions and/or procedures
- Replacement part information (that is, vendor manual, assembly drawing, bill of material, critical spares data base, and so on)
- Component identification (that is, master equipment list, P&ID, electrical drawings, and so on)
- Technical equipment specifications
- Maintenance experience and equipment performance history
- Confined space permit, if needed
- Hot work permit, if needed
- Scaffolding inspection documentation, if needed

## **6.2 Job Plan #1: Heating Element Inspection**

### **6.2.1 Task Overview**

This job plan has been developed to perform visual inspections of the air preheater heating elements and baskets.

#### 6.2.1.1 Task Timing and Objective

The inspection of the heating elements should coincide with a plant outage.

### 6.2.2 Pre-Job Considerations

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### 6.2.3 Contingency Considerations

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

### 6.2.4 Work Instructions



#### Key Technical Point

Note that air heater surfaces at either the hot or cold end can be eroded by aggressive soot blowing, and soot blowing alone may not be adequate to remove deposits. The use of excessive steam pressure and extended soot blowing duration may damage heat exchange material.

The PM tasks for the heating elements should include the following:

- Inspect for wear or deformation of sheets (that is, thickness and configuration). A thorough search for signs of fouling at both the hot and cold end should be performed. Further, indications of non-uniform fouling from the “inboard” regions to the “outboard” regions should be considered. Any radial gradients in deposition suggest that soot blowing coverage is not uniform.

- Inspect for plugging between heating elements. If flue gas pressure loss data suggest fouling is occurring, but visual signs of fouling are not evident, then removal of one or more baskets is advised. Disassembly of at least one basket from each layer should verify if fouling occurs deep within the layer.
- Inspect for spiking/pockets between heating elements
- Inspect for loose or dislodged heating elements (that is, tightness, rattle, excessive spacing, and so on)
- Inspect for cracking/breakup damage caused by excessive or prolonged use of the soot blower
- Inspect for corrosion, erosion, cracking or deformation of the baskets and frame
- Inspect for movement or damage to the heating elements resulting in bypass flow around a basket
- Inspect for damage, corrosion, or deformation of basket support attachments

Additionally:

- Listen for any unusual noises that may indicate problems with the heating elements
- Visually inspect for loose fasteners and damage

### 6.2.5 Example Worksheet

Air Preheater Heating Element Visual Inspection (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Heating element	Wear or deformation
	Heating element	Plugging
	Heating element	Spiking/pockets
	Heating element	Loose or dislodged (that is, tightness, rattle, excessive spacing, and so on)
	Heating element	Damage caused by excessive or prolonged use of the soot blower
	Baskets and frame	Corrosion, erosion, cracking or deformation
	Baskets	Movement or damage to the heating elements
	Basket support attachments	Damage, corrosion, or deformation

### 6.2.6 Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

### **6.2.7 Post-Maintenance Testing**

Post-maintenance testing should be performed subsequent to the replacement of any heating elements or baskets in the air preheater. Monitor temperature differential across air preheater to verify proper heat transfer is being achieved.

### **6.2.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.3 Job Plan #2: Rotor Support Thrust Bearing and Radial Guide Bearing Inspections**

### **6.3.1 Task Overview**

This job plan has been developed to perform visual inspections of the air preheater rotor support thrust bearing and the radial guide bearing.

#### **6.3.1.1 Task Timing and Objective**

The inspection of the rotor support and guide bearings should coincide with a plant outage.

### **6.3.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed

- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space).

**6.3.3 Contingency Considerations**

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

**6.3.4 Work Instructions**

The PM tasks for the rotor support and guide bearings should include the following:

- Inspect packing in trunnion air seal cover for degradation, cracking or wear
- Inspect trunnion-to-bearing housing packing for degradation, cracking or wear
- Inspect internal components for corrosion, wear, damage or looseness by removing upper bearing cover

**6.3.5 Example Worksheet**

Air Preheater Rotor Support and Guide Bearings Inspection (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Packing in trunnion air seal cover	Degradation, cracking or wear
	Trunnion-to-bearing housing packing	Degradation, cracking or wear
	Internal components	Corrosion, wear, damage or looseness

**6.3.6 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

**6.3.7 Post-Maintenance Testing**

Check area for air leakage due to degraded areas. Perform thermography testing to check for any hot spots that could provide an indication of leakage or bearing wear.

### **6.3.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.4 Job Plan #3: Rotor Bearing Oil Circulation Systems Inspections**

### **6.4.1 Task Overview**

This job plan has been developed to perform visual inspections of the air preheater rotor bearing oil circulation systems.

#### **6.4.1.1 Task Timing and Objective**

The inspection of the rotor bearing oil circulation systems should coincide with a plant outage.

### **6.4.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### **6.4.3 Contingency Considerations**

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

### **6.4.4 Work Instructions**

The PM tasks for the rotor bearing oil circulation systems should include the following:

- Inspect for evidence of foreign matter in filters
- Inspect for evidence of oil system leakage
- Take oil samples of oil to be analyzed to check for suspended metals in oil
- Inspect and clean bearing sump by removing all sludge from housing
- Inspect all internal piping for cracks, deformation, corrosion, and leaks; and replace as needed
- Inspect cooler for evidence of internal or external leakage or loss of cooling
- Replace filter cartridges if they have been in service for more than 6 months or if the pressure gauge reading is approximately 15% psig higher than normal.
- Verify operability of temperature and pressure gauges
- Inspect rotary/positive displacement pumps in accordance with the pump manufacturer's maintenance instructions provided in their published technical manual. Before shutting down the operating pump, verify that the oil temperatures and pressures are within specifications. Once the pump is shut down, internal inspections should typically include the following activities:
  - Inspect for obvious loose, missing, or damaged fasteners.
  - Note abnormal noises.
  - Inspect for oil and water leaks.
  - If visible, verify that the oil level is correct and that the oil is not discolored or "milky".
  - Verify that the packing coolant temperature is within specification and that the level of the supply tank is correct.
  - Perform a visual axial alignment inspection of the crank shaft.
  - Check tension and evidence of wear on oil pump drive chain and sprockets.
  - Inspect the integrity of oil lines, fittings, and mounting hardware.
  - Inspect the bull gear and pinion teeth for damage and abnormal wear.
  - Look for the presence of metallic fines in the oil reservoir.
  - Inspect for signs of leaking lubricant.
  - Inspect mating surfaces for cleanliness, wear, and integrity; record as-found and as-left conditions.

- Verify condition of lubricant looking for dirt, amount of lubricant, and indications of coupling wear; recharge with the proper lubricant and quantity.
- Inspect gear teeth or shim packs for wear and damage.
- Inspect non-metallic parts for condition and wear.
- Inspect bolting for damage.
- Ensure proper orientation during reassembly.
- Perform an as-found / as-left alignment check.

**6.4.5 Example Worksheet**

Air Preheater Rotor Bearing Oil Circulation Systems Inspections (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Filters	Foreign matter
	System piping	Oil system leakage
	Oil	Take oil samples of oil to be analyzed to check for suspended metals in oil
	Bearing sump	Remove all sludge from housing
	Internal piping	Cracks, deformation, corrosion, and leaks
	Cooler	Internal or external leakage or loss of cooling
	Filter cartridges	Replace filter cartridges if they have been in service for more than 6 months or if the pressure gauge reading is approximately 15% psig higher than normal.
	Instrumentation	Verify operability of temperature and pressure gauges
	Rotary pumps	Inspect pumps in accordance with the pump manufacturer's maintenance instructions provided in their published technical manual

**6.4.6 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

### **6.4.7 Post-Maintenance Testing**

Post-maintenance testing should include the following activities:

- Verify the calibration of gauges (pressure, temperature, flow, and so on).
- Visually inspect oil circulation piping and components to ensure no leaks are found in the system. Clean up area of any oil that may have leaked during inspection/repair/replacement.
- Verify proper rotation and discharge pressure of lubrication pumps.

### **6.4.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.5 Job Plan #4: Motor Off-Line Test and Inspection**

### **6.5.1 Task Overview**

This job plan has been developed to discover electrical degradation of the machine's insulation system and electrical connections that cannot be detected while the machine is running or on-line. For CHM conditions the task, by itself, mainly addresses the discovery of degraded insulation, degraded electrical connections, and high resistance shorts and grounds in electrical components. In a full program for CHM conditions, the failure rate is not sensitive to the task interval.

These PM activities may be considered for electrical motors associated with the air preheater system, which may include the following:

- Rotor drive motor
- Motors for lubrication pumps
- Motor for soot blower compressor
- Motor for water wash pump

These tests and inspections for medium voltage motors has the objective of discovering the degradation of mechanical components that may require a minimal level of intrusive inspection and can only be detected while the machine is off-line. For CHM conditions the task, by itself, discovers evidence of bearing seal leakage and wear, blocked or dirty air filters and screens, frame damage, performance and structural issues of the internal bearing oil cooler (if present), and damage to rotor fans and hardware.

#### 6.5.1.1 Task Timing and Objective

The motor off-line electrical and mechanical motor tests should coincide with a plant outage.

#### **6.5.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

#### **6.5.3 Contingency Considerations**

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

#### **6.5.4 Work Instructions**

Motor off-line tests and inspections can only be conducted meaningfully when all parts of the motor are within 10° F of ambient temperature. The tests should include some or all of the following; these tests should be trended and compared to historical data to derive their maximum benefit:

- Winding resistance
- Insulation resistance
- Polarization indexing
- Motor circuit evaluation
- AC high-potential (high-pot)
- DC step voltage
- Surge testing
- Power factor tip-up testing

Motor off-line tests and inspections might include:

- Borescope inspection of—all accessible motor internals, air passages, and air gap.
- Verification for proper alignment.
- Inspect motor mountings for indications of soft-foot.
- Hand rotate to determine presence of any shaft run-out, binding or rubbing noise.
- Inspect for: damaged, loose, missing or vibrating parts, externally visible oil leaks around bearings and bearing seals, external water leaks around water bearing and stator cooling interfaces, broken or loose grounding cables, damaged conduits and seal flex, damaged wiring and insulators, damaged junction boxes and their gaskets, blocked/clogged/plugged air filters and inlet air screens.
- Inspect bearing slinger rings for proper operation and movement.
- Verify proper oil level; oil should not be discolored.
- Inspect for plugged oil sight glass vent.
- Listen for unusual noises.

### 6.5.5 Example Worksheet

<b>Air Preheater Motor Off-Line Tests and Inspections (Check-off any unacceptable conditions)</b>		
<b>Unsatisfactory</b>	<b>Failure Location</b>	<b>Reportable Condition</b>
	Bearing Insulation (External)	Degraded insulation
	Lubrication – Oil	Insufficient or excessive level
	Motor Lead Electrical Connections – crimped lugs	Degraded insulation
	Motor Lead Electrical Connections – crimped lugs	Loose
	Motor Leads	Abraded
	Motor Leads	Degraded insulation
	Space Heater wiring	Degraded insulation
	Space Heaters	Broken, loose or grounded connections
	Space Heaters	Open element
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Degraded insulation
	Surge Capacitors	Bushing Damage
	Surge Capacitors	Bushing tracking
	Surge Capacitors	Degraded insulation

<b>Air Preheater Motor Off-Line Tests and Inspections (Check-off any unacceptable conditions)</b>		
<b>Unsatisfactory</b>	<b>Failure Location</b>	<b>Reportable Condition</b>
	Surge Capacitors	Task is not likely to discover the condition
	Winding Electrical Connections – brazed	High resistance
	Bearing Insulation (External)	Broken, cracked, or detached
	Bearing Seals (all types)	Excessive wear
	Bearing Seals (all types)	Leakage
	Bearing Seals (contact type)	Deformed
	Bearing Seals (contact type)	Excessive wear
	Bearing Seals (non-contact type)	Excessive wear
	Breather Caps and Sight Glass Vents	Blocked
	Filters - Air coolers	Clogged or dirty
	Frame, Enclosure– and Mounting	Clogged air screens
	Frame, Enclosure, and Mounting	Deformed
	Frame, Enclosure, and Mounting	Loose or damaged
	Frame, Enclosure, and Mounting	Soft Foot
	Gaskets – general	End of useful life
	Internal Cooling Coil – Bearing Cooling Water	Coil separation
	Internal Cooling Coil – Bearing Cooling Water	Corroded
	Internal Cooling Coil – Bearing Cooling Water	Fouled
	Internal Cooling–Coil – Bearing Cooling Water	Leakage
	Internal Cooling Coil – Bearing Cooling Water	Packing or gasket failure
	Lubrication – Oil	Insufficient or excessive level
	Machine Fits	Damaged or misaligned
	Piping and Connections	Leakage
	Rotor Bars and Shorting Rings	Task is not likely to discover the condition
	Rotor Fans and Hardware	Task is not likely to discover the condition
	Rotor Fans with interference fit design	Task is not likely to discover the condition
	Rotor Laminations	Dirty

<b>Air Preheater Motor Off-Line Tests and Inspections (Check-off any unacceptable conditions)</b>		
<b>Unsatisfactory</b>	<b>Failure Location</b>	<b>Reportable Condition</b>
	Rotor Laminations	Task is not likely to discover the condition
	Shaft	Bowed
	Shaft	Sagged
	Shaft	Task is not likely to discover the condition
	Space Heater Wiring	Task is not likely to discover the condition
	Space Heaters	Broken, loose or grounded connections
	Stator Laminations	Task is not likely to discover the condition
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Broken surge ring
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Failure of surge ring support brackets
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Fretting of insulation materials
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Loose blocking, bracing, or tying
	Stator Windings, includes Blocking, Bracing, Tying, Surge rings, Wedges	Loose wedges
	Surge Capacitors	Bushing damage
	Surge Capacitors	Bushing tracking
	Surge Capacitors	Leakage

### **6.5.6 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

### **6.5.7 Post-Maintenance Testing**

Post-maintenance testing should including verification of the motor starting after providing the start signal. Verify that the initial amperage spikes on start, then drops to its normal operating range once the motor has reached its design speed.

### **6.5.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.6 Job Plan #5: Rotor Drive Assembly including Gearbox and Couplings Inspection**

### **6.6.1 Task Overview**

This job plan has been developed to perform visual inspections of the air preheater rotor drive assembly including gearbox and couplings.

#### **6.6.1.1 Task Timing and Objective**

The inspection of the rotor drive assembly including gearbox and couplings should coincide with a plant outage.

### **6.6.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### 6.6.3 Contingency Considerations

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

### 6.6.4 Work Instructions

The PM tasks for the gear box and couplings should include the following:

- Inspect for corrosion or wear of sleeve bearings.
- Inspect for wear or degradation of oil seals and gaskets.
- Inspect for wear and damage to gears.
- Inspect for wear and damage of roller element bearings and seals.
- Inspect for signs of leaking lubricant, if present.
- Inspect all mating surfaces for cleanliness, wear, and integrity.
- Inspect the condition of the lubricant for evidence of wear particles and water before replacement, if present.
- Inspect for evidence of unusual or excessive wear and damage.
- Inspect non-metallic parts for wear and damage.
- Inspect all bolting for evidence of damage or galling.
- Inspect the shaft, keys, and keyway for proper fit, key size, and any evidence of damage or unusual wear.

### 6.6.5 Example Worksheet

Air Preheater Rotor Drive Assembly including Gearbox and Couplings Visual Inspection (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Gear box and couplings	Corrosion or wear of sleeve bearings
	Gear box and couplings	Wear or degradation of oil seals and gaskets
	Gear box and couplings	Wear and damage to gears
	Gear box and couplings	Wear and damage of roller element bearings and seals
	Gear box and couplings	Signs of leaking lubricant, if present
	Gear box and couplings	Mating surfaces for cleanliness, wear, and integrity.
	Gear box and couplings	Lubricant for evidence of wear particles and water before replacement, if present
	Gear box and couplings	Evidence of unusual or excessive wear and damage

Air Preheater Rotor Drive Assembly including Gearbox and Couplings Visual Inspection (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Gear box and couplings	Non-metallic parts for wear and damage
	Gear box and couplings	Bolting for evidence of damage or galling
	Gear box and couplings	Shaft, keys, and keyway for proper fit, key size, and any evidence of damage or unusual wear

### 6.6.6. Feedback Mechanisms

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

### 6.6.7 Post-Maintenance Testing

Post-maintenance testing should include the following activities:

- Verify there is no oil leakage of the support thrust or radial guide bearing lubrication systems.
- Verify there is no excessive vibration and/or noise (for example, grinding) when the air preheater is started.



#### Key Technical Point

Care should be taken to ensure the preheater is rotated during start-up to avoid damage due to uneven thermal expansion of the rotor assembly.

- Perform thermography testing to check for any hot spots that could provide an indication of leakage or bearing wear.

### 6.6.8 References

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.7 Job Plan #6: Rotor and Rotor Seals Inspection**

### **6.7.1 Task Overview**

This job plan has been developed to perform visual inspections of the air preheater rotor and rotor seals.

#### **6.7.1.1 Task Timing and Objective**

The inspection of the rotor and rotor seals should coincide with a plant outage.

### **6.7.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### **6.7.3 Contingency Considerations**

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

### **6.7.4 Work Instructions**

The PM tasks for the rotor should include the following:

- Inspect for cracking or erosion of post to diaphragm welds.
- Inspect for warping, cracking or thinning of the diaphragm.
- Inspect for cracking, corrosion or erosion of the grating, welds, supports, and blocks.
- Inspect for cracking, thinning or circumferential deformation of the shell plate.

The PM tasks for the pin rack should include the following:

- Inspect for looseness and detachment from the shell.
- Inspect for excessive wear and corrosion of the pin.
- Inspect for loss of pinion gear contact with the rails.
- Inspect for loss of pinion contact with the pin rack.
- Inspect for oil leakage.
- Inspect for excessive pinion gear wear.
- Inspect for excessive pin rack pin wear > 3/16 inch.
- Inspect for corrosion or physical deformation of the rails.

The PM tasks for the housing, structural members, bracing and connecting plates should include the following:

- Inspect for excessive wear and thinning of the housing and connecting plates.
- Inspect for damage from erosion or corrosion.
- Inspect for deformation, warping, weld cracking.
- Inspect for expansion and distortion.
- Inspect sector plates for tilting from one side to the other and if out of alignment correct the appropriate actuator.
- Inspect tops of sector plates for accumulation of ash that may prevent the proper movement particularly being able to return to its cold position.
- Inspect structural supports inside the air preheater for evidence of corrosion and erosion with particular attention on the flue gas side as it will experience fly ash erosion.
- Visually inspect for thinning of metal, corrosion and cracking in welds. If weld cracking is occurring, an engineered solution that identifies the root cause should be pursued, so the cracking will not continue.



**Key Technical Point**

Erosion of the structural supports can be mitigated by welding on sacrificial protection. For rounded sections, often a flat plate perpendicular to the flow can be more effective for protection rather than a right-angled or curved piece that is able to conform to the curvature of the support.

The PM tasks for the rotor seals should include the following:

- Inspect for improper clearance resulting in leakage or bypass air/gas flow.
- Inspect for inadequate contact with seal plates or sealing surfaces.
- Inspect for excessive wear, physical damage, cracking, warping, erosion, corrosion or deformation.
- Inspect for thinning of the seals.
- Inspect for detachment or looseness of fasteners.
- Adjust rotor seal clearances as needed, in accordance with the original equipment manufacturer’s recommendations and procedure (if provided).

**6.7.5 Example Worksheet**

<b>Air Preheater Rotor and Rotor Seals Visual Inspection and Test (Check-off any unacceptable conditions)</b>		
<b>Unsatisfactory</b>	<b>Failure Location</b>	<b>Reportable Condition</b>
	Rotor	Cracking or erosion of post to diaphragm welds
	Rotor	Warping, cracking or thinning of the diaphragm
	Rotor	Cracking, corrosion or erosion of the grating, welds, supports, and blocks
	Rotor	Cracking, thinning or circumferential deformation of the shell plate
	Pin rack	Looseness and detachment from the shell
	Pin rack	Excessive wear and corrosion of the pin
	Pin rack	Loss of pinion gear contact with the rails
	Pin rack	Loss of pinion contact with the pin rack
	Pin rack	Oil leakage
	Pin rack	Excessive pinion gear wear
	Pin rack	Excessive pin rack pin wear > 3/16 inch
	Pin rack	Corrosion or physical deformation of the rails
	Housing and connecting plates	Excessive wear and thinning of the housing and connecting plates
	Housing and connecting plates	Damage from erosion or corrosion
	Housing and connecting plates	Deformation, warping, weld cracking
	Housing and connecting plates	Expansion and distortion
	Rotor seals	Improper clearance resulting in leakage or bypass air/gas flow

<b>Air Preheater Rotor and Rotor Seals Visual Inspection and Test (Check-off any unacceptable conditions)</b>		
<b>Unsatisfactory</b>	<b>Failure Location</b>	<b>Reportable Condition</b>
	Rotor seals	Inadequate contact with seal plates or sealing surfaces
	Rotor seals	Excessive wear, physical damage, cracking, warping, erosion, corrosion or deformation
	Rotor seals	Thinning of the seals
	Rotor seals	Detachment or looseness of fasteners
	Rotor stop alarm	Alarm fails to activate upon stoppage of the rotor

### **6.7.6 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

### **6.7.7 Post-Maintenance Testing**

Post-maintenance testing should be performed subsequent to the inspection of the rotor and rotor seals. Monitor temperature differential across air preheater to verify proper heat transfer is being achieved, and there is no excessive leakage due to worn rotor subcomponents and seals.

### **6.7.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.8 Job Plan #7: Cleaning System Inspection and Functional Test**

### **6.8.1 Task Overview**

This job plan has been developed to perform visual inspections and a functional test of the air preheater cleaning systems. These inspections are best conducted by the OEM representative and require one complete man-day during an outage.

#### **6.8.1.1 Task Timing and Objective**

The inspection and testing of the air preheater cleaning system should coincide with a plant outage.

### **6.8.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed
- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### **6.8.3 Contingency Considerations**

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

### **6.8.4 Work Instructions**

Routine maintenance for soot blowing equipment should include the inspection, adjustment, and repair (and replacement as necessary) of the following elements:

- Inspect the general condition of the drive mechanism and motor including the stroke of the soot blower and alignment verification.
- Inspect nozzles for cracking, plugging, deformation or corrosion, and that none are missing.
- Verify electrical functions, particularly limit switches.
- Inspect components installed in the steam/air path, including pressure gauges, valves, gaskets and packed joints.
- Ensure soot blower traverses the heating elements with the correct stroke and coverage.
- Inspect piping for leakage, corrosion, and physical deformation.

The PM tasks for the cleaning/washing equipment should include the following:

- Inspect the general condition of the drive mechanism, motor and pump.
- Inspect the general condition of the washing device for corrosion and physical damage.
- Ensure the washing equipment traverses the heating elements with the correct stroke and coverage.
- Inspect the header for leakage.
- Inspect nozzles for cracking, plugging, deformation or corrosion, and that none are missing.

**6.8.5 Example Worksheet**

Air Preheater Cleaning System Inspection and Functional Test (Check-off any unacceptable conditions)		
Unsatisfactory	Failure Location	Reportable Condition
	Soot blower drive mechanism and motor	General condition
	Soot blower nozzles	Cracking, plugging, deformation or corrosion, and that none are missing
	Soot blower	Ensure soot blower traverses the heating elements with the correct stroke and coverage
	Soot blower piping	Leakage, corrosion, and physical deformation
	Cleaning/washing drive mechanism, motor and pump	General condition of the
	Cleaning/washing device	Corrosion and physical damage
	Cleaning/washing equipment	Ensure the washing equipment traverses the heating elements with the correct stroke and coverage
	Cleaning/washing header	Leakage
	Cleaning/washing nozzles	Cracking, plugging, deformation or corrosion, and that none are missing

**6.8.6 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

**6.8.7 Post-Maintenance Testing**

Post-maintenance testing should include the following activities:

- Verify that the soot blower will insert completely and retract completely.
- Verify that steam pressure is appropriate and meets design requirements.

### **6.8.8 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual

## **6.9 Job Plan #8: Heating Element Water Wash**

### **6.9.1 Task Overview**

This job plan has been developed to perform a water wash of the air preheater heating elements. Washing of air heater elements has been demonstrated to be an effective means for removing deposits of ammonium sulfate and bisulfate, thus reducing flue gas pressure loss to pre-SCR or clean conditions. The key variables in water washing are the cleaning time required and the quantity and treatment of effluent wash water. The washing methodology for each site depends on the availability of suitable water, facilities on-site to store and/or treat effluent wash, specific washing equipment available, and the amount of fouling on surfaces.

#### **6.9.1.1 Task Timing and Objective**

The inspection and testing of the water wash should coincide with a plant outage, and should be performed on an as-required basis.

### **6.9.2 Pre-Job Considerations**

The maintenance supervisor should determine if 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:
  - Lock-Out-Tag-Out (LOTO)
  - Calibration procedure
  - Foreign Material Exclusion (FME)
- Identification of clearance/tag out boundary
- Identification of foreign material exclusion (FME) potential and mitigation
- Environmental considerations (reference MSDS)
- Identification of hazards in the area of the work to be performed

- Identification of any special equipment that may be needed for the job (for example, harness, pneumatic equipment, and so on)
- Identification of special permit that workers will need or will need to sign on to (for example, confined space)

### 6.9.3 Contingency Considerations

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

### 6.9.4 Work Instructions



#### Key Technical Point

If possible, all dust should be removed by vacuum or other techniques prior to water washing. This dust removal includes any dust accumulated on the APH support shaft and steel, as well as associated ductwork. Also, when ash with high calcium content is being washed, the water cleaning cycle should be continuous, without interruption until all ABS and ash are removed. Without this precaution, the partially removed material will form cement-like deposits.

The heating element water wash process should consider the following:

- In order to facilitate the washing of the heating elements, a pressure gauge and valve in the wash water supply line should be provided. If it is necessary to minimize the amount of water carryover to the opposite side of the preheater during the washing process, the rotor speed should be reduced to approximately ¼ RPM using an auxiliary drive.
- Whenever the rotor speed is reduced, automatic timer controls should be used with the power-driven washing device so as to prevent spiraling actions and a reduction in the effectiveness of the wash.
- To effectively wash the heating surfaces, the following water conditions should be met:
  - Pressure at power-driven washing device inlet: 150 psig max
  - Pressure at stationary washing device inlet: 85 psig
  - Flow for ¼" x 4-½" flared nozzle at 75 psig: 80 gpm
  - Flow for stationary washing device: 900 gpm
- Because deposits are often more soluble in hot water, it may be advantageous to heat the wash water to approximately 180°F.
- Care should be taken to ensure adequate facilities to trap and drain the wash water to a sump are provided. Ensure the drain lines have sufficient pitch to prevent settling of the deposits in the line. Drain hoppers should be inspected before washing to ensure that the openings are not plugged or corroded.

- Washing should continue until visual inspection indicates the heating elements are clean. The inspection should be as thorough as possible because any deposits remaining after the washing can be baked onto the element, and generally become insoluble when the preheater is returned to service.



**Key Technical Point**

The most significant risk of air heater washing is accelerated corrosion to heat transfer surfaces, which subsequently increases surface roughness. Increased corrosion further exacerbates deposition of ammonium compounds and compromises the effectiveness of soot blowing, thereby requiring even more washing.

- After the washing is complete, care should be taken to ensure the water supply is completely closed off and the wash effluent is eliminated from adjacent ducting and drain traps.
- Care should be taken to provide sufficient time for the preheater rotor and heating surfaces to dry before the preheater is returned to service.

**6.9.5 Feedback Mechanisms**

Identify mechanism to provide work order feedback for improvements and errors. This may include performing a post job review and/or initiating any corrective action program documents necessary to resolve problem areas that were identified.

**6.9.6 Post-Maintenance Testing**

Post-maintenance testing should verify that the water wash mechanism will completely retract, and that the washed components are completely dry prior to exposing them to hot flue gas.

**6.9.7 References**

The job plan may include one or more of the following references to provide additional guidance to craft labor and/or component-specific information based on the model/size/type of equipment installed.

- Industrial Safety Manual
- Foreign Material Control Procedure
- Material Safety Data Sheets
- Vendor Technical Manual



# 7

## PERSONNEL SAFETY ISSUES

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The purpose of this section is to provide safety guidance for operations and maintenance personnel working on or around a typical combustion turbine installed at a combined cycle facility. Guidance is also provided for fossil power plant owners that may be beneficial for enhancing their existing site-wide worker-safety program.

### 7.1 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.

### 7.2 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.

#### 7.2.1 *Personal Protective Equipment (PPE)*

##### 7.2.1.1 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 insuring the proper use of required personal protective equipment.

##### 7.2.1.2 Hard Hats

All contract employees, subcontractors, visitors, and delivery personnel should be required to wear hard hats while at the fossil-fuel power plant.

##### 7.2.1.3 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.

#### **7.2.1.4 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 ANSI Z87.1-1968 standards.

#### **7.2.1.5 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 they have first been evaluated by a physician to determine their physical ability to wear the respirator and fit-tested.

#### **7.2.1.6 Foot Protection**

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

### **7.2.2 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 5,400 pounds. A lanyard should be a minimum of ½-in nylon rope, or equivalent, with a maximum length to provide for a fall of no greater than 6 feet, 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 feet above the next lower level, except when working on an approved scaffold.

Safety nets should be provided when work places are more than 25 feet 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.

### **7.2.3 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 fossil-fuel power plant

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. Refer to the Welding and Cutting section for more details.
- Store combustible or flammable liquids in appropriate containers that are properly labeled, 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 feet from oxygen cylinders.
- Ensure that no material is stored within 3 feet of an electrical panel, outlet, or fire-suppression system.
- Prohibit smoking within 100 feet of any plant enclosure or gas piping and in the Maintenance Building and Substation-Control Building.

#### **7.2.4 Housekeeping and Foreign-Material Exclusion**

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 non-slip 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 accumulate, that might create a tripping hazard.
- 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 EPA regulations.

### **7.2.5 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 feet of any hoist-way or other inside floor opening or within 10 feet 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 1 day's operation.
- Materials must never be thrown or dropped from a distance of more than 20 feet. 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 feet.
- 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.

### **7.2.6 Rigging**

In addition to the guidelines listed below, maintenance personnel should consider the guidance provided in EPRI 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, and EPRI 3002001203, *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.
- Never strain wire rope over sharp corners.
- Remember that increasing the angle between the legs of a sling increases the load on each leg.

- Do not paint hooks.
- Only qualified personnel may be assigned to rigging operations.
- Rigging equipment is not permitted for working closer than 10 feet 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.

### **7.2.7 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 by 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 from Underwriters Laboratories (UL)-approved cans only. All gas-powered tools must be turned off before being refueled.

### **7.2.8 Welding and Cutting and Other “Hot” Work**

No “hot” work should be permitted at the fossil-fuel power plant 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 fossil-fuel power plant site manager, and must be in accordance with site procedures.

### **7.2.9 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 personal protective equipment, such as coveralls, safety goggles, face shield, welding hood, or welding jacket, as demanded by the type of work completed.

### **7.2.10 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 free from repair or splices for a minimum of 10 feet 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 personal protective equipment, such as coveralls, safety goggles, face shield, welding hood, or welding jacket, as demanded by the type of work completed.

### **7.2.11 Electrical Safety**

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

- All construction electrical installations and temporary wiring should be made in accordance with the National Electric Code ANSI/NFPA latest edition and all federal, state, and local codes.
- Temporary lights should be equipped with guards. Broken burned-out bulbs should be replaced.
- Temporary electric cords must be covered or elevated. They must be kept clear of walkways where they may 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 fossil-fuel power plant owners are subject to the Power Generation and Transmission OSHA standard 29 CFR 1910.269. Contractors working on fossil-fuel power plant premises may also be subject to portions of this regulation.

### **7.2.12 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 de-energized should be rendered inoperative and should have tags and/or locks attached at all points where such equipment or circuits can be energized.
- If feasible, the breaker being tagged out should be racked out/disconnected to ensure a second line of defense for safety. The control power (DC) for larger breakers should also be off and tagged out.

### **7.2.13 Scaffolding**

In addition to the guidelines noted below, maintenance personnel should consider the guidelines provided in EPRI 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, and EPRI 3002001203, *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, mid-rails, and toe boards must be installed on all open sides of scaffolds that are 10 feet or more in height. Guardrails must be 2 x 4 in or equivalent, supported at intervals of not more than 8 feet. Toe boards should be a minimum of 4 in. in height.
- 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 ½-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 x10 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 feet horizontally and 26 feet vertically.
- Lean-to scaffolds and makeshift platforms are prohibited.
- All scaffolds over 10-feet 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.

#### **7.2.14 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 are drops of more than 4 feet, and the bottom of the opening is less than 3 feet above the working surface, will have a standard guardrail.

- Open-sided floor or platforms 6 feet or more above the adjacent floors or ground level, and runways 4 feet 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.

### **7.2.15 Cranes, Hoist, Elevators, and Conveyors**

In addition to the guidelines noted below, maintenance personnel should consider the guidance provided in EPRI 1007914, *Lifting, Rigging, and Small Hoist Usage Program Guide*, and EPRI 3002001203, *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, or 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 make-shift designs.
- Wire rope slings should be padded to protect against damage from sharp corners.
- Hard hats and proper personal protective equipment 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 feet 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.

### **7.2.16 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-to-1 pitch, have clear access at top and bottom, and 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 over-reaching when working from ladders.
- Manufactured ladders must comply with OSHA, ANSI, manufacturer, and job specifications.
- The six-foot 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.

### **7.2.17 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 feet or by a 5-foot high barrier wall that has a minimum 1-h fire rating.
- Compressed-gas cylinders should not be taken into confined spaces.

### **7.2.18 Permit-Required Confined Spaces**

Only contract employees who have been trained in compliance with OSHA confined-space standard 29 CFR 1910.146 or equivalent, 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 fossil-fuel power plant 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 re-check 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 fossil-fuel power plant 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
- EHC skid reservoir
- Gas-filter separator vessel
- Lube-oil reservoir
- Turbine-building ventilation fan and exhaust-hood enclosures
- Evaporative -cooler water-supply valve pit

## **7.3 Worker Safety and Health Guidelines for Fossil-Fuel Power Plant Owners**

### ***7.3.1 General Safety Requirements for Fossil-Fuel Power Plant Owners***

Owners should provide a work place free of hazardous, unsanitary, or 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 fossil-fuel power plant.

It should be the responsibility of the owner to ensure that all subcontractors and contractor employees abide by the safety rules and regulations while on the fossil-fuel power plant. Technicians should stay in only their assigned work areas.

The owner should ensure that any maintenance technicians do not bring any explosives, firearms, alcoholic beverages, or drugs on the fossil-fuel power plant premises. 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 de-energizing the circuit and grounding or guarding it effectively by insulation or other means.



#### **Key Technical Point**

When doing welding on the air preheater, care should be taken to ensure the ground is made from the rotor structure to the rotor frame and not grounded through the support thrust bearings or radial guide bearings.

- 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.

### **7.3.2 Occupational Safety and Health**

Construction, operation, and maintenance activities associated on or around the fossil-fuel power plant 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 personal protective equipment, 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.

### **7.3.3 Injury- and Illness-Prevention Programs**

Prior to beginning construction activities, the fossil-fuel power plant owner should develop a site-specific construction injury- and illness-prevention program (IIPP). Once the construction of the proposed project is complete, a site-specific IIPP for operations and maintenance activities will be implemented.

#### **7.3.3.1 Construction Injury- and Illness-Prevention Programs**

Consistent with applicable state and OSHA policy on multi-employer work sites, each fossil-fuel power plant 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.

#### **7.3.3.2 Operations and Maintenance Injury- and Illness-Prevention Programs**

Upon completion of construction, startup of the proposed project, and implementation of routine operations, the construction IIPPs should transition into an operations-oriented program that reflects the hazards and controls necessary during routine operations and maintenance of the fossil-fuel power plant.

#### *Injury- and Illness-Prevention Plan*

The primary mitigation measures for worker hazards during normal plant operation and maintenance are contained in the IIPP, as required by state and OSHA requirements, and site-specific procedures. The written IIPP should designate an individual who is responsible for implementing the program. It also should describe safety training and procedures for tracking safety training. An IIPP 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:
  - 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 fossil-fuel power plant 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 feet, 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 personal protective equipment (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.

### *Personal Protective Equipment (PPE) Program*

PPE requirements for work at the fossil-fuel power plant should be identified during the job-hazard analyses process. The PPE requirements should be developed and incorporated into the site-specific IIPP. 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

#### *Operations and Maintenance 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 fossil-fuel power plant. These programs will be made components of the overall operations and maintenance IIPP for the facility. These programs include, but are not limited to, 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:
  - 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

#### **7.3.4 Safety-Training Programs**

To ensure that employees recognize and understand how to protect themselves from hazards at the fossil-fuel power plant, comprehensive training programs for construction and operations personnel should be implemented.

Operations and maintenance 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.
- Material-safety data sheets 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 as described below:

- A list of safe work rules for the fossil-fuel power plant 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 fossil-fuel power plant 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 foreman upon initial assignment and upon any reassignment.



# A

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# B

## GLOSSARY OF TERMS

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### B.1 Industry Definitions and Nomenclature

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

**Corrective Maintenance (CM)** – 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 such that failure is imminent (within its operating cycle/preventive maintenance interval), and it no longer conforms to its design function.

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

**Frequency-Based or Periodic Maintenance (FBM)** – 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, with the level of detail dependent upon 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.

### B.2 Acronyms

ABS – Ammonium Bisulfate

AC – Alternating Current

ACET – Average Cold End Temperature

ANSI – American National Standards Institute

APH – Air Preheater

AR – As-Required

ASME – American Society of Mechanical Engineers

CBM – Condition Based Maintenance  
CFR – Code of Federal Regulations  
CHM – Critical, High, Mild  
DC – Direct Current  
DCS – Distributed Control System  
EHC – Electro-Hydraulic Controls  
EPA – Environmental Protection Agency  
EPRI – Electric Power Research Institute  
FME – Foreign Material Exclusion  
GenMAC – Generation Maintenance Applications Center  
Gpm – gallons per minute  
HBr – Hydrogen Bromide  
ID – Inside Diameter  
IIPP – Injury- and Illness-Prevention Plan  
LOTO – Lock Out Tag Out  
Lpm – liters per minute  
MSDS – Material Safety Data Sheet  
MW – Megawatts  
NFPA – National Fire Protection Association  
O&M – Operations & Maintenance  
OD – Outside Diameter  
OEM – Original Equipment Manufacturer  
OSHA – Occupational Safety and Health Administration  
pH – Power of Hydrogen  
PM – Preventive Maintenance  
PMBD – Preventive Maintenance Basis Database  
PPE – Personal Protective Equipment  
Ppm – parts per million  
Psi – pounds per square inch  
Psia – pounds per square inch atmospheric  
PTC – Performance Test Code

RCM – Reliability Centered Maintenance  
rpm – revolutions per minute  
RTD – Resistance Temperature Detector  
SAE – Society of Automotive Engineers  
SCR – Selective Catalytic Reduction  
SNCR – Selective non-Catalytic Reduction  
TM – Trademark  
TR – Technical Report  
UL – Underwriters Laboratory



# C

## LISTING OF KEY POINTS

### C.1 Key O&M Cost Points



#### Key O&M Cost Point

Emphasizes information that will result in overall reduced costs and/or increase in revenue through additional or restored energy production.

Referenced Section	Page Number	Key Point
2.3.1	2-7	Industry experience suggests keeping the cold end thick enough to cover all acid condensation but small enough to physically handle. This allows for better soot blowing effectiveness. Basket design is critical in balancing maintenance, replacement, and soot blowing activities.
2.3.8.2	2-16	Due to inadequate water pressure at the facility, some owners have found it more beneficial to use the services of a commercial vendor if water washing of the heating elements and baskets are needed.
2.3.8.2	2-17	Air heater washing should be performed only when deemed necessary to reduce flue gas pressure drop (that cannot be corrected with soot blowing).
4.4	4-18	As a general rule of thumb, if the repair costs 50% or less of the replacement cost, then repair should be considered. If the percentage is greater, then replacement is generally the best option.
4.5.2.2	4-35	Because there are hundreds of baskets in an air preheater rotor assembly, the timing to remove and replace each one must be well choreographed to ensure a timely completion at minimal cost.

## C.2 Key Technical Points



### Key Technical Point

Targets information that will lead to improved equipment reliability.

Referenced Section	Page Number	Key Point
2.3.1	2-8	The optimum design profile of the basket heating elements should be selected based on parameters such as the type of fuel, air temperature differential, heat transfer requirements and flue gas particulate composition. Selection of the optimum profile is typically performed during the design phase of the air preheater by the equipment manufacturer
3.5	3-15	Seal leakage can also result in inadequate fan capacity or the inability to supply enough air for full-load operation, that is, running out of air.
3.5	3-16	Sector plate damage can also result in air leakage issues, because if sector plates warp or degrade, the seals may not be able to isolate the flows of air and flue gas.
3.6.3	3-18	In addition to ABS, pressure drop can increase as a result of fouling. Most air preheater vendor manuals have a recommended minimum average cold end temperature (ACET). Weather, operating load, sulfur content of fuel can all impact fouling.
4.3.8	4-16	When replacing the lubricant in the rotor thrust bearing, the oil level should be checked after the lubricant has been able to heat up and circulate through the system. Failure to do this may result in a false oil level reading, which could lead to the bearing being insufficiently lubricated during service.
4.3.8	4-16	At this point in the process, the cartridge should be inspected to identify the amount and type of debris found inside the assembly.
4.5.1.1	4-24	It is advisable to pour a small amount of oil on each bearing or journal surface to ensure rotation of an oil film whenever rolling gear elements in their fluid film bearings, as the lubrication system is inoperable.
4.5.1.3	4-28	Before replacing a wiped bearing, determine and correct the cause of the failure.
4.5.1.4	4-29	Tighten connectors uniformly; when tightening bolts, studs, or screws on an assembled portion with three or more holes, always partially tighten connectors equally in a "cross" pattern to avoid torquing, binding, or warping the section.
4.5.1.4	4-29	When reassembling, manufacturer torque limits should be followed. Over-torquing can lead to damage and issues with equipment after reassembly and being placed back into service.

Referenced Section	Page Number	Key Point
4.5.2.2	4-35	Care should be taken to ensure the rotor remains balanced as baskets are removed. To do this, remove a "pie of baskets" and then rotate the rotor assembly 180 °F to remove the "pie of baskets" from the opposite side of the rotor.
4.5.2.3	4-36	When checking seal clearances, both sector plates should be checked at multiple points along the plates, such as at the leading edge, the clearing edge, and at the center to find any high spots that may result in air or flue gas leakage.
4.5.2.3	4-37	Care should be taken to ensure the preheater is rotated during start-up to avoid damage due to uneven thermal expansion of the rotor assembly.
4.5.4.1	4-39	The hub will stand off the shaft at the key location after cooling, if the coupling is heated for installation to facilitate an interference fit.
4.5.4.3	4-40	Due to unacceptable vibration between the rotor drive motor and the gearbox, some owners have replaced the original gear-type coupling with a magnetic coupling.
4.5.7	4-41	However, due to the erosive nature of particulates that may be present in the air supply for the soot blowing system, it is common to replace the nozzles every outage.
6.1.2.2	6-4	When doing welding on the air preheater, care should be taken to ensure the ground is made from the rotor structure to the rotor frame and not grounded through the support thrust bearings or radial guide bearings.
6.1.2.2	6-4	LOTO procedures may require special allowances due to the need to rotate the rotor while certain maintenance activities are on-going such as basket replacements and air seal leakage testing.
6.1.2.3	6-5	Only replacement parts that are physically identical to the original should be installed unless an alternate replacement item has been determined to be a suitable equivalent.
Job Plan #1	6-8	Note that air heater surfaces at either the hot or cold end can be eroded by aggressive soot blowing, and soot blowing alone may not be adequate to remove deposits. The use of excessive steam pressure and extended soot blowing duration may damage heat exchange material.
Job Plan #5	6-22	Care should be taken to ensure the preheater is rotated during start-up to avoid damage due to uneven thermal expansion of the rotor assembly.
Job Plan #6	6-24	Erosion of the structural supports can be mitigated by welding on sacrificial protection. For rounded sections, often a flat plate perpendicular to the flow can be more effective for protection rather than a right-angled or curved piece that is able to conform to the curvature of the support.

*Listing of Key Points*

Referenced Section	Page Number	Key Point
Job Plan #8	6-30	If possible, all dust should be removed by vacuum or other techniques prior to water washing. This dust removal includes any dust accumulated on the APH support shaft and steel, as well as associated ductwork. Also, when ash with high calcium content is being washed, the water cleaning cycle should be continuous, without interruption until all ABS and ash are removed. Without this precaution, the partially removed material will form cement-like deposits.
Job Plan #8	6-31	The most significant risk of air heater washing is accelerated corrosion to heat transfer surfaces, which subsequently increases surface roughness. Increased corrosion further exacerbates deposition of ammonium compounds and compromises the effectiveness of soot blowing, thereby requiring even more washing.
7.3.1	7-13	When doing welding on the air preheater, care should be taken to ensure the ground is made from the rotor structure to the rotor frame and not grounded through the support thrust bearings or radial guide bearings.

### C.3 Key Human Performance Points



#### Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent personal injury, equipment damage, and/or improve the efficiency and effectiveness of the task.

Referenced Section	Page Number	Key Point
2.3.8.2	2-17	Operators should also be aware of the need to properly dry the air heater before it is returned to service.
4.5.2.1	4-33	Plate replacement commonly requires significant pre-planning and the development of a safe rigging plan both within the air preheater heater and externally to the equipment.
4.5.5	4-40	Do not rely on the jacks to hold the rotor. The jacks should be left in position, but the rotor should be blocked by using heavy-steel shaft material cut to specific lengths that can be placed between the jacks and prevent the rotor from falling.
5.2	5-1	Always consider sources of energy input to a component. Double feeds for electrical and for water present special concerns for isolation. Isolation of one does not ensure the other feed is isolated. Consult drawings and walk downs to ensure isolated.

Referenced Section	Page Number	Key Point
6.1.1.1	6-1	One key attribute to consistently developing a quality job plan is to perform a critical task analysis.
6.1.1.2	6-2	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, then it should be placed in the work package.
6.1.2.2	6-4	The work planner should typically prepare a pre-job brief traveler for any maintenance activities posing risk to unit operation/generation.
6.1.2.3	6-5	The work planner should review bill-of-materials, drawings, component maintenance philosophy and maintenance history to identify parts and consumables that are likely to be needed for the job.
6.1.2.6	6-7	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.

#### C.4 Key Supervisory Observation Points



##### 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.

Referenced Section	Page Number	Key Point
2.3.7	2-14	Care should be taken to ensure rotor-stopped alarms and associated proximity probes are functional, so operators can take the necessary actions to secure the unit should the rotor stop.
5.5	5-4	Crew supervisors should take the opportunity on critical work to review the planner's work on instructions and parts selection. Provide coaching as needed.





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