8.7 AIR PRE HEATER PERFORMANCE TEST

8.7.1 Introduction

This procedure provides a systematic approach for conducting routine Air Heater performance tests on tubular and rotary regenerative air heaters.

Air heater leakage % can be determined using this procedure, which is defined as the weight of air passing from the airside to the gas side of the air heater. This index is an indicator of the condition of the air heater’s seals. As air heater seals wear, air heater leakage increases. The increase in air heater leakage increases the station service power requirements of the forced draft and induced draft fans, increasing unit net heat rate and at times limiting unit capacity.

Air heater gas side efficiency can also be determined using this procedure and is defined as the ratio of the temperature drop, corrected for leakage, to the temperature head, expressed as a percentage.

Gas side efficiency is an indicator of the internal condition of the air heater. As conditions inside the air heater worsen (baskets wear, ash pluggage, etc), the air heater gas side efficiency decreases. This is generally accompanied by an increase in exit gas temperature and a decrease in air heater air outlet temperature, resulting in an increase in unit heat rate.

X-Ratio depends on the moisture in coal, air infiltration, air & gas mass flow rates, leakage from the setting and specific heats of air & flue gas. X-ratio does not provide a measure of thermal performance of the air heater, but is a measure of the operating conditions.

A low X-ratio indicates excessive gas weight through the air heater or that airflow is bypassing the air heater. A lower than design X-ratio leads to higher than design gas outlet temperature & can be used as an indication of excessive tempering air to the mills or excessive boiler infiltration.

8.7.2 Objective

1. To identify abnormal changes in air heater leakage or efficiency and provide information for identifying the cause of performance degradation.

2. To provide information to allow accounting for the contribution of air heater performance degradation to unit heat rate and capacity.

3. To crosscheck the readings of important station instruments.
8.7.3 Parameters for AH Performance Monitoring

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Load</td>
<td>MW</td>
</tr>
<tr>
<td>Feed water and / or Main Steam flow</td>
<td>T/hr</td>
</tr>
<tr>
<td>Total Air flow</td>
<td>T/hr</td>
</tr>
<tr>
<td>Coal Flow</td>
<td>T/hr</td>
</tr>
<tr>
<td>Mills in service</td>
<td>Nos.</td>
</tr>
<tr>
<td>Avg. Flue Gas O2 - AH Inlet</td>
<td>%</td>
</tr>
<tr>
<td>Avg. Flue Gas CO2 - AH Inlet</td>
<td>%</td>
</tr>
<tr>
<td>Avg. Flue Gas O2 - AH Out</td>
<td>%</td>
</tr>
<tr>
<td>Avg. Flue Gas CO2 - AH Out</td>
<td>%</td>
</tr>
<tr>
<td>Avg. Flue Gas Temp - AH In</td>
<td>C</td>
</tr>
<tr>
<td>Avg. Flue Gas Temp - AH Out</td>
<td>C</td>
</tr>
<tr>
<td>Avg. Primary Air to AH Temp In</td>
<td>C</td>
</tr>
<tr>
<td>Avg. Primary Air from AH Temp Out</td>
<td>C</td>
</tr>
<tr>
<td>Avg. Secondary Air to AH Temp In</td>
<td>C</td>
</tr>
<tr>
<td>Avg. Secondary Air from AH Temp Out</td>
<td>C</td>
</tr>
<tr>
<td>Pressure Drop across Flue gas path</td>
<td>mmWC</td>
</tr>
<tr>
<td>Pressure Drop across Primary air path</td>
<td>mmWC</td>
</tr>
<tr>
<td>Pressure Drop across Secondary air path</td>
<td>mmWC</td>
</tr>
<tr>
<td>Total Secondary Air Flow</td>
<td>T/hr</td>
</tr>
<tr>
<td>Total Primary Air Flow</td>
<td>T/hr</td>
</tr>
<tr>
<td>Design Ambient / Ref Air Temp</td>
<td>C</td>
</tr>
<tr>
<td>FD/ID/PA fan current</td>
<td>A</td>
</tr>
</tbody>
</table>

8.7.4 Test Procedure

8.7.4.1 Unit Operation- Operating Conditions of Test Runs

Test runs are conducted at an easily repeatable level at defined baseline conditions at full load with same number of mills in service and same total air levels as previous tests. The operating conditions for each test run are as follows.

i. No furnace or air heater soot blowing is done during the test.

ii. Unit operation is kept steady for at least 60 minutes prior to the test.

iii. Steam coil Air heaters' (SCAPH) steam supply is kept isolated and gas recirculation dampers if any, are tightly shut.
iv. No mill change over is done during the test.

v. All air and gas side damper positions should be checked and recorded.

vi. The test is abandoned in case of any oil support during the test period.

vii. Eco hopper de-ashing or Bottom hopper de-ashing is not done during the test.

viii. Regenerative system should be in service with normal operation.

8.7.4.2 Test Duration

The test run duration will be the time required to complete two traverses for temperature and gas analysis. Two separate test crews should sample the gas inlet and outlet ducts simultaneously.

8.7.4.3 Measurement Locations

The number and type of instruments required for conducting this test depend on the unit being tested. The following table lists the measurement locations.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Temperature</th>
<th>Gas Analyzers</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH Gas Inlet</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AH Gas Outlet</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AH Air Inlet</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>AH Air Outlet</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8.7.4.4 Traverse Locations – Gas side

i. The gas inlet traverse plane should be located as close as possible to the air heater inlet. This is done to ensure that any air ingress from the intervening duct / an expansion joint is not included in air heater performance assessment.

ii. The gas outlet traverse plane should be located as far downstream from the air preheater as possible, to allow mixing of the flow to reduce temperature and O₂ stratification. However, it should not be located downstream of other equipment or access ways that might contribute to air ingress (e.g. Mechanical collectors, ESP’s, manways, ID fans).

iii. ASME PTC 19.10 provides guidelines for the number, location and orientation of ductwork ports.
8.7.4.5 Traverse Locations – Air side

i. The air inlet traverse plane should be located after any air heating coils and as close as possible to the air heater inlet. Since the entering air temperature is usually uniform, a single probe with 2 / 3 temperature measurement points is adequate.

ii. The air outlet traverse plane should be located as far downstream from the air heater as possible to allow mixing of the flow to reduce the gas stratification.

Fig-8.7.1
8.7.4.6  **Ports and Probes**

Typical Test Port and probe sketches are provided below.

![Sketch of Ports and Probes](image)

- 6 mm dia hole for thermocouple wire tip
- Circular stiffener plates

**Fig-8.7.2**

i. Tubes numbered 1, 2 & 3 are carbon steel 3/8” OD tubes and tube no. 4 is carbon steel 12-15 mm OD

ii. Tubes numbered 1, 2 & 3 are for gas sampling while tube no. 4 is for carrying thermocouple wires for temperature measurement.

iii. Tube no. 4 has 2 no. 6 mm dia hole for thermocouple wire tip protrusion (made elliptical for ease in wire insertion)

iv. If d is flue gas duct width at the test cross-section then lengths of tube 1, 2 & 3/4 from flange is d/6 +i, d/2+i, 5d/6 +i respectively (i is the thickness of the insulation + flange).

v. Tube protrusions beyond the flange are 80 mm for tube 1 and 120 mm for tube 2 & 150 mm for tubes 3 & 4 (approx.).

vi. The probe flanges match the port flanges.

8.7.4.7  **Data Collection**

8.7.4.7.1  **Control Room Data**

A separate test log for control room data is created in unit DAS for data collection at an interval of five minutes or less and averaged over the test period.
8.7.4.7.2 Flue Gas & Air Temperatures

The online measurements of flue gas and air temperatures at air heater inlet and outlet are used for efficiency computations. It’s important to ensure that the online measurements of air and flue gas temperatures are representative of average temperatures in the duct. The online feedback of flue gas exit temperature after air heaters can be affected by gas stratification and may require more number of thermocouples than presently installed.

In some layouts, the online thermocouples for flue gas temperature measurement are mounted too close to air heaters in a cluster and need to be relocated for representative measurement. Similarly the location and number of temperature sensors on airside at air heater inlet and outlet should be reviewed to obtain a representative average.

The new locations can be decided only by doing multiple point temperature measurements in a plane perpendicular to the flow in the respective ducts. The number of measurement points is determined as per ASME PTC 19.10, 'Flue and Exhaust Gas Analysis' and would vary with duct configuration and size.

8.7.4.7.3 Flue Gas Composition

A representative value of flue gas composition ($O_2 / CO_2 /CO$) is obtained by grid sampling of the flue gas at multiple points in a plane perpendicular to the flow at air heater inlet and outlet using a portable gas analyser. Two complete sets of data are collected for each traverse plane during each test run to ensure data repeatability. A typical cross section of the flue gas duct with an 18-point grid is shown here along with a typical probe. Each dot indicates a sampling point for measurement of gas composition and temperature.(Fig-8.7.3)

![Fig-8.7.3](image)

Flue gas samples are drawn by a vacuum pump from the test grid probes and sent to a portable gas analyzer through a gas conditioning
system. Typically gas-conditioning system consists of a wash bottle, partially filled with water for cleaning the sample, a condenser to condense the water vapor out of the gas sample and a desiccant column to remove any water vapor that got through the condenser.

8.7.4.7.4 Special Test Instruments

The portable analysers should be calibrated prior to the tests with calibration gases. Purity grade Nitrogen should be used for ‘Zero’ calibration, while span calibration should be done with standard calibration gases.

The instrument accuracy requirements are summarized in the following table.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Pressure</td>
<td>2 mmWC</td>
<td>2 mmWC</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.1 deg C</td>
<td>1.0 deg</td>
</tr>
<tr>
<td>Gas Analysers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- O2</td>
<td>0.1%</td>
<td>+/- 1.0%</td>
</tr>
<tr>
<td>- CO2</td>
<td>0.1%</td>
<td>+/- 1.0%</td>
</tr>
<tr>
<td>- CO</td>
<td>1ppm</td>
<td>+/- 2%</td>
</tr>
<tr>
<td>Calibration gases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>O2</td>
<td>Around 4%</td>
</tr>
<tr>
<td></td>
<td>CO2</td>
<td>14 – 16%</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>100 to 200 ppm</td>
</tr>
</tbody>
</table>

A thermocouple (such as chromel–alumel) and digital thermometer

8.7.4.7.5 Analysis & Report

The test values can be compared with the design / PG test and historical values. The comparison can also help in detection of measurement errors, if any. The air heater gas side efficiency, air heater leakage, corrected exit gas temperature and measured exit gas temperature, gas side to air side differential pressure and gas side pressure drop can be plotted on a time line graph showing historical, design, and possibly acceptance test data.

If a significant reduction in air heater gas side efficiency occurs and operator controllable parameters (air heater soot blowing, damper adjustments, etc) are determined not to be responsible, an internal inspection of the air heater should be performed at the next available shutdown. Possible causes of performance degradation include: bypass, isolation or recirculation dampers mispositioned, air heater baskets corroded/eroded/fouled air heater baskets. A fouled air heater will experience a significant increase in gas side pressure drop. Generally, a decrease in gas side efficiency will increase the measured exit gas temperature.
Bi-sector regenerative air heaters with proper seal clearances should have leakage rates between 6% to 8% while the leakage rates for tri-sector air heaters should be between 10 - 13%. The leakage levels depend on the differential pressure between the air and gas side of the air heater, the degree of air heater pluggage and the condition of the seals. A significant increase in air heater leakage warrants a physical inspection of the air heater. Possible causes of increased leakage are axial and radial seal mechanical damage or wear; sector plate mechanical damage or warping; rotor eccentricity or excessive air to gas side differential pressure. Typically recuperative air heaters should have zero leakage, but tube failures due to corrosion or mechanical damage can result in leakage. If the unit is equipped with bypass dampers or recirculation dampers, they should also be inspected. Generally, an increase in air heater leakage will cause a decrease in the measured exit gas temperature.

All test instrument readings should be compared to station instrument readings to determine if any station instruments need calibration / up gradation.

The economic impact of increased air heater leakage is typically reflected in increased station service power consumption of FD and ID fans. In extreme cases unit de-rating may be caused due to insufficient fan capacities.

The results should include a narrative describing any unusual findings, plots of performance indices on a time line graph showing historical, design and/or acceptance test data with analysis of variations, if any, and the test data listed in a tabular form.

8.7.4.7.6 Measurement of Flue gas Oxygen and Temperature at ESP Inlet and ID fan Outlet

Air ingress from eroded ducts, openings, and expansion joints increases the flue gas volume and leads to loss of draught margins. Increase in oxygen percentage in the flue gas and drop in temperature of the flue gas provides an indication of the increase in air ingress.

Along with the air heater tests, the oxygen in flue gas at ESP inlet and ID fans’ outlet is measured separately in each duct and compared to the average oxygen in flue gas at air heater outlet. Air ingress quantification is done with the same formulae as those used for calculation of AH leakage.

\[
\text{Air ingress} = \frac{O_{2\text{out}} - O_{2\text{in}}}{21 - O_{2\text{out}}} \times 0.9 \times 100 = \frac{6.5 - 5.7}{21 - 6.5} \times 90 = 4.96 \%
\]
8.7.5 References

ASME PTC 4.3 Air Heaters
ASME PTC 19.10, Flue and Exhaust Gas Analysis
8.7.6 Annexure I - AH Performance Indices Computation

1. **Air heater leakage** is determined by an empirical approximation as following.

\[
AL = \frac{(CO_{2e} - CO_{2gl})}{CO_{2gl}} \times 0.9 \times 100
\]

- \(AL\) = air heater leakage (%)
- \(CO_{2e}\) = percent \(CO_2\) in gas entering air heater
- \(CO_{2gl}\) = percent \(CO_2\) in gas leaving air heater

\(CO_2\) measurement is preferred due to high absolute values; In case of any measurement errors, the resultant influence on leakage calculation is small. Alternatively, the air heater leakage may also be determined from the following equation:

\[
AL = \frac{(O_{2gl} - O_{2ge})}{(21 - O_{2gl})} \times 0.9 \times 100
\]

\(AL\) = air heater leakage (%)
- \(O_{2ge}\) = percent \(O_2\) in gas entering air heater \((2.8\ %)\)
- \(O_{2gl}\) = percent \(O_2\) in gas leaving air heater \((5.7\ %)\)

\[
= \frac{5.7 - 2.8}{21 - 5.7} \times 90 = 17.1\%
\]

The numerical average of the air heater’s gas inlet, gas outlet and air inlet temperatures is calculated. Then the corrected air heater gas outlet temperature is calculated using the following formula.

\[
T_{gnl} = \frac{AL \times C_{pa} \times (T_{gl} - T_{ae}) + T_{gl}}{100 \times C_{pg}}
\]

- \(T_{gnl}\) = gas outlet temperature corrected for no leakage
- \(C_{pa}\) = the mean specific heat between \(T_{ae}\) and \(T_{gl}\)
- \(T_{ae}\) = temperature of air entering air heater \((36.1\ C)\)
- \(T_{gl}\) = temp of gas leaving air heater \((133.8\ C)\)
- \(C_{pg}\) = mean specific heat between \(T_{gl}\) and \(T_{gnl}\)

\[
T_{gnl} = \frac{17.1 \times (133.8 - 36.1) + 133.8}{100} = 150.5\ C
\]

2. The **gas side efficiency** is defined as the ratio of the temperature drop, corrected for leakage, to the temperature head, expressed as a percentage. Temperature drop is obtained by subtracting the corrected
gas outlet temperature from the gas inlet temperature. Temperature head is obtained by subtracting air inlet temperature from the gas inlet temperature. The corrected gas outlet temperature is defined as the outlet gas temperature calculated for 'no air heater leakage'.

Gas Side Efficiency (GSE) = \( \frac{\text{Temp drop}}{\text{Temperature head}} \times 100 \)

\[
\begin{align*}
\text{GSE} & = \frac{\text{Tge} - \text{Tgnl}}{\text{Tge} - \text{Tae}} \times 100 \\
\text{Tae} & = \text{Temperature of air entering air heater (36.1 C)} \\
\text{Tgnl} & = \text{gas out temp corrected for no leakage (150.5 C)} \\
\text{GSE} & = \frac{(333.5-150.5)}{(333.5-36.1)} \times 100 = 61.5 \%
\end{align*}
\]

3. **X ratio** is the ratio of heat capacity of air passing through the air heater to the heat capacity of flue gas passing through the air heater and is calculated using the following formulae

\[
\begin{align*}
&= \frac{\text{Wair out} \times \text{Cpa}}{\text{Wgas in} \times \text{Cpg}} \\
&= \frac{\text{Tgas in} - \text{Tgas out (no leakage)}}{\text{Tair out} - \text{Tair in}} \\
&= \frac{(333.5 - 150.5)}{(288 - 36.1)} = 0.73
\end{align*}
\]

(*AH leakage – 17.1%, Gas In Temp – 333.5 C, Gas Out Temp – 133.8 C, Air In Temp – 36.1 C, Air Out Temp – 288 C*)