Experiences with Regenerative Air Heater Performance Evaluations & Optimization

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Introduction

The Air heater accounts for ~10% of a unit’s thermal efficiency and is a critical component of combustion system. Air heater leakage has a major impact on overall plant performance and therefore the intent of this paper is to focus on 3 areas:

1. Evaluating Air Heater Performance
2. Evaluating the Impact of the APH on the Combustion Process and Overall Unit Efficiency
The Airheater impacts the efficiency of most plant equipment

- FD Fans
- ID Fans
- Pulverizers
- Burners
- Precipitators
- Bag houses
- Boiler Operation
- Environmental Equipment (SCR, FGD)
Evaluating Air Heater Performance

- Air heater leakage can occur from different paths.
- Path 1: Normal air flow path
- Path 2: Normal gas flow path
- Path A: Ambient FD fan leaking directly to the APH Gas Outlet
- Path B: Pre-heated FD fan air flow short circuiting the APH
- Path C: Ambient FD fan air leaking around air heater.
- Path D: Hot gas exiting boiler

Leakage paths through a regenerative air heater
Gases Leaking Past the Seals

Bypass Seal Leakage passing around the APH into the warm air flow

Bypass Seal Leakage passing the axial seals into the gas flow

Hot Radial Seal Leakage

Cold Radial Seal Leakage

Circumferential leakage through an air heater
Sample Grid Considerations

- Test grid should be reasonably spaced with 1 point per 0.6 – 0.8 square meters (or 7-9 per sq ft)
- More test points do not substitute for insufficient number of test ports.
Non-Uniform Test Grid

- Additional test points needed if suspected of more than average leakage near radial seals or expansion joints.
- The additional points may need to represent a smaller area.

Example of a Non-Uniform Test Grid Near an Air Heater Radial Seal
Measuring Air Heater Leakage

- Air In-Leakage calculation:
  \[
  \text{Leakage} \, (\%) = \frac{O_{2,\text{Out}} - O_{2,\text{In}}}{20.9 - O_{2,\text{Out}}} \times 90
  \]

- Corrected gas outlet temperature:
  \[
  T_{\text{Gas Out Corrected}} = \frac{\% \text{Leakage} \times C_{p,\text{Gas}} \times (T_{\text{Gas Out}} - (60\% \times T_{\text{Air In}} + 40\% \times T_{\text{Gas Out}}))}{C_{p,\text{Gas}}} + T_{\text{Gas Out}}
  \]

- Heat transfer efficiency:
  \[
  \text{Heat Transfer Efficiency} = \frac{C_{p,\text{Air}} \times (T_{\text{Air Out}} - T_{\text{Air In}}) \times \text{Air Mass Flow}}{C_{p,\text{Gas}} \times (T_{\text{Gas In}} - T_{\text{Gas Out Corrected}}) \times \text{Gas Mass Flow Less Leakage}}
  \]

- Fan efficiency:
  \[
  \text{Power Consumption} = \frac{\text{Flow (ACFM)} \times \text{Static Pressure ("w.c."ера)}}{6356 \times \text{Fan Efficiency} \times \text{Motor Efficiency}} \text{ HP}
  \]
Measuring Air Heater Leakage

- Approximate leakage rates:

\[ Q = C_d A \left[ \frac{2 \Delta \rho}{\rho} \right]^{0.5} \]

- Equation designed to calculate flows through large defined shape openings.
- Provides closer approximation than traditional Crack Flow Equations.
Measuring Air Heater Performance

- Need to know the following:
  - Temp in and out both air sides
  - $O_2$ before and after gas side
  - Air and gas flows before and after air heater
- Velocity heads need to be measured

- Static Pressure
  1, 2, 3, 4
- Velocity Head
  2, 3, 4
- Oxygen Concentration
  3, 4
- Temperature
  1, 2, 3, 4

Testing Locations
Theoretical vs. Measured Airflow

Theoretical airflow vs. Actual combustion airflow audits should be considered

Theoretical Airflow vs. Measured Air at 15% Excess Air

Theoretical vs. Measured Airflow on a 460 MW unit
Direct Effect of the APH on Fuel Consumption and CO$_2$ Emissions

- Air heater responsible for at least 10% of a unit's thermal efficiency
- Excessive leakage can deteriorate net unit efficiency as well as reduce power generation
- Air Heater Performance correlates directly with excess CO$_2$ emissions
Design Considerations

(5) Key Points:

1. Leakage Reduction
2. Power Savings
3. Erosion & Abrasiveness
4. Corrosion
5. Heat Transfer
Air Heater Leakage

- Major drawback of regenerative air heater
  - Undesired leakage inherent to design
  - Difficult to seal
  - Inherent thermal distortion

Blue = Cold Condition of Rotor

Yellow = Hot Condition of Rotor

Hot End of Rotor

Cold end of Rotor

Leakage Path (HOT)

Thermal Turn-down
Leakage Solutions

- Replace original seals with newer high performance radial seals
- Reinforce circumferential/bypass seals
Leakage Solutions

DuraMax™ Radial Seal

GROWTH
Leakage Solutions

DuraMax™ Radial Seal

Continuous Contact DURAMAX Seal (before & after sector plate contact)
OEM Circ/Bypass Seal

Air Flow

Leakage occurs through the gaps on the OEM Seals.
Leakage Solutions

DuraMax™ Radial Seal

DURAFLEX Circumferential Seal

Original Style Circumferential Seal
Leakage Reduction Case History

The following case history illustrates the positive benefit of leakage reduction accomplished with full contact radial seals. A reduction in induced draft fan amperage of over 23% was achieved with full contact DuraMax seals at the AEP Welch Station, a 500MW coal fired plant in Texas, USA.

<table>
<thead>
<tr>
<th>FAN</th>
<th>Before (AMPS)</th>
<th>After (AMPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A ID FAN</td>
<td>572</td>
<td>459</td>
</tr>
<tr>
<td>3B ID FAN</td>
<td>691</td>
<td>468</td>
</tr>
<tr>
<td>3A FD FAN</td>
<td>131</td>
<td>125</td>
</tr>
<tr>
<td>3B FD FAN</td>
<td>128</td>
<td>113</td>
</tr>
</tbody>
</table>

23% Reduction in total fan amps with full contact radial seals
Air Heater Leakage

Power Consumption vs Volumetric Flow

- Power Consumption (%)
- Volumetric Flow (%)
Design Considerations

- Erosion / Abrasiveness
- Ash Velocity
- Turbulence
- Basket Element Type

Basic erosion equation: $Erosion\ Equation = C_x M_x V^n$
Design Considerations

- **Reducing Air Heater Outlet Gas Temperature**
  - Recommended air heaters operated at low exit gas temp
  - Cold end element layer is intended as sacrificial layer

- **Increased Element Depth**
  - Added during basket replacement
  - Supplier calculate temperature changes

- **Environmental Control Equipment Relationships to Consider**
  - SCR Performance
  - ABS plugging
  - ESP Velocity
  - FGD Performance