Effect of Air In Leakage on Heat Rate

EPRI Heat Rate Improvement
Atlanta, GA

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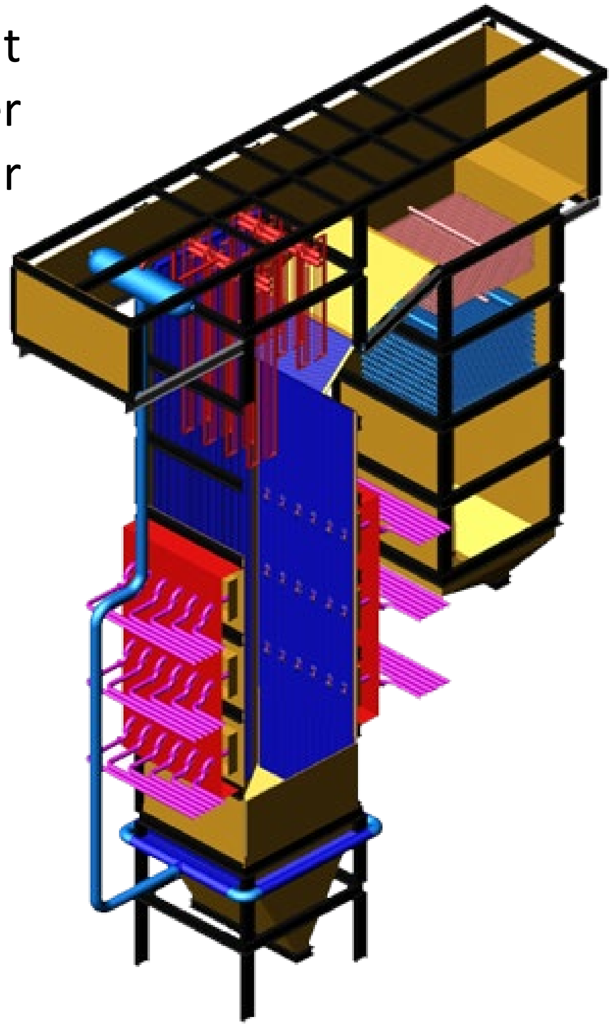
Outline

- Introduction to Air In Leakage
- Typical Sources of Air In Leakage
- Air in Leakage Detection Techniques
- Air In Leakage Field Test Results
- Conclusion

Introduction – What is Air In Leakage?

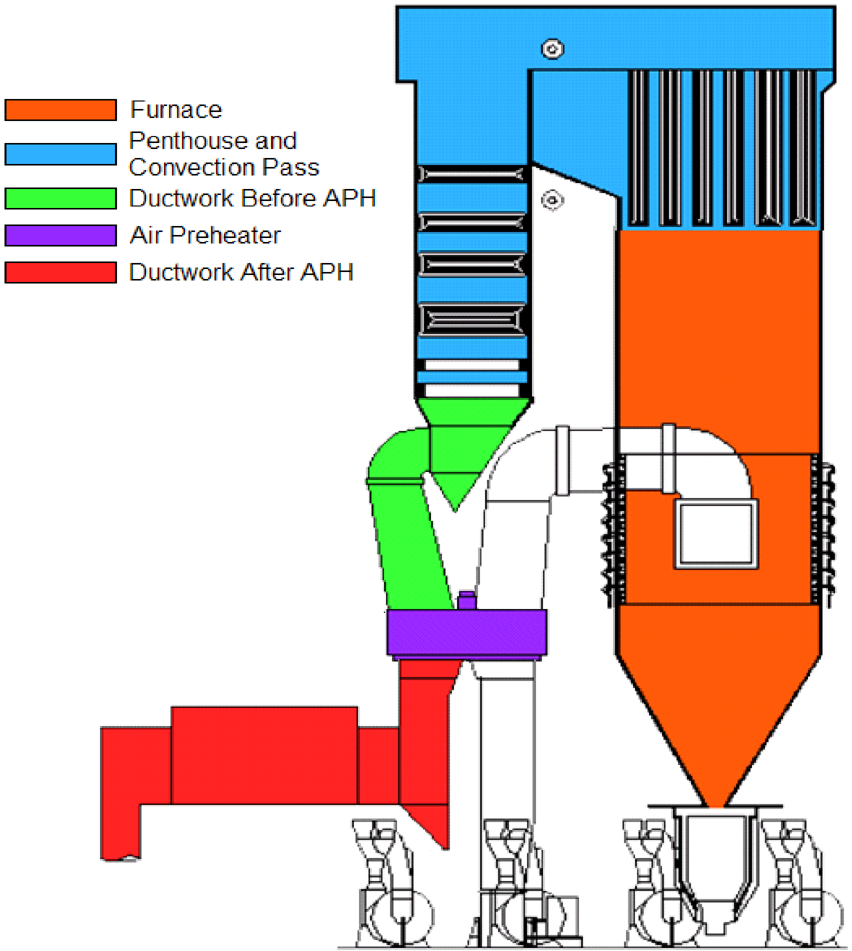
- Air that leaks into the gas stream absorbs heat that would otherwise be given up to the boiler or other surface (i.e. SH, RH, Economizer, APH). Tramp air infiltration can negatively impact the following:
  - Efficiency/Heat Rate
  - APH Performance
  - Fan Capacity
  - ESP/Baghouse Performance
  - Unit Load



Where Does Air In-Leakage Occur?

- **Location plays a large part of how much the leakage contributes to efficiency decreases and heat rate penalties.**

- **The main areas for leakage are**
  - Main Furnace up to the first pendants
  - Penthouse and convection pass(includes SH and RH)
  - Ductwork after economizer but before the APH
  - APH
  - Ductwork after the APH up to the ID Fan

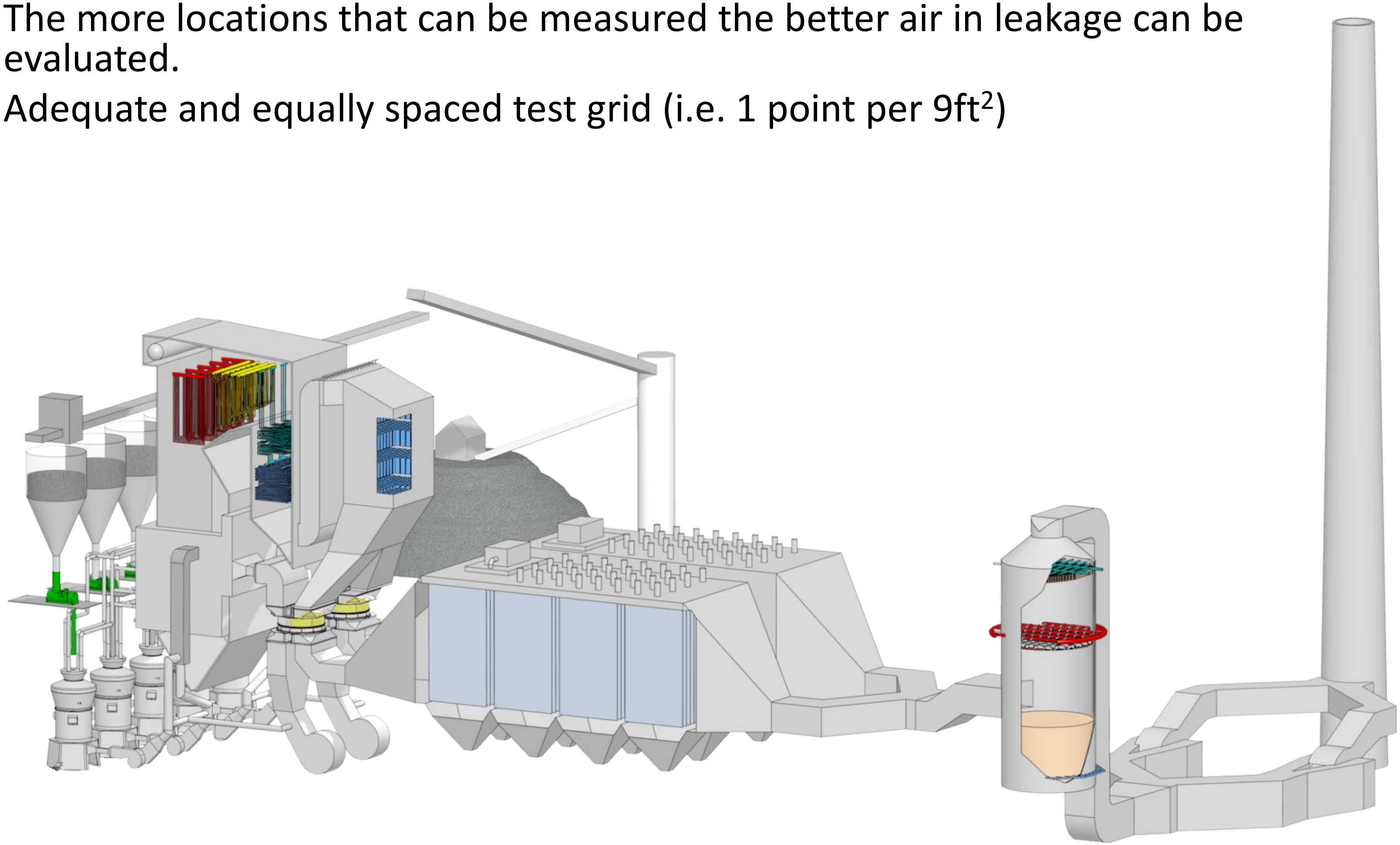


Air in Leakage Test Methods

- **Online Methods**
  - Excess oxygen rise (preferred)
  - Smoke tests and external inspections
  - Infrared thermal imaging
  - Audible methods
  - Plant indications
- **Offline Methods**
  - Internal crawl through inspections (preferred)
  - Smoke tests

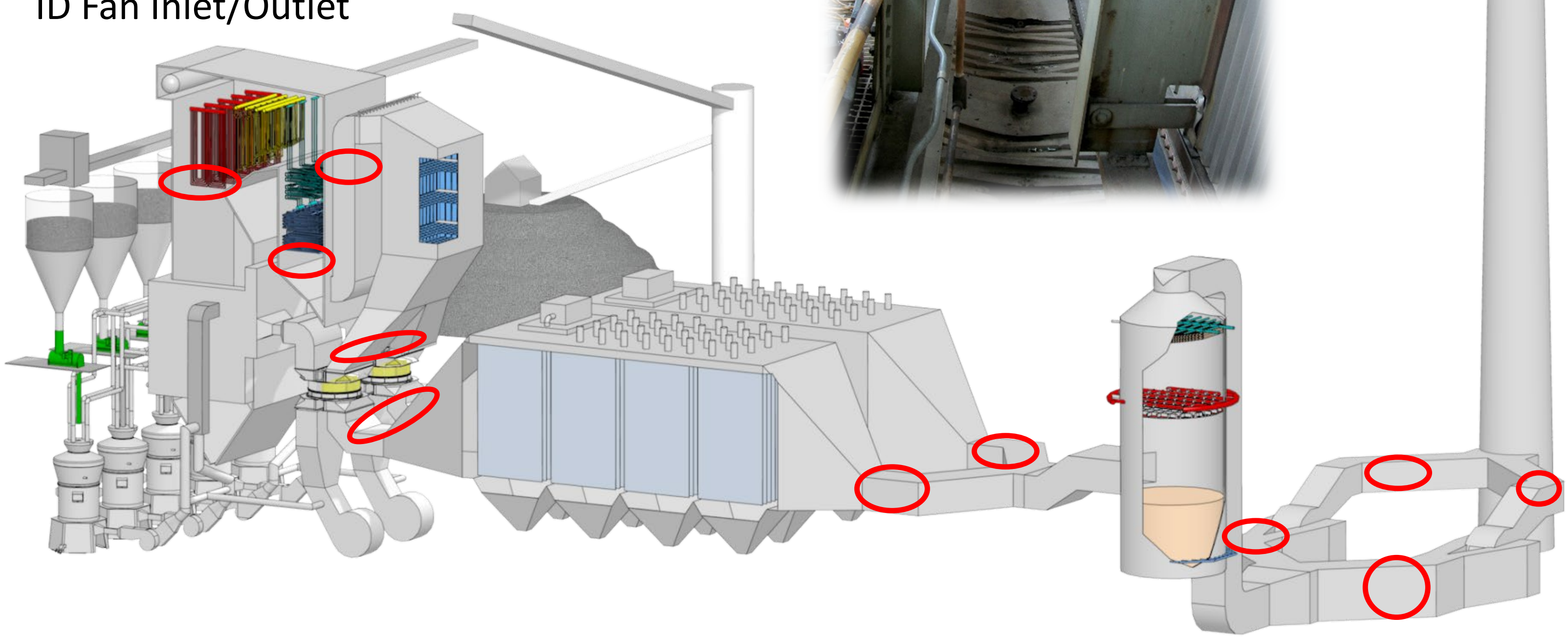
Air in Leakage Measurement

- The more locations that can be measured the better air in leakage can be evaluated.
- Adequate and equally spaced test grid (i.e. 1 point per $9ft^2$)



Air in Leakage Measurement

- Typical measurement locations
  - Furnace exit
  - Economizer exit
  - SCR Inlet/Outlet
  - APH Inlet/Outlet
  - ESP/Baghouse Inlet/Outlet
  - Scrubber Inlet/Outlet
  - ID Fan Inlet/Outlet



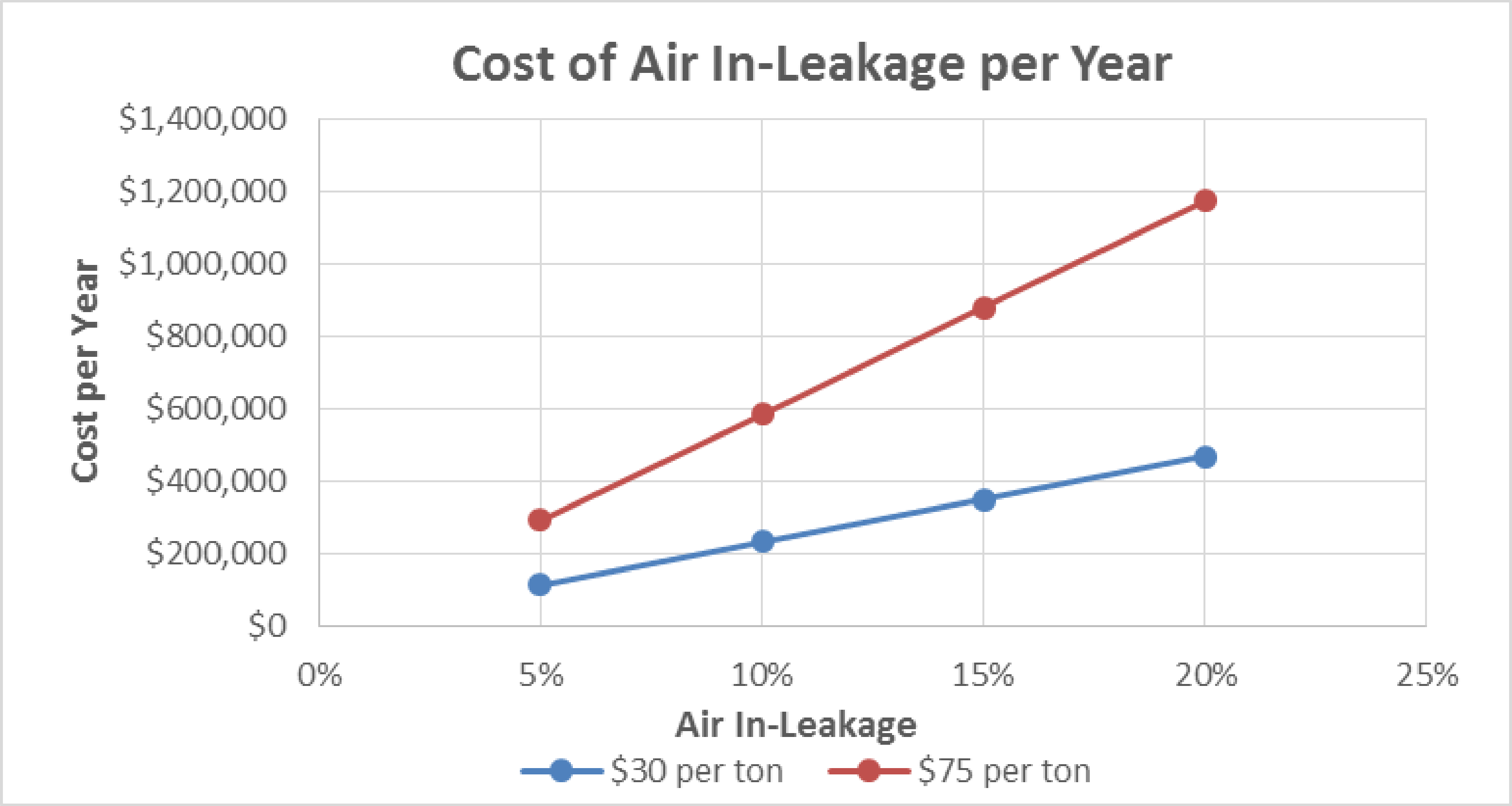
Typical Heat Rate Impact from Leakage

- Storm typically finds that air in leakage throughout the boiler can directly account for approximately 300 Btu/kWhr of heat rate penalties.
- Indirect heat rate penalties can exceed the 300 Btu/KWhr.

		Controllable Variable Quantities
Reduction of Air In-Leakage (Before APH)	Interrelated	240 Btu/kWh
Reduction of Dry Gas Loss		
Reduction of Coal Rejects		40 Btu/kWh
Reduction of Air Heater Leakage		60 Btu/kWh
Reduction of Carbon in Ash		100 Btu/kWh
Reduction of De-Superheating Spray Water Flows		60 Btu/kWh
Achieve By:		
-Primary Airflow Optimization		
-Pulverizer Optimization and Improved Fuel Line Balance		
Total		500 Btu/kWh

Increased Fuel Costs from Leakage

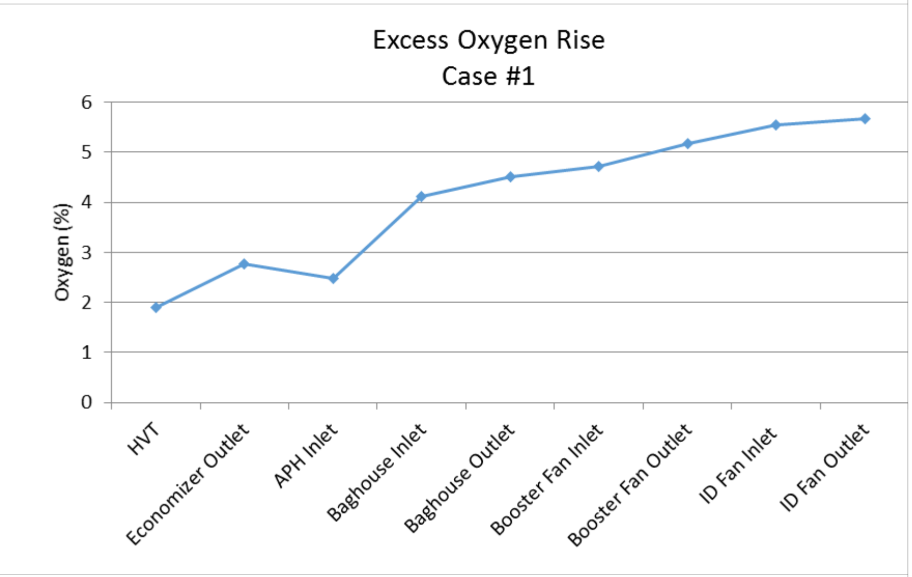
- Example of additional fuel costs required to heat ambient air to the air heater outlet temperature
  - Based on 500 MW, 80% capacity factor, 10,000 Btu/kWhr heat rate, 11,000 Btu/lb HHV

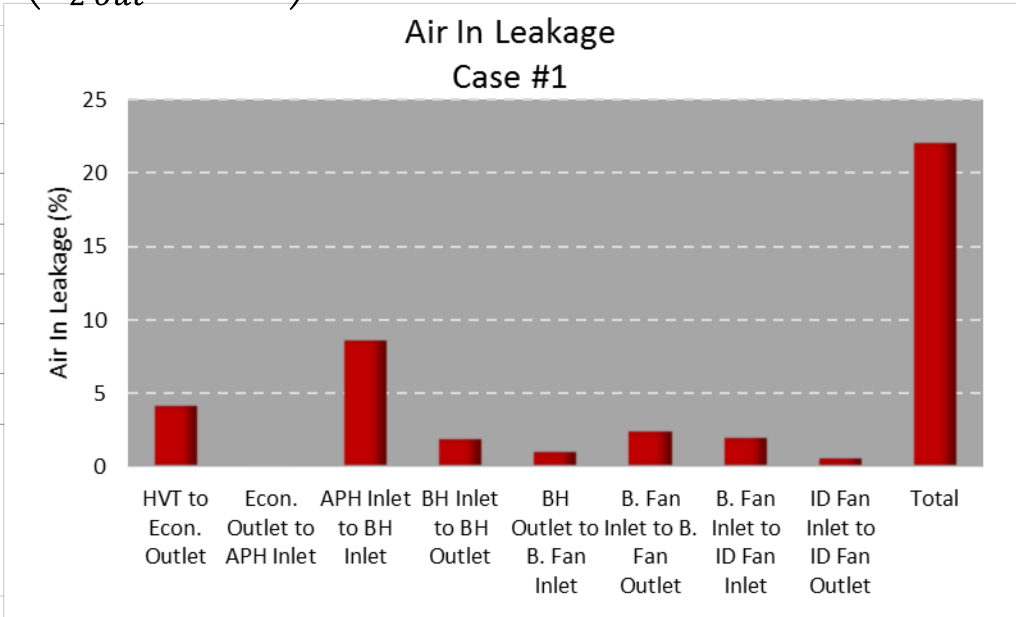


Air in Leakage Testing Case #1

- Measurement Locations
  - Furnace Exit
  - Economizer Outlet
  - APH Inlet
  - Baghouse Inlet
  - Baghouse Outlet
  - Booster Fan Inlet
  - Booster Fan Outlet
  - ID Fan Inlet
  - ID Fan Outlet

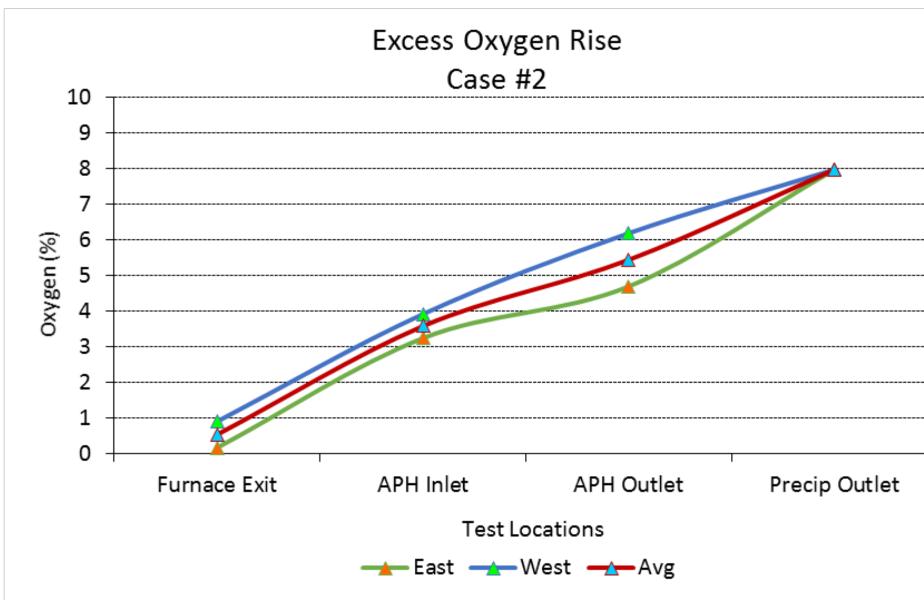
$$Air\ In\ Leakage\ (\%) = \left(\frac{O_{2\ in} - O_{2\ out}}{O_{2\ out} - 20.9}\right) \times 90$$

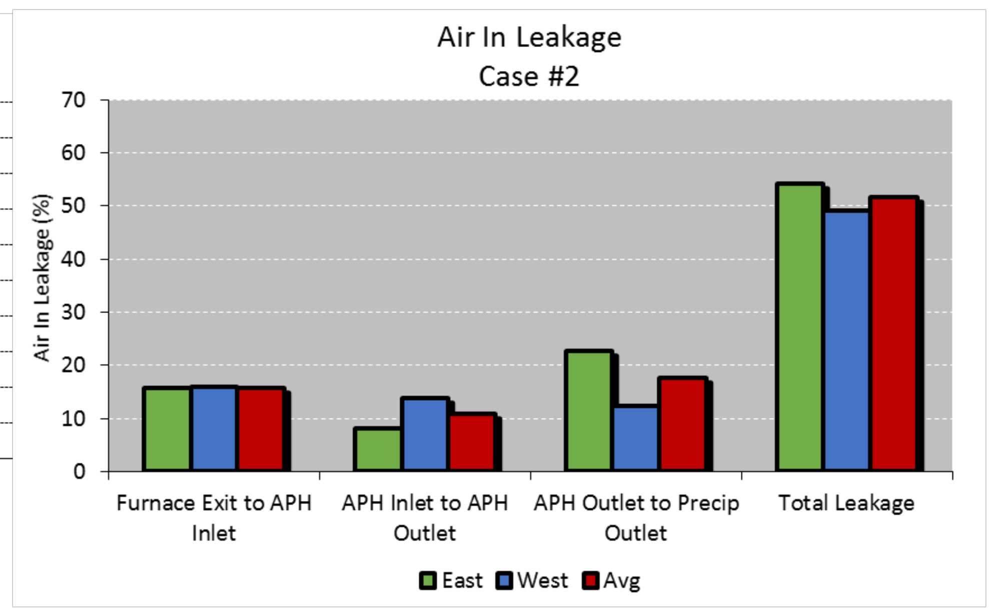




Air in Leakage Testing Case #2

- Measurement Locations
  - Furnace Exit
  - APH Inlet
  - APH Outlet
  - Precip Outlet
- Average of ~50% air in leakage
- **~16% Air In Leakage from Furnace to APH Inlet!**
- Unit was de-rated due to ID fan limitations



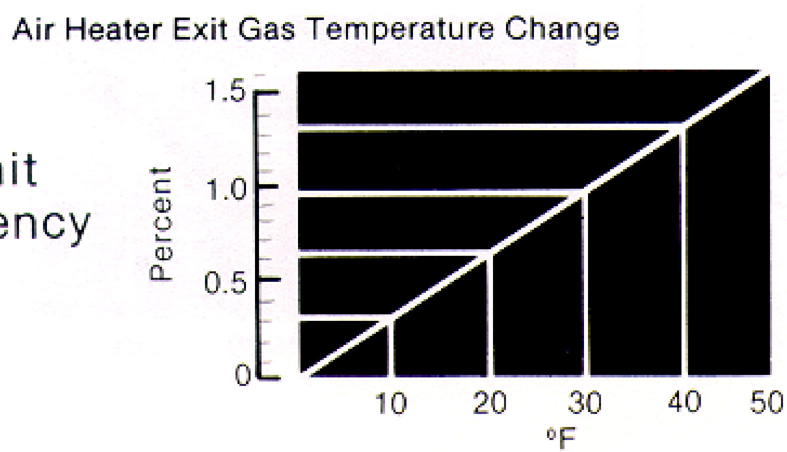


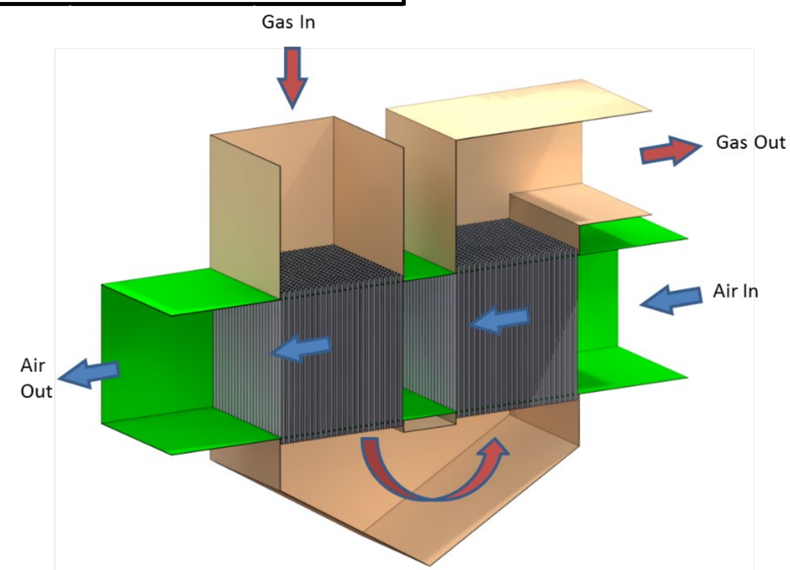
Air In Leakage Case #3

- Measurement Locations
  - APH Inlet
  - APH Outlet
- Corrected gas outlet temperature decreased 53 deg. F.

Year	Percent Leakage	Exit Gas Temperature*	Corrected Exit Gas Temperature**	Gas Side Efficiency	X-Ratio
2016	1.40%	337	340	65.30%	0.75
2015	26.30%	337	393	56.72%	0.65
*measured value with leakage					
**calculated value without leakage					

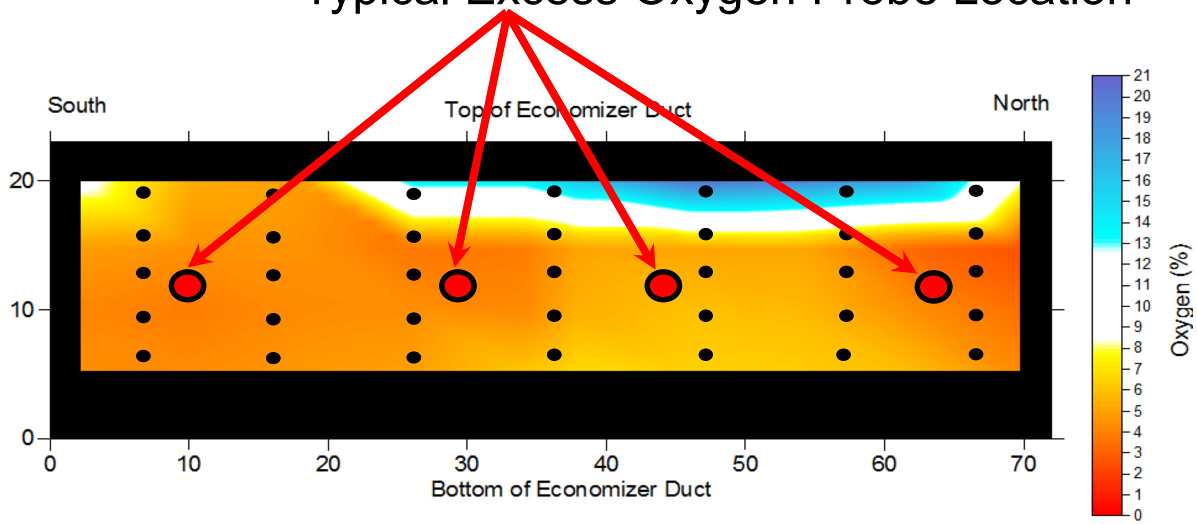
Effect On Unit Efficiency

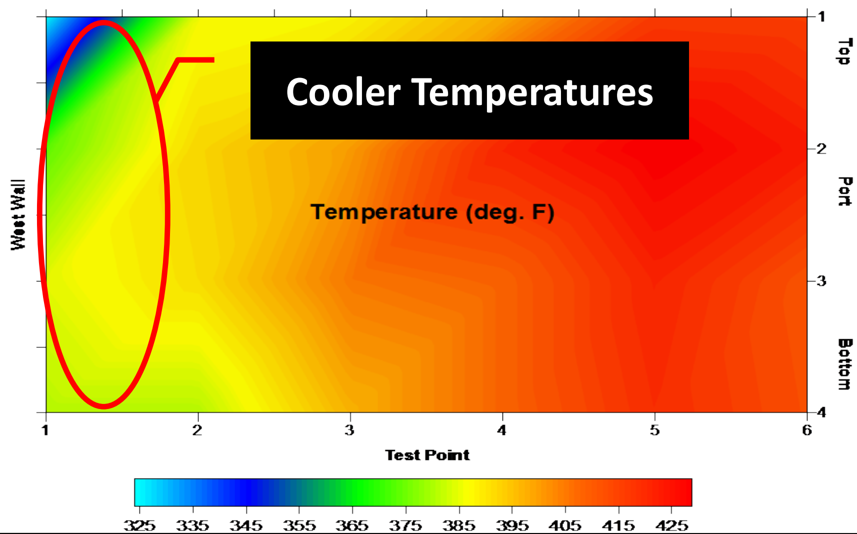


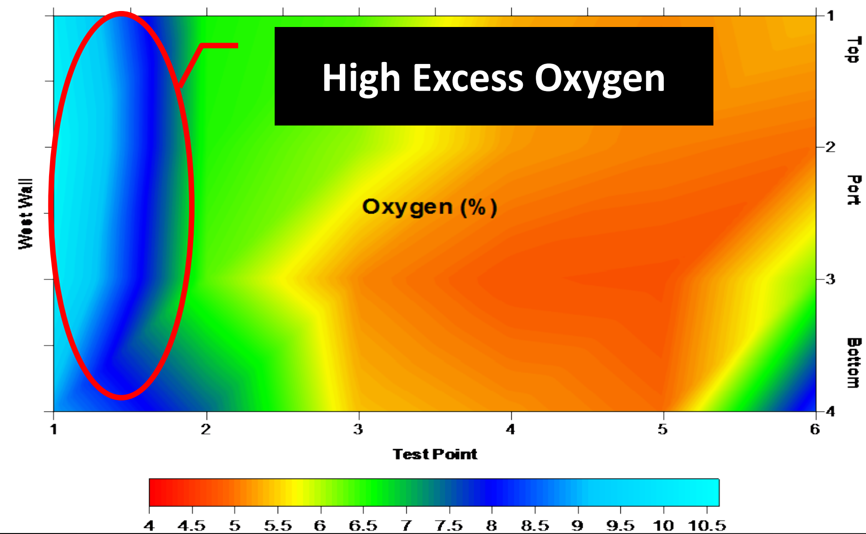


Importance of Point by Point Mapping

Typical Excess Oxygen Probe Location





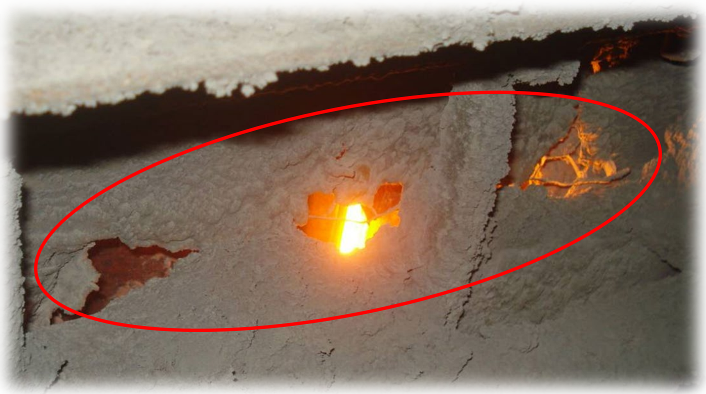


External Inspections

Furnace

Economizer Ash Hoppers

ESP Outlet duct



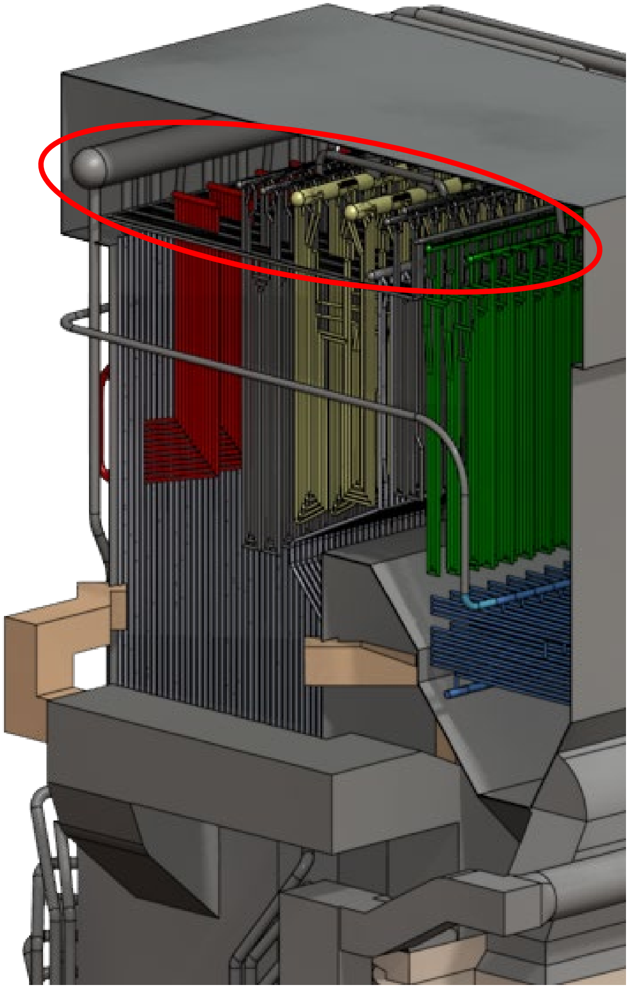
Furnace casing

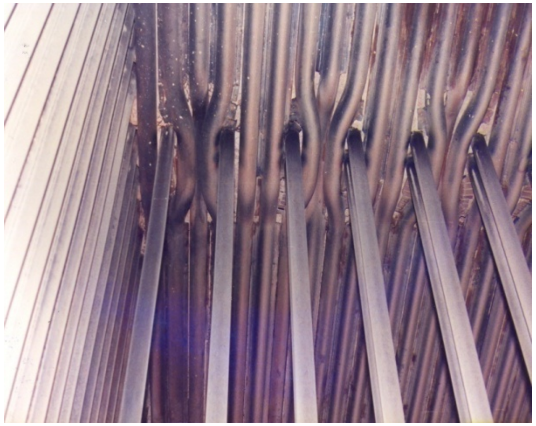
Internal Inspections

Lower Ash Hopper Damaged Seal (Due to In-Adequate Water Flow & Ash Build Up)

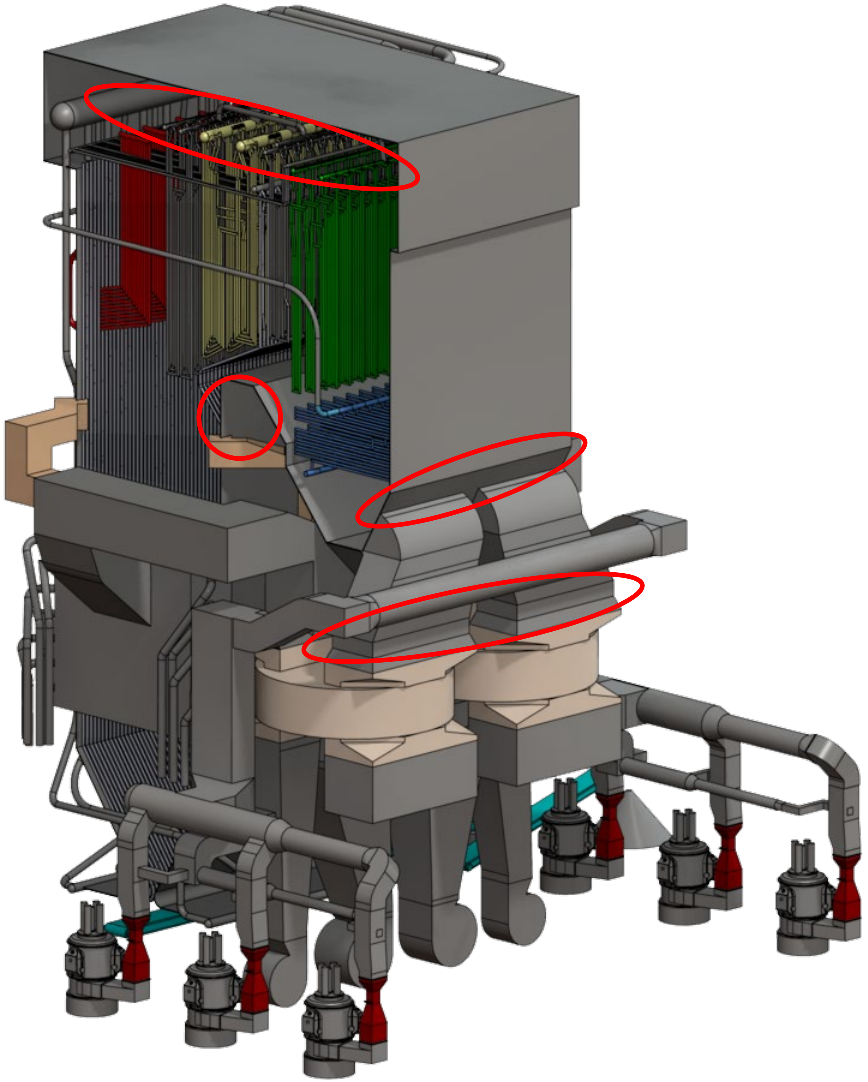
Lower Ash Hopper Seal Damage and Water Seal Damage Caused by Expansion

Internal Inspections



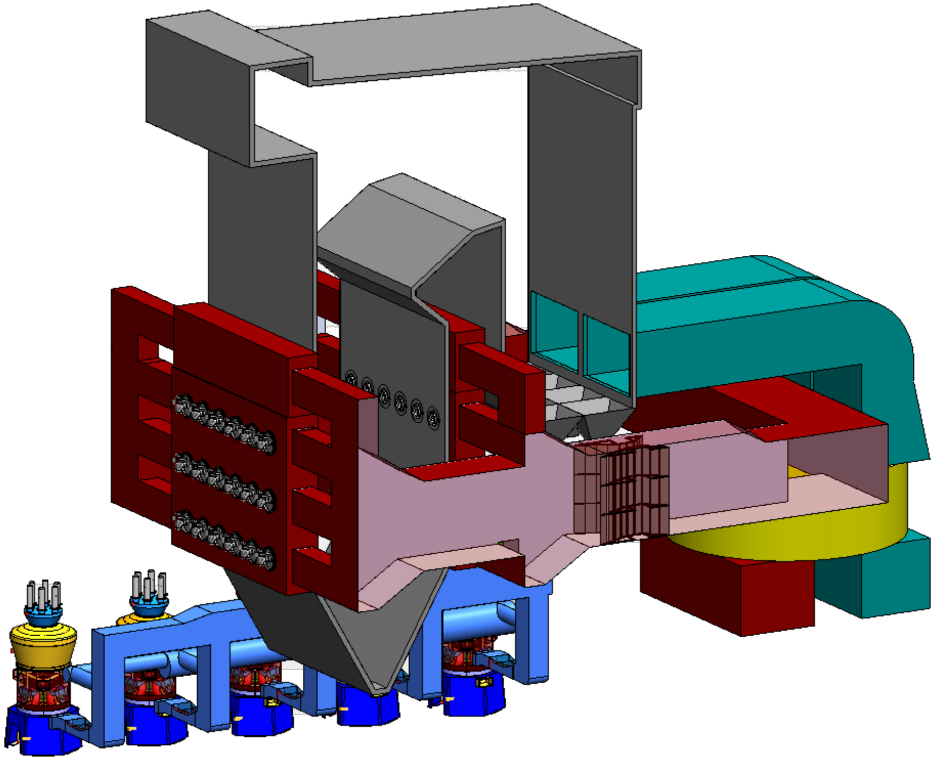


Internal Inspections



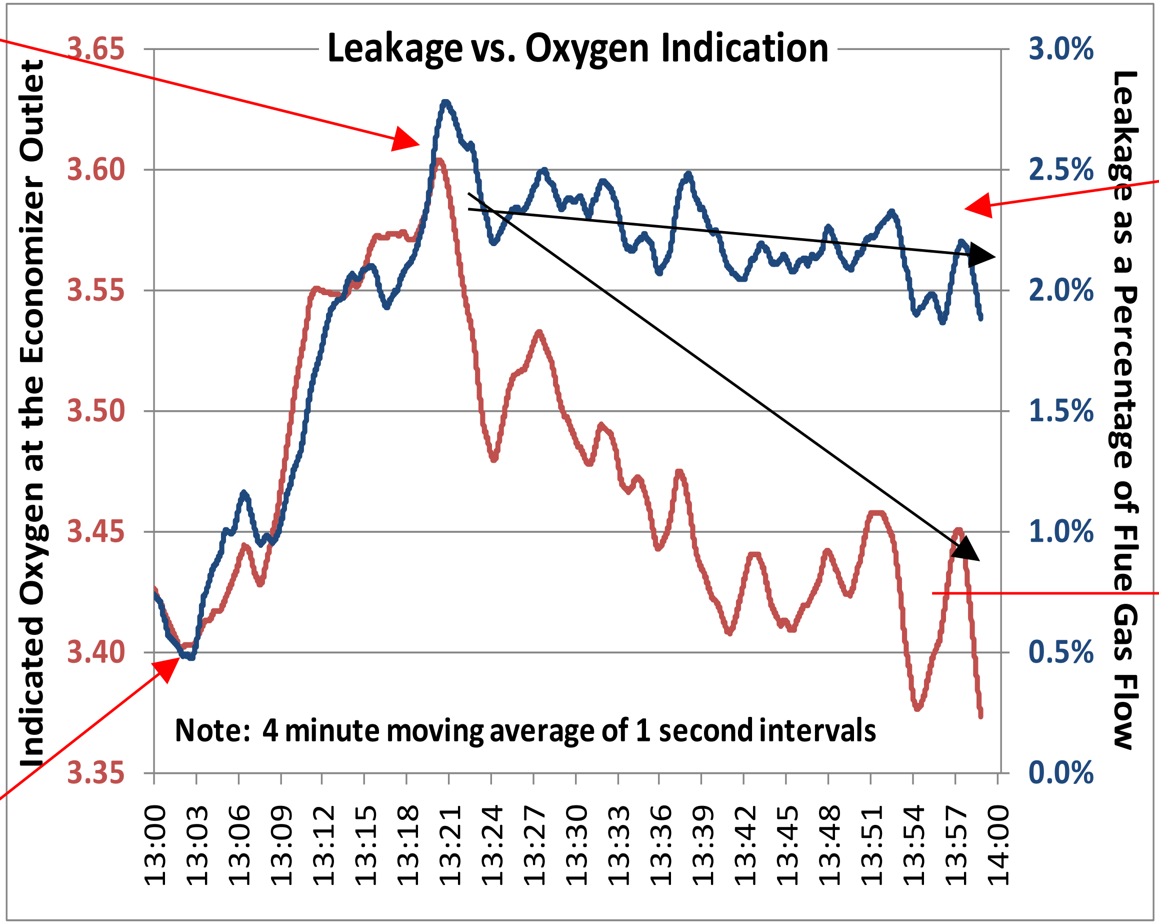
Online Air In Leakage Detection

- Accurate airflow measurement and excess oxygen measurement
  - Total secondary airflow measured within 3% of actual flow with total left and right venturis
  - Primary airflow measured within 3% of actual to each of the five pulverizers with venturis
  - Excess oxygen measured with 8 excess oxygen probes
  - Fuel flow measured via calibrated gravimetric feeders
  - Theoretical air calculation based off of given fuel constituents and excess oxygen curve



Online Leakage Monitoring

Airflow into the unit stabilizes



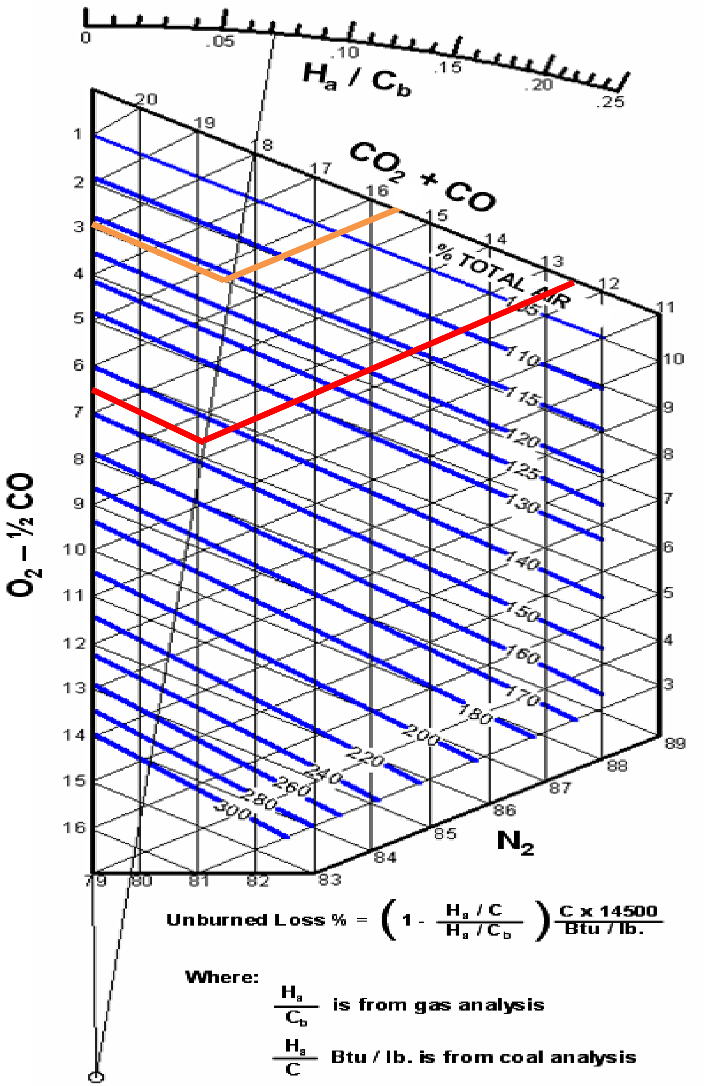
Leakage indication remains relatively constant despite a reducing excess O_2

Oxygen trim "pulls" air out of the unit to return to the set-point

Observation Doors Opened

Accurate measurement of total air flow and excess oxygen at the economizer outlet is required!

Online Leakage Monitoring



- Evaluate oxygen rise between economizer outlet and stack
  - Utilize economizer outlet excess oxygen probes & stack CO_2 along with volumetric flue gas chart

Example:

Average excess oxygen probe indication = 3% ≈ 115% Theoretical Air

Stack CEMS CO_2 indication = 12.5% ≈ 145% Theoretical Air

$$Air\ In\ Leakage\ (\%) = \left(\frac{O_{2\ in} - O_{2\ out}}{O_{2\ out} - 20.9}\right) \times 90 = 21.9\%$$

GENERAL DATA

S.F.	
A.F.	

FUEL ANALYSIS

H	
O	
C	
Btu / lb.	
H_a / C	

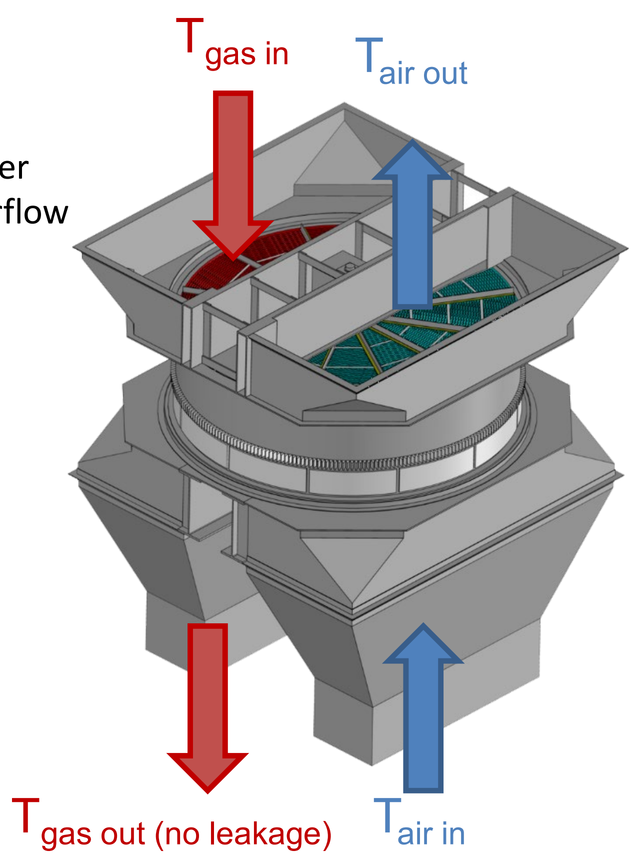
Online Leakage Monitoring

- Air Heater X-Ratio Monitoring
  - X-Ratio is the ratio of the heat capacity of the air flowing through the air heater as compared to the heat capacity of the flue gas

$$X\ Ratio = \left(\frac{T_{gas\ in} - T_{gas\ out\ (no\ leakage\ basis)}}{T_{air\ out} - T_{air\ in}} \right)$$

  - Tramp air in leakage into the boiler affects the X-ratio of the air heater
    - Increases ratio of flue gas through the air heater versus airflow through the air heater
    - Increases the corrected air heater exit gas temperature

Year	Percent Leakage	Exit Gas Temperature*	Corrected Exit Gas Temperature**	X-Ratio
2016	1.40%	337	340	0.75
2015	26.30%	337	393	0.65
*measured value with leakage				
**calculated value without leakage				



Boiler Efficiency Testing

- Improvement in boiler efficiency can lead to improved heat rates
- Air in leakage upstream of the air heater is a stealth heat rate penalty
- PTC 4.0 does not take this air in leakage into account

$$Dry\ Gas\ Loss = 100 \times MqDFgi \times HdFgLvCr$$

Where:

$$Dry\ Flue\ Gas\ Weight\ Entering\ APH\ (MqDFgi) = (MqDAi + MqWAi + MqFgF + MqWAdz) - MqWFgi$$

$$Quantity\ of\ Dry\ Air\ Entering\ APH\ (MqDAi) = MqThACr \times \left(1 + (XpAi/100)\right)$$

$$Percent\ Excess\ Air\ (dry\ basis)\ Entering\ APH(XpAi) = 100 \times \frac{DVpO2i \times (MoDP + 7.905 \times MoThACr)}{\left(MoThACr \times (20.95 - DVpo2i)\right)}$$

Excess oxygen measured at the APH Inlet

Conclusions

- Excess air in leakage can impact heat rate in multiple ways
  - Decreases heat transfer to the working fluid due to heating of ambient air
  - Increases volume of flue gas which affects ID fan
    - This can increase auxiliary power usage
  - Reducing atmospheres created by air in leakage can lead to
    - Increased spray flows, slagging, decreased reliability, poor LOI's, etc.
- Point by point mapping has proven over the years to be a very effective way of evaluating air in leakage
- Evaluating air in leakage on an annual basis will help plants identify potential problem areas early to minimize heat rate impact and repair costs.

Thank You

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