# Boiler Energy Efficiency: Opportunities and Case Studies

Aqeel Zaidi
Union Gas

Dan Valente
Vexco Corp

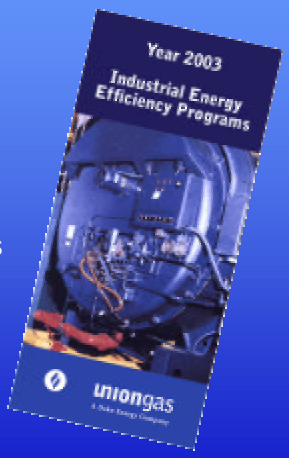
Low NOx Boilers, Burners and Boiler Efficiency Workshop
November 13, 2002

## *Outline*

- Union Gas Boiler Performance Testing Program
- As-found key results
- Major energy saving opportunities based on as-found tests
- Two case studies (Dan Valente)

# Boiler Performance Testing Program

- Major component of Union Gas Industrial Energy Efficiency Program
- Boiler Program Scope:
  - Determine boiler operating efficiencies
  - Identify and quantify energy and cost saving opportunities
  - Establish implementation costs and paybacks
  - Measure NOx and CO emissions






# Boiler Performance Testing Program

- How Program Works?
  - Customer and Union Gas develop site-specific scope of work
  - Select a qualified consulting engineer
  - Conduct on-site testing at various firing rates, using portable flue gas analyzers provided by Union Gas

# *Boiler Performance Testing Program* *(cont'd)*

- How Program Works?
  - Conduct a walk-through audit of steam plant
  - Analyze data to meet project scope
  - Comment on safety and reliability
  - Submit report
  - Present key results to customer team including senior management in a 1 to 2 hr presentation



# *Boiler Performance Testing Program*

- How Much Does it Cost?
  - Union Gas pays 2/3rd of consultant's cost, to a maximum contribution of $20,000
  - Customer pays the balance
  - Union Gas provides instruments and services of a technical representative on complimentary basis

## Boilers Tested

- 70 boilers tested since 1999
- Size range: 10,000 pph – 450,000 pph (50 boilers over 50,000 pph)
- Types: Package fire-tube, water-tube, field erected power boilers
- Fuels: natural gas, #6 fuel oil, woodwaste, sludges, coal, fuel gas



## As-found Key Results

| Parameter | Minimum | Maximum |
|---|---|---|
| Excess O2 (%) | 0 | 19 |
| Stack Temp (F) | 100 | 585 |
| CO (ppm) | 0 | Over 5000 |
| NOx (ppm) corrected to 3% O2 | 23 | 292 |
| Boiler Efficiency Stack loss method (%) | 62 | 89 |
| Boiler Efficiency Input/output method (%) | <60 | >100 |

## *As-found Major Energy Saving Opportunities*

- Improve combustion efficiency by reducing stack losses and improving combustion
- Recover waste heat from flue gases
- Improve balance of steam plant operation



## *Improve Combustion Efficiency*

- Reduce excess O2 to achieve optimum air/fuel ratio
- Reduce flue gas temperature
- Increase combustion air temperature
  - Consider air pre-heater
  - Draw air from a high point in the boiler room
- Reduce CO and unburnt Hydro-carbons
  - Optimize air/fuel mixing and air/fuel ratio

# Reduce Excess O2

- Excess air wastes heat as air enters at ambient temp and leaves at stack temp
- Excess air is required to achieve complete combustion
  - How much excess air is required?
  - Depends on boiler configuration, burner design, controls and fuel type.
  - Determine by reducing O2 until CO starts to appear.
  - 2 % excess O2 with zero CO is achievable with gas-firing
  - Controlling excess air is the most important tool for managing boiler efficiency and emissions.



# Reduce Excess O2 - Example

- Boiler operating at 100,000 pph year round:
  - O2 11%
  - $T_{stack}$ 300 F
  - $T_{comb.\ air}$ 85 F
  - $NOx_{\text{corrected to 3\% O2}}$ 160 ppm
- Reduce O2 from 11% to 2%
- Improve efficiency from 80% to 84%
- Save about $400,000 per year for $6/GJ gas
- Reduce NOx emission by about 12,000 lbs/year

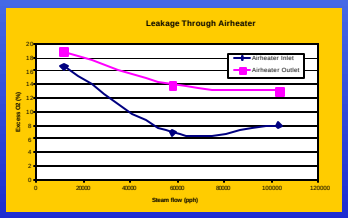
# *Observations for O2 and CO Measurements*

- Small boilers (<25,000 pph) typically do not have in-situ O2 analyzer and rely on regular burner tune-up
- Large boilers generally have in-situ O2 analyzer - sometimes even large boilers (100,000 pph range) do not have O2 analyzer
- Most boilers do not have CO sensor
- At some sites with no O2 analyzers, dangerously high level of CO (over 5,000 ppm) were observed due to extremely low level of O2



# *Observations for O2 and CO Measurements*

- At some sites with O2 analyzers but no CO sensors, high levels of CO were observed at low loads and high excess air due to poor mixing
- Excess O2 measurements are influenced by:
  - air leakage through air heater
  - tramp air through boiler, ducts and un-fired burners
  - Non-uniform flow and stratification along the x-section of a large duct for boilers having multiple burners



## *Observations for O2 and CO Measurements*

- Ensure properly calibrated O2 analyze is installed at suitable location
- Consider installing CO sensor when operating in the 2% O2 range
- To determine analyzer location
  - traverse probe along the duct at desired location
  - Take readings before and after the air-pre-heater to ensure no air leakage



## *Observations on Flue Gas Temperature Measurements*

- Observed temp from 100 – 600 F for boilers with and w/o heat recovery devices (air heater)
- In most cases, T gauges were incorrect
- Low temp caused by air heater leakage gives:
  - False impression of efficient boiler
  - Increases electrical consumption of ID/FD fans
- High temp is generally caused by poor heat transfer or damaged baffles
- Conduct boiler inspection to know the cause
- Keep track of temp and notice change
- Fix problem first before considering heat recovery device

## *Recover Heat from Flue Gas*

- Preheat combustion air with air preheater
- Preheat make-up/feed water/process water with economizer
- Evaluate condensing heat recovery: Indirect Condensing HX or Direct contact HX
- A 40 F temp drop increases efficiency by 1% point
- Example:
  - Reduce from 450 to 320 @ 3% O2
  - Increase combustion efficiency from 81.3% to 84.4%
  - Save $275,000/yr for 100,000 pph load ($6/GJ)



## *Benefits of Boiler Testing Program*

- Identified significant $ and energy saving opportunities for customers
- Improved safety and reliability of boiler operation
- Reduced emissions
- Contributed to cubic meter gas saving targets set by the Ontario Energy Board for Union Gas
- Good for the business and good for the environment