COOPERATIVE EXTENSION
WASHINGTON STATE UNIVERSITY
ENERGY PROGRAM

Energy Efficiency FACTSHEET

BOILER COMBUSTION MONITORING & OXYGEN TRIM SYSTEMS

Description: Boilers mix air with fuel to provide oxygen in the combustion process. For safety reasons, a small amount of additional or "*excess air*" is always provided to assure that all fuel is burned inside the boiler. By operating your boiler with a minimum amount of excess air, you can decrease *stack heat losses* and increase *combustion efficiency*.

Large, unnecessary amounts of excess air can occur because of:

- Burner/control system imperfections
- Variations in boiler room temperature, pressure, and *relative humidity*
- Control system "slop"
- Need for burner maintenance
- Changes in fuel composition

Given complete mixing, a precise amount of air is required to completely react with a given quantity of fuel. In practice, combustion conditions are non-ideal and additional or "excess air" must be supplied for complete combustion to occur. The presence of excess air means that more air is available for combustion than is actually required.

Table 1. Levels of Excess Air Possible on Well-Designed, Well-Tuned Systems

Fuel	Minimum Excess Air, %
Natural Gas	10%
#2 Oil	12%
#6 Oil	15%

Table 2. Combustion Efficiency Table for Natural Gas

Excess %		Combustion Efficiency (%)				
		Flue gas temperature less combustion air temperature, °F				
Air	Oxygen	200	300	400	500	600
9.5	2.0	85.4	83.1	80.8	78.4	76.0
15.0	3.0	85.2	82.8	80.4	77.9	75.4
28.1	5.0	84.7	82.1	79.5	76.7	74.0
44.9	7.0	84.1	81.2	78.2	75.2	72.1
81.6	10.0	82.8	79.3	75.6	71.9	68.2

Assumes complete combustion with no water vapor in the combustion air.

Air is comprised of approximately 21% oxygen and 79% nitrogen. When air is delivered for combustion, the nitrogen absorbs heat and is carried up the stack, resulting in energy losses. If there is excess air, the result is unused oxygen as well as even more nitrogen to absorb heat that is carried up the stack. Table 1 shows the levels of excess air that are possible on well-designed, well-tuned systems.

Boiler efficiency can be improved by incorporating an excess air trim loop into the boiler controls. It is easy to detect and monitor excess air, as oxygen not used for combustion is heated and discharged with the exhaust gases. A stack gas oxygen analyzer can be installed to continuously monitor excess air and adjust the boiler fuel-to-air ratio for optimum efficiency. A carbon monoxide trim loop, used in conjunction with the oxygen analyzer, assures that incomplete combustion cannot occur due to a deficient air supply.

Applications: Boilers 300 horsepower or larger (10,000 *lb/hr*) may benefit from installation of an oxygen trim control system (note: one *boiler horsepower* is equal to 33,475 Btu/hour). The control of excess air is increasingly important for boilers with a high stack gas temperature.

Performance/Costs: An often-stated rule of thumb is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40˚F reduction in stack gas temperature. An annual fuel savings of 5% is often obtained with tighter excess air control. Table 2 relates stack readings to boiler performance, clearly demonstrating the efficiency improvements available through control of excess air.

You can periodically "tune" your boiler and manually optimize fuel-to-air ratios after measuring the oxygen in the flue gas with an inexpensive test kit. More expensive ($500 to $1,000) hand held computer-based analyzers display percent oxygen, stack gas temperature, and boiler combustion efficiency. An automatic oxygen trim control system minimizes operating costs through ensuring that the proper fuel-to-air mixture is maintained at all boiler loads. Cost for a trim control system is about $10,000 for a 300-horsepower boiler.

A 300-horsepower boiler operating continuously for a year at 80% average load will use 902,280 therms of gas if average efficiency is 78%. Improving average efficiency to 83% with a continuous monitor and an oxygen trim system will reduce gas consumption to 847,925 therms, for savings of 54,355 therms per year. If your gas price is $0.40 per therm, that's a saving of $21,742 per year.

Availability: Combustion monitoring and oxygen trim systems are available from many manufacturers. Contact your local boiler supplier for information on equipment compatible with your boilers and control system.

For Additional Information:

Improve Your Boiler's Combustion Efficiency

A DOE BestPractices Steam Tip Sheet

http://www.oit.doe.gov/factsheets/steam_challenge/pdfs/boiler.pdf

Office of Industrial Technologies BestPractices Steam Resources

A website for access to *Steam System Energy Efficiency Handbook*, *Steaming Ahead Newsletter*, Tip Sheets, etc.

http://www.oit.doe.gov/bestpractices/just_need/steam.shtml

Slashing Steam-System Costs

Chemical Processing, October 1999

http://www.chemicalprocessing.com/web_first/cp.nsf/Contents/8625688C005A2497862568D3007260B6?OpenDocument

Boilers

From FEMP Greening Federal Facilities http://www.eren.doe.gov/femp/greenfed/3.0/3_2_1_boilers.htm

Industrial Gas Boiler O&M Strategies

Factsheet on Pacific Energy Center website, sponsored by Pacific Gas and Electric

http://www.pge.com/pec/inftoc/facboilr.html

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