USING BOILER FLUE TEMPERATURE TO CALCULATE IMPROVED BOILER EFFICIENCY DUE TO DESCALING

Introduction
A steam boiler with any amount of scale fouling (mineral deposits) on the boiler tubes will experience degradation in heat transfer and boiler efficiency. The ECO series mineral binding system treats the make up water so that not only does scale not form but existing scale is in fact removed. This will naturally improve boiler efficiency.

The following outlines the methodology for measuring boiler efficiency improvement resulting from the installation of the ECO series mineral binding system as it de-scales the boiler heat transfer surfaces. It is based on the Stack Loss Method and assumes that the “before” and “after” measurement of CO2 remains the same which is typically the case during a 2-3 month demonstration period (this method would be adjusted to account for any changes in CO2).

This method is a simple way to calculate the savings that is attributed to the decaling of the boiler tubes with a low margin of error.

Description of Method
Measuring the changes in dissipated heat energy released to the atmosphere through the smoke stack provides an accurate view of increases or decreases in boiler efficiency.


Under the heading “Heat Lost in Flue Gases”, “This should be regarded as the greatest single heat thief in the operation of a boiler plant. Flue gas heat losses are divided into two parts; the heat content of the dry flue gases and the [latent] heat content of the water from combustion.”

And, continuing,

“The most effective guide to the rate of fouling is the increase in the flue gas temperature.”

In boilers, fuel, gas or oil, is burned in air. A standard ratio is 13 CFM (Cubic Feet per Minute) of air per boiler horsepower. The resulting BTU released are
transferred to the boiler water. Raising water from 120 degrees F return/feedwater temperature to 5 PSIG steam pressure requires a total of 1036 BTU/pound of water.

A sample 400-horsepower Cleaver-Brooks Model CB-400 boiler operates at a rated output of 13,600,000 BTU-per-hour, or 13,127 pounds of water to steam-per-hour. The boiler will consume some 5,200 CFM of air and 16,750,000 BTU of fuel (natural gas or light oil). The flue temperature will run at approximately 270 degrees F. This capacity assumes that there is no mineral scaling or other fouling to affect heat transfer on the water side. It also assumes that there is no carbon fouling (soot) on the heat transfer surfaces on the burner side.

The difference between the gross input and net output, 3,150,000 BTU/hour, is dissipated via the exhaust flue and radiated out through the insulated boiler shell. This difference is the main determinant of the boiler efficiency, with, for the above boiler, in new condition, is rated at 84%. The heat losses typically break down as follows:

- **Sensible heat loss** 11% or 2,165,625 BTU/hr, or 416 BTU/CFM
- **Combustion (latent) loss** 3% or 590,625 BTU/hr or 113 BTU/CFM
- **Radiation and Other Loss** 2% or 393,750 BTU/hr

### Electronic Mineral Binding systems

Electronic mineral binding systems will prevent the formation of and in most cases break down existing scale or fouling on heat transfer surfaces and will have a profound effect on boiler performance. This is measured by resulting lower flue temperatures, indicating more-efficient heat transfer.

Below are examples of situations indicating the nature and degree of potential savings that can be achieved, as well as the methodology used to measure and calculate the savings.

### A Standard Case

An increase in flue temperature due to fouling will affect performance as follows.

With clean boiler operation, the difference in temperature between the combustion air, at a standard 70 degrees F and the outlet temperature of 270 degrees F will be 200 degrees F. Per the above BTU breakdown, an increase in temperature to 290 degrees F, or 20 degrees F delta, will increase the sensible heat loss by a factor of
20 degrees delta/200 degrees F, or 10%, equivalent to

216,563 BTU/hour

We must add a portion of the latent loss, the rise in the temperature of the water vapor by 20%, by the same factor, equivalent to and additional

59,062 BTU/hour,

for a total of 275,625 BTU/hour.

Calculating the cost of energy at $1.00/100,000 BTU, this seemingly small increase in flue temperature will increase the boiler operating cost by $33.00/day. Over a 2,000 hour heating season, this will increase the operating cost by $5,513, as the boiler will have to cycle longer to meet the heating load.

Regarding the radiation loss which remains relatively constant UWT uses a conservative 2% that would typically cover miscellaneous factors including radiation, convection, unburned carbon and moisture-in-air losses. Additional heat radiated outwards, instead of into the boiler water, typically raises the temperature of the boiler room, thus pre-heating the combustion air.

An Extreme Case
UWT typically encounters boilers operating at significantly higher flue temperatures. A sample 400 horsepower boiler was found to have a flue gas temperature of 540 degrees F. The additional latent loss with this heating plant, per the above calculations, totaled

270 degrees delta/200 degrees F, or 135%

This is a staggering loss of 3,720,849 BTU/hour, over 27% loss in efficiency. In this case, the boiler continues to operate at its designated input but is de-rated and did not meet the heating load, even under continuous operation.

The additional operating cost is approximately $37/hour, or $446/day in the heating season. Over a 2,000 hour heating season, this will increase the operating cost by $74,419.

A Smaller Installation
In another sample boiler audit, a 50 horsepower boiler, with a net 1,710,000 BTU/hour, was discharging flue gas at 455 degrees F. Using the above calculations, and assuming a comparable 84% design efficiency, the normal 11% sensible heat loss is augmented by 92%:

185 degrees delta/200 degrees x 11% inefficiency = 21%
With a gross input of 2,100,000 BTU/hour, the normal heat loss should total 390,000 BTU/hour.

With the higher flue temperature, an additional 92% sensible loss, or 248,016 BTU/hour is being wasted. Adding an additional 67,641 BTU/hour for latent losses totals 248,016 BTU/hour. The additional operating cost is approximately $3.16/hour, or $37.88/day in the heating season, some $6,300/year.