Article # 11

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The Art of Practical Boiler Performance Testing and Result Reporting.

For years I have noticed that performance testing of boilers and agreeing with a client firm about procedure and comprehensiveness of the test seems to be pretty murky. The objective of such a test is to identify and quantify losses and reduce them in a technically sound as well as financially attractive manner. The contractual arrangements between an energy auditor and a client for testing a boiler (not commissioning) should be only one line under the Energy Conservation Act:

“Both parties agree to test and report performance according to BEE-Steam Boiler Test Code.

However, since such a code does not exist yet, boiler testing and performance is done either “free style”, or energy auditors attempt to follow BIS, ASME, VDI or BS procedures. Such attempts usually fail because the mentioned codes are either too demanding or outright useless for field testing. They all require modification to be used in testing smaller boilers. I have seen so far no contract between an energy auditor and a firm that states the code used for testing as part of the contract. In other words the codes are either not followed, or not known, or regarded as impracticable. The latter is my observation.

Let us tackle the problem in a very logical and practical manner. Since both the client and energy auditor are interested in reducing fuel costs, start with an equation that specifies losses:

$$\eta_{Boiler} = 1 - \text{Losses}$$

Define the major losses as:

$$\text{Losses} = q_A + q_c + q_{rad} + q_{Ref} + q_x$$

Where q_A = Stack gas losses
q_C = Losses due to combustibles in the stack gas
q_{rad} = Losses due to radiation and convection
q_{Ref} = Losses due to unburned carbon in the refuse.
q_x = Whatever you decide and agree with the client to call a loss.

Step 2: Parties decide which losses are important and therefore should be quantified. A boiler performance test can be inexpensive and quick, or expensive and time consuming. The test may require expensive measuring equipment or could be done with simple instruments depending on the selection of the losses both parties want to identify and of course size of the boiler.

In a gas or oil fired boiler, it is unnecessary to quantify q_{Ref} the loss in the refuse. Furthermore, quantification of the radiation and convection losses in a package type 6 t/h boiler does not make sense. Insulation thickness is usually sufficient.

Step 3: Agree which energy content of the boiler fuel the, Gross calorific value (GCV) or Net calorific value (NCV) should be used for the calculation. With respect to the objective “first quantify and then minimize losses” it is irrelevant whether we use GCV or NCV in the calculation. Be aware that the GCV is a value directly from a bomb calorimeter test of the fuel whereas the NCV is a derived value requiring additional information such as its atomic Hydrogen content in % weight. Using NCV only complicates matters and introduces unnecessary inaccuracies.

Example for q_A

The stack gas loss q_A will be always measured and equals:

$$q_A = \frac{V_A \times C_{pA}}{GCV} \cdot (T_s - T_{amb})$$

Where

V_A = dry stack gas and water vapor in normal cubic meter per kg of fuel (m^3_n/kg) per as fired.

C_{pA} = average specific heat capacity of the stack gas in kJ/ m^3_n - ^oC.

GCV = Gross Calorific Value of fuel in MJ/kg as fired.

T_s = stack gas temperature in ^oC.

T_{amb} = ambient temperature in ^oC.

The above equation is rather impracticable because it requires one to determine V_A and C_{pA}. Instead one can use:

$$q_A = (T_s - T_{amb}) * \left(\frac{A}{21 - O_2} + B \right)$$

and determines A and B based on local fuel properties. In other words only % O_2 in the stack gas and two temperatures need to be measured if the fuel is known and its physical/ chemical properties are reasonable fixed. This approach gives a reliable and cost effective way to calculate q_A, involving a minimum of measurement that are easy to conduct for gaseous and liquid fuels. This approach, however requires modification if coal is used as a fuel.

Similar equations can be developed for the other losses. The above equation is used to test 18 million small combustion systems (boilers & furnaces) per year in Germany.

The same generic approach applies as well with other energy intensive equipment such as compressors, fans and blowers, etc., only the losses and equations look differently.