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Steam Technology MPEP 326X

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BOILER EFFICIENCY

Boiler Efficiency

- It is the measure of the capability of the boiler to transfer heat liberated in the furnace from the fuel to water and steam.
- Thus the boiler efficiency depends upon the performance of the superheater, economizer, air-heater, besides the furnace performance.
- The term efficiency is expressed as;
  1. For solid fuel. The ratio of heat transferred to water and steam/kg of fuel to the calorific value of the fuel.
  2. For liquid and gases fuels. The ratio of heat transferred to water and steam/kg or m^3 of fuel to the calorific value of the fuel.

Factor Influencing Boiler Efficiency

The factors on which the boiler efficiency mainly depends;

A) Fixed factors B) Variable factors

A) Fixed Factors

1. Heat recovery equipment which includes the economizer, superheater, air heater, feed water heater.
2. Boiler design which includes the arrangement and effectiveness of the heating surfaces,
3. The shape and volume of the furnace,
4. The arrangement of flues, and the arrangement of steam and water circulation.
5. Built in losses which include the heat transfer properties of the construction material, flue gas and ash heat losses.
6. Properties and characteristics of fuel burnt, and rate of firing.

B) Variable Factors

1. Fuel condition as it is fired,
2. Humidity and temperature of the combustion air,
3. Excess air fluctuations,
4. Incomplete combustion,
5. Actual firing rate,
6. The conditions of the heating absorbing surfaces.

Effect of Ambient Conditions on Boiler Efficiency and Design

- Efficiency of a boiler is always measured with ambient conditions as the datum or the atmosphere condition as the sink.
- Ambient conditions, namely temperature, humidity, altitude have an important role in determining the efficiency of a boiler and the sizing of auxiliaries.
- The ambient conditions have a significant effect on the efficiency and the design.

- Stack loss, which constitutes ~70–80% of the total loss, is measured with ambient temperature. The efficiency would therefore appear to be lower by ~0.25% for each 5°C increase in ambient temperature.
- It is important to determine the range of temperature and humidity variation to ensure proper sizing of the fans and other volumetric devices.
- The fan must be sized by the maximum temperature.
- Thermal insulation in area affected by the ambient temperature.
- The effect of humidity is rather small in both boiler efficiency and auxiliary sizing.
- Altitude has a major impact on the sizing of fans as the specific volume of air increases with altitude.

Performance Testing of Boilers

Input–Output Method (direct method)

- This is a simple method for calculating the efficiency, which gives an approximately correct value.
- It is applicable for small and medium oil and gas–fired boilers, which use fuels with nearly constant CV.
- Whereas it needs fairly accurate flow measurement.

Heat Loss Method (indirect method)

1. It is practical because it calls for no flow measurements to calculate efficiency.
2. More accurate because it involves measuring only the loss and not the efficiency.

The main measurements in the heat loss method for calculating efficiency are;

- Temperatures (feed in, SH out, RH in, RH out, exit gas, and ambient air);
- Pressures (SH, drum, and RH);
- Flue gas analysis at exit;
- Heating values of ash and fuel.

Boiler Evaluation

- Boiler specification and purchase are very important functions as the life of a boiler plant exceeds 30 years.
- Proper purchase can save huge amounts in capital and running costs.
- Because a boiler costs a lot of time and effort for the boiler maker to prepare and an equal effort by the customer so, the efforts can be saved if the specification is prepared carefully and the evaluation is done efficiently.
- The two most important parameters for evaluation are;
  1. Efficiency
  2. Auxiliary power consumption.

The following points should be considered in evaluating boilers:

- The first step is a careful analysis of the plant requirement under all conditions of operation, at both full and part loads;
- A request for purchase must include parameters for evaluation and the corresponding loading factors, to enable the user to understand the operating behavior in the most appropriate manner;
- The specification must clearly state what parameters must be met without fail and what items may be customized.

Boiler Design for Optimum Performance

The goals of good boiler design include:

1. Customization to meet specific requirements;
2. Optimization of performance;
3. Good build quality for reliable operation.

- Performance optimization is the most important, mainly by lowering of the boiler losses and auxiliary power consumption.
- The losses that can be lowered only stack and unburnt losses, and the savings in power are mainly in the fans and pumps.

Stack Loss Reduction

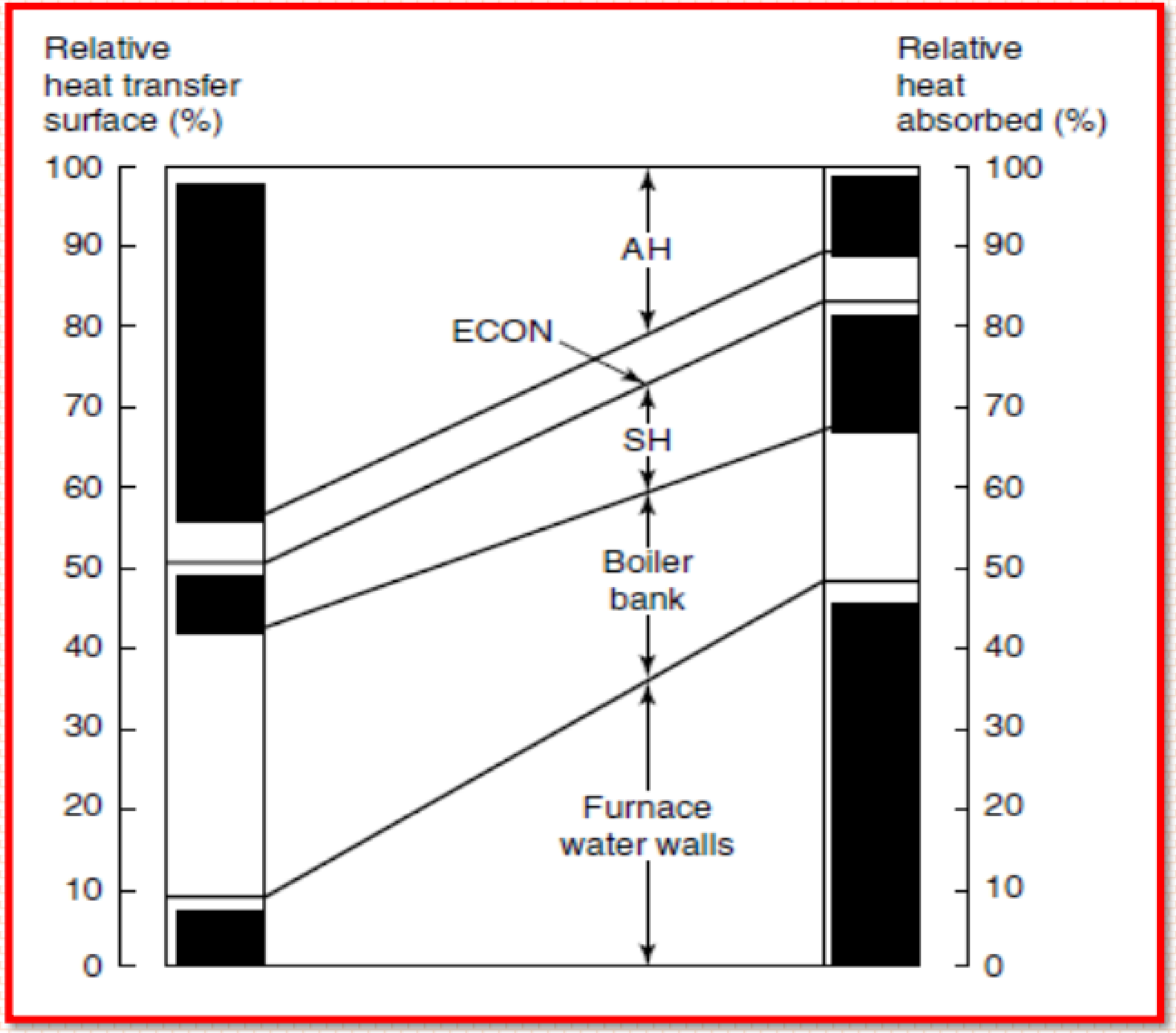
There are two important components to the stack loss:

1. Exit gas temperature ;
2. Minimum excess air.

Exit gas temperature should be as low as possible, with the avoidance of low-temperature gas side corrosion.

The larger the surface, the better the cooling of gases, and the higher the boiler efficiency. But there is a sharp rise in costs, as surfaces required to cool the gases. Approximately 40% of total heated surface of boiler accomplished in AH captures only ~10% of the total heat.

Excess air should be at minimum without compromising on the completeness of combustion as evidenced by only some traces of CO in flue gas. This Optimum excess air for each type of firing is tabulated.



Relative Effectiveness of Heating Surfaces

Unburnt Loss Reduction

Unburnt loss indicates how well the firing equipment and furnace are sized and matched such that air pressures, temperatures, and distribution are selected properly to help release the fuel heat fully.

Radiation Loss Reduction

- All the walls of the furnace are to be fully water-cooled, as achieved regularly in modern boilers by membrane walls.
- The boiler along with ducts and piping is insulated such that the surface temperature is not more than 20–25°C over the ambient temperature.

Fan Power Reduction

- Lowering the gas velocities over the tubes can reduce gas pressure drop in the boiler. But this reduces the heat transfer rates and makes the boiler larger and more expensive;
- Lowering the excess air quantity is necessary to lower the volumetric capacity of the fans;
- Choosing the highest available fan efficiency;
- For small fans up to ~150 kW, belt drives are popular as they provide the optimal revolutions per minute (rpm) for the duty that consumes the least power;
- Variable-speed hydraulic couplings, installed between the constant-speed motor and the fan, reduce the speed of the fans at lower loads, and help to reduce the power consumption more effectively;
- When the fans are large, as in utility applications, axial flow design is considered, as axial flow is inherently more efficient.

Feed Pump Power Reduction

Feed pumps absorb the most auxiliary power in a power plant, and hence power savings here make a big difference in actual kilowatt hour (kWh) terms.

- Selection of pumps at the highest efficiency point is the best way to secure the least Power;
- Speed variation by hydraulic coupling or by variable-frequency drives (VFD) helps to reduce the pump power even more;
- Variable-pressure operation of the power plant is the next step in saving even greater power, applicable largely for large utility boilers.

Evaporation Rate

- It is defined as the quantity of water evaporated into steam per hour.
- It is expressed in kg of steam per hour, or kg of steam per hour per m^2 of heating surface or kg of steam per hour per m^3 of the furnace volume.

Equivalent Evaporation from and at 100 ^0C

- It is the equivalent of the evaporation of 1 kg of water at 100 ^0C to steam at 100 ^0C where the pressure is the atmospheric pressure (1.01325 bar).
- Therefore, equivalent evaporation of 1 kg of water from and at 100 ^0C requires 2256 kJ.

Factor of Evaporation

- Actually in the steam generator the feed water temperature is not at 100 ^{0}C and the pressure is also different from the atmospheric value.
- The actual heat required to evaporate 1 kg of water into steam (wet, saturated or superheated) at specified pressure from the given condition of the feed water temperature is different from equivalent evaporation from and at 100 ^{0}C.
- The ratio between the actual heat transferred to evaporate water into steam to the latent heat of steam at atmospheric pressure is known as the factor of evaporation.

$$F = \frac{(h_1 - h_{feed})}{h_{fg\,(atm)}}$$

h_1 = Specific enthalpy of steam actually produced.
h_{feed} = Specific enthalpy of feed water.
h_{fg} = Specific enthalpy of evaporation at atmospheric pressure.

The equivalent evaporation may be expressed as;
Equivalent Evaporation = Actual evaporation * Factor of Evaporation

$$m_e = m_a * \frac{(h_1 - h_{feed})}{h_{fg\,(atm)}} = F * m_a$$

m_a = Actual evaporation expressed in kg of steam/kg of fuel or kg of steam per hour

m_e = Equivalent evaporation expressed in kg of steam/kg of fuel or kg of steam per hour

Thanks for Your Attention