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Evaluating the Boiler Efficiencies using Different Methods and Improve the Boiler Efficency using Combustion Air

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Abstract— Operating the boiler with an ideal measure of overabundance air will limit heat damage up the stack and enhance ignition proficiency. In this examination we have set up a ten stage framework to enhance the heater proficiency by upgrading the ignition air. Ignition productivity is a proportion of how effectively the heat substance of a fuel is moved into usable heat. The stack temperature and flue gas oxygen (or carbon dioxide focuses are essential pointers of combustion proficiency.

Keywords- *boiler; efficiency; combustion, air, oxygen, flue gas.*

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I. EVALUATING BOILER EFFICIENCIES

Thermal proficiency of boiler is characterized as the level of heat input that is adequately used to create steam. There are two strategies for getting boiler effectiveness [1].

American Society of Mechanical Engineers (ASME) [2] defines efficiency in two ways:

A. *By the input-output method (Direct method):*

This is the method in where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel [3]

$$\%E = \frac{\text{Output}}{\text{Input}} = \frac{\text{Enthalpy of Steam - Enthalpy of feedwater}}{\text{Heat released in Boiler}} * 100$$

This is otherwise called "input-output method" because of the way that it needs just the valuable output (steam) and the heat input (fuel) for assessing the effectiveness. The system is as per the following:

- Measure amount of steam flow over a set period, e. g. one hour time span. Utilize steam integrator readings, if accessible, and revise for orifice calibration pressure. Then again, utilize the feed water integrator, if accessible, which will as a rule not require a improvement for pressure [4].
- Measure the amount of fuel utilized over a similar period. Utilize the gas or oil integrator, or decide the mass of solid fuel utilized.
- Define the working pressure in kg/cm2 (psi) and superheat temperature, C (F)
- Define the temperature of Feed water C (F)
- Convert steam flow, feed water flow and fuel flow to identical energy units, e.g. k j/kg
- Determine the type of fuel and gross calorific value of the fuel (GCV or HCV) in k j/kg
- Measure the efficiency using the following equation [4]:

$$\%E = \frac{\text{Output}}{\text{Input}} = \frac{\text{Enthalpy of Steam - Enthalpy of feedwater}}{\text{Heat released in Boiler}} * 100$$

B. *By the heat loss method (Indirect method) [5]:*

This is the method where the efficiency is the difference between the losses and the energy input

$$\%E = \frac{\text{Heat Input - Heat Losses}}{\text{Heat Input}}$$

$$\%E = 100 - \left(\frac{\text{Heat losses}}{\text{Heat in fuel}}\right) * 100$$

The ASME power test code (PTC4.1, 1973) gives heat loss technique, which applies to all sort of fuels. The greater part of the information required is ordinarily acquired by basic estimations and examination [6].

The major heat losses from boiler are [7]:

- Loss of heat due to dry flue gas loss (Stack loss).
- Loss of heat due to moisture in fuel and combustion air –leaves boiler stack as water vapour.
- Loss of heat due to combustion of hydrogen.
- Loss of heat due to un burnt combustibles in refuse (un burnt fuel in ash & flue gas).
- Loss of heat due to radiation from surfaces of boiler
- Losses unaccounted for un measured losses [7].

II. EVALUATING HEAT LOSSES FROM BOILER

Out of 6 losses indicated above, the 4 significant losses that apply to natural gas and heating oil system are:

1. Dry Flue Gas Loss (LDG)
2. Loss due to moisture from the combustion of hydrogen (LH)
3. Loss due to radiation and convection (LR)
4. Losses those are unaccounted for (LUA)

A. *Dry flue gas Loss*

The dry flue gas damage represents the heat lost up the stack in the dry results of combustion that is CO2, O2, N2, CO and SO2. The dry items divert the sensible heat, while the wet item for the most part moisture from the combustion of hydrogen, divert both latent and sensible heat ,The groupings of SO2 and CO are ordinarily in the parts per million range (ppm) [8].

The ASME power test code formula for dry flue gas loss (LDG) is define as follows:

LDG %= [DG x Cp x (FGT –CAT)] x100 /HHV

Where,

DG is the weight of dry flue gas loss

Cp is the specific heat of flue gas usually assumed to be 0.24

FGT is the flue gas temperature in F
CAT is the combustion air temperature in F
HHV is the higher heating value of fuel

If temperature are measured in C and other units remain unchanged the formula becomes

LDG % = [43.2 x DG x (FGT- CAT)]/HHV [9]

The weight of dry gas (DG), differs with fuel content and the measure of surpluses air utilized for ignition. For the typical instance of zero CO or unburned hydrocarbons, it very well may be figured as

$DG= (11\ CO_2 + 8\ O_2 + 7\ N_2) \times (C + 0.375\ S)/ 3\ CO_2$ [10]

Where,
CO_2 and O_2 are % by volume in the flue gas
N_2 is the % by volume in the flue gas = (100 – CO_2 – O_2)
C and S are weight fractions from the fuel analysis

HIGH HEAT VALUE OF VARIOUS FEULS

Fuel	Natural Gas	No. 2 Oil (light oil)	No. 4 Oil (bunker A)	No. 6 Oil (bunker C)
HHV, Btu/lb	22,450	19,450	18,750	18,350
Ultimate analysis, weight fraction				
Carbon	0.721	0.865	0.867	0.867
Hydrogen	0.239	0.132	0.115	0.108
Sulphur	Nil	0.003	0.015	0.020
Nitrogen	0.032	Nil	0.003	0.005
Oxygen	0.008	Nil	nil	nil
lb $CO_2/10^6$ Btu input	117.8	163.1	169.6	173.2

Table 1: High heat value of various Fuels

B. *Loss due to moisture from the combustion of hydrogen (LH):*

In combustion of hydrocarbon fuels, water vapor is delivered in huge sum because of the hydrogen segment of fuel. This combustion of hydrogen leaves the boiler as water vapor, taking with it the warmth content – relating to its state of temperature and pressure. The vapor is a steam at low pressure, however with a high stack Temperature [3].

The significant loss is about 11 % for natural gas and 7% for fuel oil.

The ASME formula for calculating the loss due to moisture from the combustion of hydrogen is [10]:

LH,%= [900 x H2 x (Hg-Hf)]/HHV

Where,

H2 is the weight fraction of hydrogen in the ultimate analysis of the fuel

HHV is the higher heating value

Hg is the enthalpy of water at 1 psi and the flue gas temperature (FGT) in F

Hf is the enthalpy of water at the combustion air temperature (ACT) in F [10].

C. *Loss due to Radiation and convection (LR):*

The outside surfaces of a shell boiler are hotter than the environment. The surfaces along these lines lose heat to the surroundings relying upon the surface zone and the distinction in temperature between the surfaces and the environment.

The heat damage from the boiler shell is basically consistent and is communicates as a level of the boiler" s heat output. As a rule the radiation and convection damage is bring down for bigger boilers and higher for a littler boiler. Estimations of the radiation and convection loss are generally decided from standard graphs accessible with American Boiler Manufacturer Association (ABMA) and are exhibited in figure below:

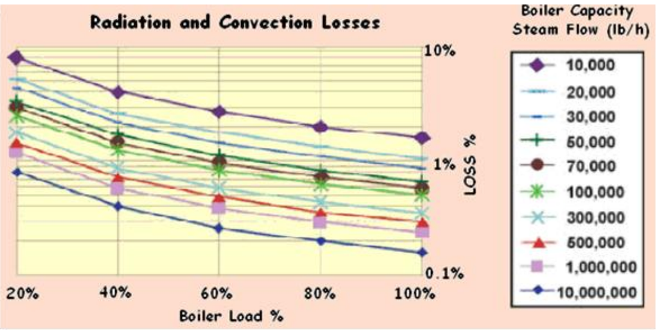


Figure 1-Convection and Radiation Losses

With present day boiler structure, this show to just 1.5% on the gross calorific incentive at full evaluating, however will increment around 6%, if the boiler works at just 25 % output. Working the boiler at full load optimize this loss [9].

D. *Losses those are unaccounted (LUA):*

Sensible suppositions concerning these losses are 0.1 % for natural gas terminated boiler frameworks and 0.2 % for light oil terminated frameworks. For an overweight oil, an incentive somewhere in the range of 0.3 and 0.5% might be fitting, to represent fuel warming and, maybe, atomizing steam [4].

III. SCALE DEPOSITION

The nearness of hardness salts in boiler water prompts arrangement of stores, in fact known as "scale" which has a low thermal conductivity and effects the evaporation rates. The most imperative salts contained in water, which impact the arrangement of stores in the boilers, are the salts of calcium and magnesium, which are known as hardness salts. Calcium and magnesium bicarbonate break up in water to frame a soluble arrangement and these salts are known as "alkaline" hardness. They break down after warming, discharging carbon dioxide and framing a soft sludge, which settles out. These are classified "temporary" hardness-hardness that can be expelled by bubbling [10].

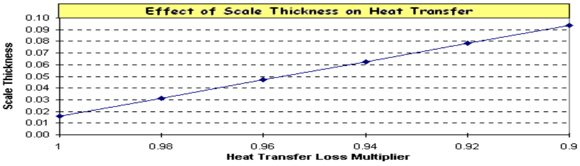
The key effects of scale deposits on boiler operation are:

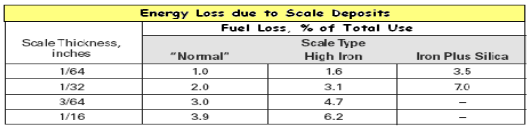
- Scale retainer act as insulators and slow heat transfer. Huge amounts of deposits throughout the boiler could diminish the heat transfer enough to diminish the boiler efficiency significantly.
- Scale in addition to its high insulating value; progressively narrows pipe internal diameters, roughen tube surfaces and impede proper flow.

- The insulating effect of scale deposits causes the boiler metal temperature to rise, which increases the flue gas temperature. In extreme cases, the tubes fail from overheating.
- Scale causes fuel wastage typically up to 2 % for water- tube boilers and up to 5 % in fire –tube boilers [10].

As a rule of thumb, one millimetre of scale build up can increase fuel consumption by two per cent.

The figures below bring out the importance of the scales and its influence on energy consumption.





Energy Loss due to Scale Deposits			
Scale Thickness, inches	Fuel Loss, % of Total Use		
	Scale Type		
	"Normal"	High Iron	Iron Plus Silica
1/64	1.0	1.6	3.5
1/32	2.0	3.1	7.0
3/64	3.0	4.7	–
1/16	3.9	6.2	–

Figure 2: Heat Transfer Loss

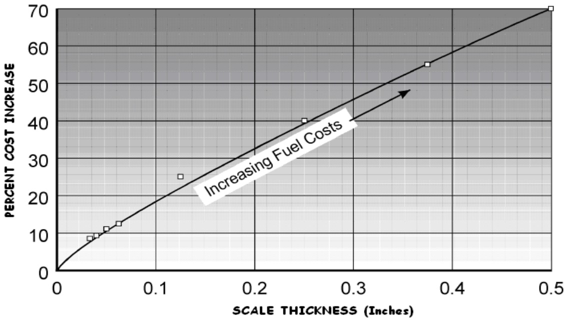


Figure 3: Scale thckness

This draws out the significance of the scales and its impact on energy preservation in a boiler. It is instinctively clear that the presence of any scale in a boiler is unwanted. The most ideal approach to manage scale isn't to let it from in any case [10].

IV. MANAGING AIR TO IMPROVE COMBUSTION EFFICIENCY

A comparable basic yet compelling methodology can be utilized to survey the execution of a coal-fired steam generator. Deal with the wind stream first and after that the fuel stream to acquire the most ideal ignition results given the requirements of the boiler structure. Ideally, the outcomes will be like those accomplished with CPR: a long and profitable life [11].

Get the Air flow right:

Perfect pounded coal combustion happens when a coal molecule is burned totally and the complete of the carbon is changed over to CO2, all H2 is changed over to H2O, and all sulfur is changed over to SO2. Deviations from perfect combustion are shown by higher-than-wanted carbon in ash, secondary combustion at the super heater, and offensive CO levels in the flue gas. Most expansive utility boilers were initially intended to work with 15% to 20% overabundance air to compensate for air and fuel irregular characteristics in the burner belt. Basic resistances for the ignition wind current ways to the boiler are noted [11].

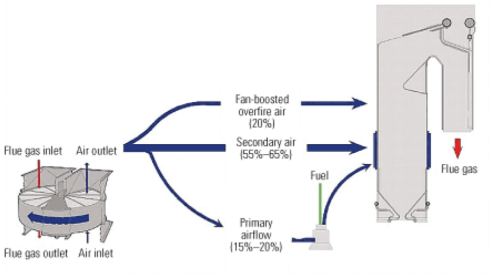


Figure 4: Air Flow Right

1. Different paths

Air usually takes three distinct ways; however everything winds up in the furnace—regardless of whether you need it there or not. The way to accomplishing phenomenal combustion productivity is appropriately dealing with the measure of air supply and stopping the holes [11].

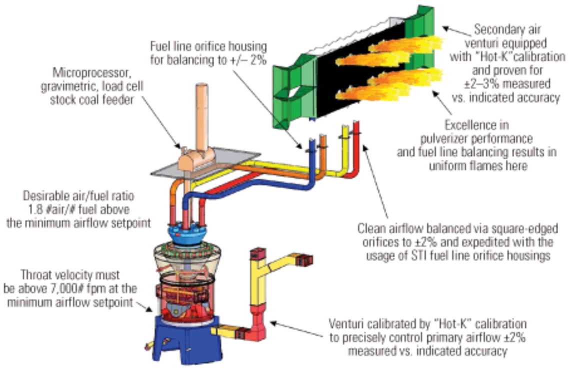


Figure 5: Different paths

2. Short course

These are the key structure and working measures for combustion air, from the pulveriser to the furnace, for a run of the mill 50-MW coal-fired plant. Source: Storm Technologies.

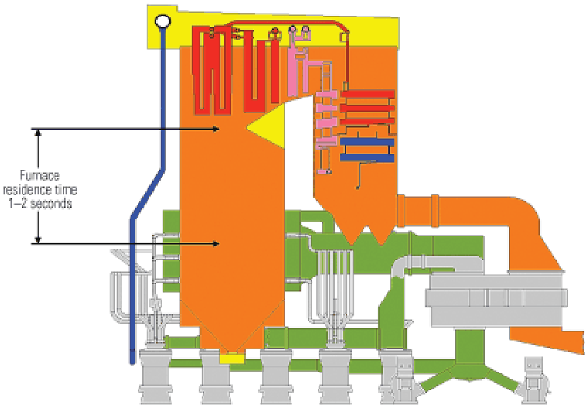


Figure 6: Storm Technologies

3. Burning desire:

Best practices direct organized combustion with various air zones in the furnace to oversee NOx creation. Numerous boilers have moderately short furnace boxes with habitation times underneath the desired 1 to 2 seconds.

4. Time in stir

This chart shows how the typical coal particle spends its residence time in a coal-fired boiler. Smaller particles (better fineness) increase the amount of carbon changed to CO2 and decrease the amount remaining in fly ash leaving the boiler.

Low-NOx burners purposely and deliberately stage combustion for a slower burn with a flame of reduced intensity. The reduced-intensity flame has a lower temperature, generates less NOx, and releases less fuel-bound nitrogen. Staged combustion may reduce flame intensity, but it causes increased flame lengths. Burners designed in the 1970s or earlier were developed for high-intensity and closely spaced burners with high heat release—typically between 150 and 200 mmBtu input. They produced a flame length of between 15 and 20 feet. A similar sized low-NOx burner with lower flame intensity and internally staged combustion may have a flame length of 50 to 60 feet (or more if operating below a stoichiometry of 1.0). The inevitable flame impingement on super heater and other radiant and convection tubes will drive up O&M costs as a result of tube replacement or will reduce plant availability when tube leaks are repaired [12].

5. Learn from others:

Air in-leakage into a typical balanced-draft 50-MW coal-fired boiler can seriously reduce plant thermal efficiency and negatively impact furnace O&M. This plant is operating at full load operating with 15% excess air with no air in-leakage.

There are many varieties of approaches to combustion airflow measurement and control. In our experience the most reliable and accurate methods use a venture or flow nozzle to measure airflow. Many believe that these devices cannot be installed in the close-coupled ductwork of airflow entering a coal pulveriser or around the bends of ductwork in an over fire air system. Not true. We routinely use either a venture, a flow nozzle, or both. However, they must be properly installed and field calibrated using hand velocity traverses. Because of the vastly different densities of cold air and operating temperature airflows, we strongly recommend the "Hot-K" calibration and measurement verification of airflows under actual operating conditions. Surface-measured static pressures at the high-pressure and low-pressure sensing taps are affected by the boundary airflow over the internal duct surfaces and are therefore influenced by surface discontinuities.

For example, placing a venture immediately after a primary air fan has always been problematic. But we have successfully added the venture many times using our calibration section of the venture throat and using the "Hot-K" calibration method. Another difficult application is on an exhauster-equipped pulveriser such as deep bowl, Raymond bowl mills. The ductwork arrangement shown in figure is typical of our approach to primary airflow measurement on pulverisers operating under suction pressure.

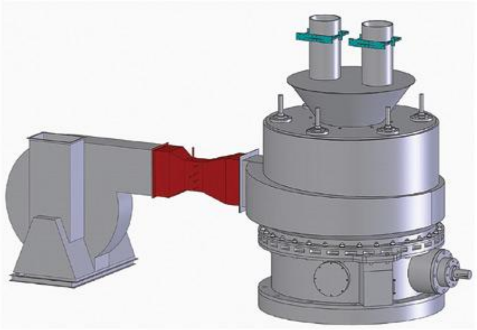


Figure 7 : Bowl Mill

6. Squeeze job

A high-accuracy venture can be placed between a close-coupled fan and a pulverize

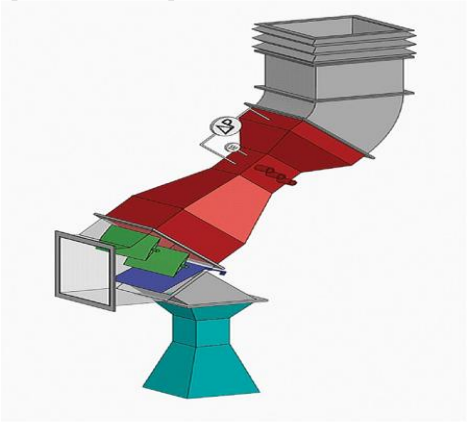


Figure 8: Sqeeze job

7. Drawing a vacuum:

A similar configuration with a venture is possible on pulveriser ductwork that’s typically under negative pressure.

Commonly used averaging pilot tube arrays, with straightening vanes such as those shown in Figure 8, have functioned satisfactorily in clean air. However, when regenerative air heaters are used, as is common on large PC boilers, a certain amount of the flyash is recirculated as the air heater rotates, resulting in honeycomb plug gage. Plugging is another reason to conduct periodic inspections and to implement a program of periodic airflow calibrations using the "Hot-K" method.

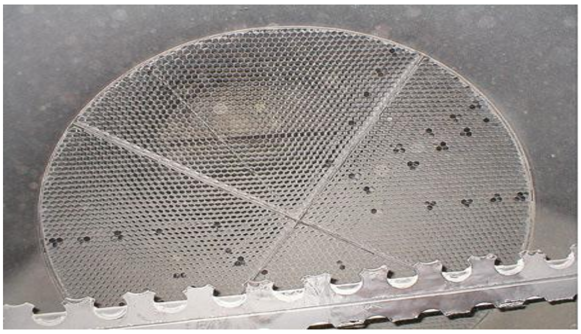


Figure 9: Drawing a vacume

8. Straight and narrow

A "honeycomb" flow-straightener was partially plugged by flyash recirculated by the regenerative air heater.

The obvious reasons to accurately measure airflows to the furnace are to ensure that inputs to the burner belt are correct and to establish those airflows as the baseline for future testing. Often we find there is simply insufficient furnace combustion airflow to complete combustion. Because the average large utility boiler is more than 30 years old, it should not be a surprise that many units not getting a good breath of air are of the balanced-draft design and have significant "tramp air" in-leakage. Air leaks not only contribute to a heat rate penalty, but they also contribute to poor furnace performance, slagging, fouling, and higher-than-optimum carbon-in-ash content.

Worse yet, air in-leakage goes undetected by normal plant instrumentation. That is, excess oxygen measured at the economizer outlet is "assumed" to have entered the furnace through the burners or overfire air ports. In fact, sometimes as much as 20% of the total air thought to have entered the furnace actually entered the boiler convection pass via what should be the postcombustion flow path of the product of combustion.

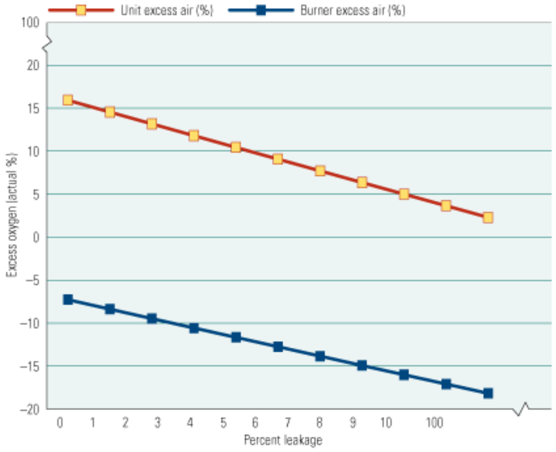


Figure 10: Leakage and excess oxigen graph

9. Air leaks reduce efficiency

Actual excess air as a function of casing leakage the data points are based on a 3% O2 setpoint with 20% overfire air.

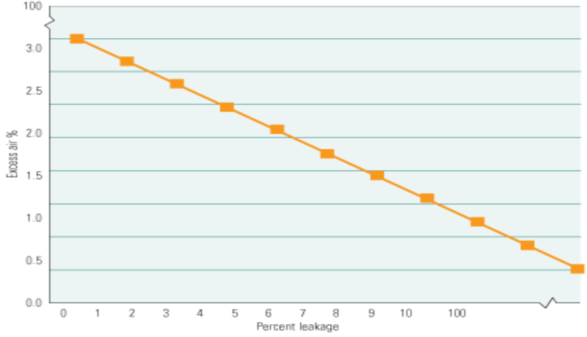


Figure 11: air leak reduce graph

10. Inaccurate measurements.

A correlation of "true" in-furnace oxygen versus the assumed oxygen levels measured at the O2 probes with varying levels of leakage upstream of the O2 probes.

V. CONCLUSION

In this paper we have studied evaluating the boiler efficiency. American Society of Mechanical Engineers (ASME) [2] defines efficiency in two ways. First one is by the input-output method or direct method and second one is by the heat loss method or indirect method. For evaluating the heat loss from boiler it is included four methods. to improve the combustion efficiency there are 10 steps are described earlier. A similar simple but effective approach can be used to assess the performance of a coal-fired steam generator. Manage the airflow first and then the fuel flow to obtain the best combustion results possible given the constraints of the boiler design.

VI. REFERENCES

[1]. documents.mx.
[2]. www.energysolutionscenter.org.
[3]. www.scribd.com.
[4]. www.i-scholar.in.
[5]. documents.mx.
[6]. www.autoclaveboiler.com.
[7]. Submitted to University of Petroleum and Energy Studies.
[8]. Hartmut Spliethoff. "Power Generation from Solid Fuels", Springer Nature, 2010..
[9]. www.pdhengineer.com.
[10]. Friedl, A. "Prediction of heating values of biomass fuel from elemental composition", Analytica Chimica Acta, 20050715.
[11]. Yang, Yongping, Cheng Xu, Gang Xu, Yu Han, Yaxiong Fang, and Dongke Zhang. "A new conceptual cold-end design of boilers for coalfired power plants with waste heat recovery", Energy Conversion and Management, 2015.
[12]. Smith, Craig B., and Kelly E. Parmenter. "Management of Process Energy", Energy Management Principles, 2016.