The Importance of Correct Operation and Economic Functionalities on Fuel Consumption for the Functioning of Industrial Boilers

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Abstract *During the operation of the boiler, there are some situations when the needs of the production process require a smaller or larger quantity of steam; the boiler must respond to these needs by consuming a smaller or larger amount of fuel or water.*
Under these conditions, proper maneuvers must be ensured, so that the combustion is complete, carbon-free and unburned; in other words, proper adjustment during operation must be ensured, which mainly involves the following: combustion control, water supply adjustment and draft control. Keeping the losses in the basket at minimum values it is.particular importance for the proper operation of the boilers, in the conditions of minimum fuel consumption.

Keywords *boiler, outbreak, draft, full combustion, incomplete combustion, combustion gases, fuel, pressure, temperature, efficiency.*

JEL Classification Q42

Introduction

The amount of heat produced in the furnace by burning the fuel is not entirely used to produce steam. A certain part is lost by:

- combustion gases discharged into the chimney;
- incomplete combustion of fuel;
- radiation of the external surfaces of the boiler;
- evacuation of hot ash;

- unheated fuel fed into the grate bar, embedded in slag, ash or entrained by the combustion gases;
- purging;
- intermittent operation (frequent stops and frequent starts).

The above mentioned losses are lower, the better the burned fuel in the boiler, the boiler efficiency is higher. Typically, boiler efficiency varies between 70% and 95%, depending on the type of boiler and the fuel used.

The maximum boiler yield is obtained at a flow rate of 0.8 of the nominal flow rate. Determination of yield is made, decreasing losses from 100%; the value of the loss is given in Table no.1.

Table no. 1 Heat loss values

Loss of heat	Value, in%	
	On small boilers	Large boilers
Through combustion gases discharged into the chimney	10 – 12	4 – 6
By incomplete combustion of fuel	0,2 – 0,5	0 – 0,1
By radiating the outer surfaces of the boiler	1,5 – 2	0,5 – 1
By evacuating the hot ashes	4 – 8	2 – 4
Through unburned fuel:		
- solid fuel	2 – 4	1 – 2
- to gaseous and liquid fuel	0	0
By purging	1 – 2	0,5 – 1
By intermittent exploitation	Depending on the number of boiler stops and starts	

The determined yield, as shown above, is also referred to as gross thermal efficiency or overall yield.

It is known that a certain amount of energy is consumed to drive ancillary installations, such as steam pumps, mills, fans and extractors. If this energy turns into heat and decreases from the global yield, the net boiler yield is obtained.

In order to achieve a higher boiler efficiency, service personnel are required to take all measures so that the heat loss is as low as possible.

To this end, it is necessary to permanently monitor the temperature of the gases evacuated to the chimney by means of thermometers or thermocouples, as well as the chemical components in the exhaust gases, by means of gas analyzers.

Also, the proper condition of masonry and insulation must be ensured to minimize heat loss through radiation. Strictly adhere to the internal instructions with regard to the ash evacuation regime, the type of fuel and its main characteristics (calorific power, granulation, fluidity, etc.), purge and continuity of operation.

In order to ensure a more economical operation, it is necessary to follow, with the help of the measuring and control devices, the above mentioned indices.

Burning indices

The main indexes of burning are as follows:

Fuel quality, respectively;

- for coals: calorific value, grain size, moisture content, ash content, volatile matter content;
- in the case of liquid fuel: calorific value, specific gravity, viscosity, solidification temperature, water content;
- in the case of gaseous fuel: the calorific power.

These indices are determined during the operation of the boiler by the chemical laboratory of the plant; the results obtained must correspond to the values indicated by the boiler manufacturer.

Fuel consumption is determined either hourly, in the case of gas or liquid fuel, by means of meters (meters) or within a 24-hour period for solid fuel by weighing.

A lower consumption than prescribed by the boiler manufacturer may cause disruptions in operation and higher consumption, incomplete combustion or increased fuel loss.

Fuel pressure and temperature have a significant influence on the boiler's operating conditions.

Thus, in the case of gaseous fuels, they will be monitored in operation:

- the pressure before the burner adjustment valve, which must be the same as the pressure in the gas distribution pipe in the boiler, indicated in the internal instructions;
- the pressure from the burner control valve, also called the burner pressure, which must vary depending on the amount of steam delivered by the boiler.

In any case, the gas pressure, irrespective of the boiler operation, must not fall below a certain value to prevent the flame extinguishing hazard.

In the case of liquid fuel or oil, the pressure is to be maintained, which must be maintained at the values indicated in the internal instructions, and the temperature should be between 110 and 1300C according to the internal instructions.

Using a low-temperature fuel can result in a worsening of its spraying (with large splashes), which will have a negative effect on the combustion process.

The combustion air temperature must be kept within the limits given in the internal instructions, depending on both the type of furnace and the nature of the fuel.

The air temperature at the entrance to the preheater must not fall below a prescribed setpoint because the condensation of the water vapor (the dew point) appears, which, together with the sulfur dioxide in the flue gas, forms the sulfuric acid, particularly corrosive.

Such a phenomenon occurs under an inlet air temperature of less than 35-400C and a decrease in the temperature of the combustion gases below 1300C and results in rapid destruction of the preheater by corrosion.

Composition of combustion gases. In the combustion gases, the following indices characterizing the quality of the combustion process are generally observed:

- carbon dioxide (CO2) content: the higher the CO2 content, the closer the theoretical, the better, the fuller the burning; measurement is usually made at the end of the furnace and the exhaust gases to the chimney, using for this purpose apparatus called CO2 analyzers.
- oxygen content (O2): the lower the O2 content, the greater the excess air and the better burning; measurement is done using O2 analyzers, in the same places as the CO2 content.
- The carbon dioxide (CO) content should be as close to zero as the combustion is complete; the measurement is also done in outbreaks and in the basket, using CO analyzers.

Table no. 2 shows optimal values of combustion indices, depending on the main fuels used in our country.

Table no. 2 Optimal values of combustion indices

Fuel type	Maximum theoretical CO2,%	Optimal values,%	
		CO2	CO
Natural gases	11,73	9 – 11	0
Oils	15,6	12 – 14	0
Lignite	18 - 19	10 - 15	0

The values in the table are valid in the outbreak. In the basket, the CO2 content is lower and the O2 is higher due to false air infiltration in the gas channels through masonry, doorways or observation meshes.

Fake air penetration modes are detected by measuring the CO2 and O2 content at different points in the gas channels; the leakages must be removed so that as much as possible the excess air in the basket approaches as much as the excess determined in the outbreak.

To complete combustion and obtain optimal indices, service personnel will track the measured values of CO2, O2 and CO (in some cases CO + H2) and make the necessary adjustments, acting appropriately on the draft, air damper or fan flap.

The temperature of the combustion gases must be followed with all the attention, throughout the entire path through the gas channels to the evacuation to the chimney. In any case, the temperature check will be done in the furnace, after the superheater and the chimney (after the last boiler heating surface).

Of a great importance is the temperature at the chimney because it allows, to a great extent, to draw conclusions on the operating conditions of the boiler.
Increasing the temperature of the evacuated gases above the value prescribed by the boiler builder actually means eliminating a significant amount of heat in the atmosphere, thus lowering the efficiency of the boiler.

The causes may be: soot soiling of the heating surfaces on the side of the combustion gases or deposits of salts in the water on the water-steam side, which leads to the formation of insulating layers by which the heat of the gases is hardly transmitted to the water or the boiler ; Under these conditions, in the chimney, the combustion gases are discharged more hot, the heat surplus actually representing a loss.

Decreasing the gas temperature below a certain value, also indicated by the boiler manufacturer, is also undesirable as water vapor can condense, forming acids that corrode both the economiser and the air preheater to destruction.

Gas temperature measurement is usually done with thermocouples and sometimes with a thermometer.

The draft must be adjusted during the boiler operation so that at the top of the furnace it does not exceed 2 mm H2O (water column).

Resistance to gas passage through channels must be maintained at values set by the boiler manufacturer. If these resistances increase, measures will be taken that the first row of pipes in the furnace is cleaned of slag and the boiler heating surfaces are blown; when blowing it is necessary to increase the depression in the furnace to about 3-7 mm H2O.

Measurement of draft is usually done with U-shaped bent tubes filled with water.

The unbound carbon content embedded in ash or slag is determined by the plant's chemical laboratory (for solid fuel); if the values are higher than the maximum admissible, the causes will be analyzed and appropriate measures will be prescribed.

Watermarks

The flow rate of water consumed by the boiler over a certain period of time is measured with devices called flowmeters or counters and must be consistent with the product flow rate.

Water pressure is measured with manometers. When the water enters the economiser, the pressure must be higher than that of the boiler. If the water pressure in the economiser rises exaggerated, it means that internal deposits have been formed that reduce the cross section; these deposits must be removed.

The temperature of the water is measured with thermometers and must correspond to the values prescribed by the boiler builder both at the entrance and exit of the economiser. A too low inlet water temperature can lead to the condensation of the vapor from the combustion gases with the negative effects described above.

Water chemical indices must match the values indicated by the boiler manufacturer and ISCIR technical prescriptions. Failure to comply with prescribed indices leads not only to a non-economic operation but also creates a risk of damage to the boiler.

Follow-up of these indices is done according to the laboratory or chemical point of the plant, by the specially trained personnel; in the same

way, the necessary measures for setting the indices in the prescribed values are established.

Steam Indicators

The flow rate of the boiler must not exceed the maximum value (maximum flow rate) as determined by the internal instructions. Measurement is done with flowmeters.

Pressure is measured with manometers at various points of which the most important are:

- the drum pressure, which represents the maximum allowable pressure in the boiler, with a red mark on the manometer dial;
- the pressure at the outlet of the superheater, which is the pressure of delivery of the steam to the consumer; it is less than the pressure in the drum.

Constant preservation of this pressure is particularly important, especially in the case of energy boilers (a 1% decrease in pressure results in an increase in turbine steam consumption by 0.7%).

The temperature of overheated steam is also a very important parameter, especially in the case of power boilers; Temperature measurement is done with thermometers.

Increasing the temperature can cause burner overheating.

The chemical indicators of steam, as in the case of water, must comply with the values indicated by the boiler manufacturer and the ISCIR technical prescriptions.

Their tracking is done according to the laboratory or chemical point of the boiler, by specially trained personnel.

Electricity and heat consumption

Electricity or heat used to drive different plants, such as mills, grills, fans, exhausts, fuel pumps or water pumps. It has to be as small as increased consumption negatively influences the net boiler efficiency, as we have shown before.

As a result, service personnel will take all necessary maintenance and periodic maintenance measures for all of these facilities, removing any defects in time.

During the operation of the boiler, there are some situations when the needs of the production process require a smaller or larger quantity of steam; the boiler must respond to these needs by consuming a smaller or larger amount of fuel or water.

Under these conditions, proper maneuvers must be ensured, so that the combustion is complete, carbon-free and unburned; in other words, proper adjustment during operation must be ensured, which mainly involves the following: combustion control, water supply adjustment and draft control.

Combustion control

Combustion control is, in fact, a complete firing, which means avoiding unpleasant fuel losses.

Combustion control is performed chemically by using automatic CO2, CO + H2 and O2 analyzers. To achieve this control, the appliances must be kept in the best operating conditions; for this purpose, they will be checked daily, with particular attention to the fact that gas sampling devices are not clogged. The correct functioning of these appliances must be checked periodically with specific analyzers, burning being considered as appropriate, when CO, H2 and CH4 are missing in the combustion gases.

The boiler servicing staff must ensure a consistent correlation between the boiler steam flow and the following elements: fuel quantity, combustion air quantity and boiler draft.

The adjustment operation is executed in a certain order, acting on the elements mentioned above. Thus, if the boiler load increases, you will first increase the draft, then the amount of air and finally the amount of fuel. In this way, it is possible to increase the amount of fuel, the air introduced to ensure complete combustion, and the draft, the evacuation of the increased amount of combustion gases.

When lowering the boiler load, the maneuvers to be executed are the same, but in reverse order.

Fuelist interventions on fuel, air and draft have to be done slowly, without great leaps, ensuring constant control of the exhaust gas, which actually indicates the quality of the combustion; this control can also be ensured by observing the flame in the furnace or the smoke evacuated on the boiler basket; in the case of a suitable burn, the flame must be yellow-lighted, with uncolored peaks and contain the entire chamber of the furnace, and the smoke to be colorless.

If the flame in the outbreak is yellow to red, orange, or even red means burning is inappropriate, to white, with elongated tongues, it means burning takes place in excessively high air conditions. In the first case, smoke in the basket is black and thick, and the second is colorless.

Fuel adjustment is provided differently, depending on the type of fuel.

In the case of solid fuel burned on the grill, the following operations will be performed:

- Adjusting the fuel layer, ensuring uniform spread of it on the grill; the thickness of the layer depends on the fuel grain size and the type of grill and is established by the internal instructions;
- adjusting the speed of the grill;
- removing the slag from the grill.

In the case of solid fuel burned as dust, the following are required:

- permanent maintenance of the flame by: proper supply of the burners, ensuring an optimal pressure of the inspiration air and a corresponding draft;
- adjusting the amount of fuel required either by operating the dust metering unit (fine adjustment) or by removing a certain number of burners (coarse adjustment) from operation.

Adjustment of the liquid fuel is ensured by proper handling of the oil, steam and injection valves; As with dust coals, a rough adjustment can also be ensured by stopping burners.

In the case of gaseous fuel, the adjustment is ensured in the same way as for the liquid fuel.

Adjusting the amount of air required for combustion is ensured by acting on the air flaps and on the air fan speed (in the case of the insulated air).

Of particular importance for the proper operation of the boilers, in the conditions of minimum fuel consumption, is keeping the losses in the basket at minimum values.

These losses depend in a ratio directly proportional to both the temperature of the combustion gases and the excess air; for the maximum values of excess air, the following values are recommended, as a percentage:

- manually fired outbreaks 0.40
- mechanical food furnaces:
- with coal grate (huila) 0,35
- with lignite barbecue 0,30
- outbreaks for pulverized coal 0.25
- outlets for liquid fuel 0,15
- gas fired furnaces 0,15

The aspiration of fake air in different areas of the boiler is recommended not to exceed the following maximum values, expressed as a percentage, of the theoretical air consumption:

- first batch of boiler pipes 0,05
- the second batch of boiler tubes 0.05
- overheater 0.02
- economizer with serpentine 0.05
- rotary air preheater 0.20
- gas channels (each up to 10 m in length) 0,01
- ash capture plants with cyclones 0.05

In order to determine the fugitive air penetration point in the boiler, it is necessary to determine the CO2 and O2 content of the combustion gases route, taking the necessary measures as necessary.

Adjusting the water supply has a permanent correlation between the quantity of steam, hot water and the supply water.

This adjustment is done with the help of the feeders, requiring careful monitoring of the water level in the boiler.

A uniform supply is made by checking the proper functioning of water gauges by tracking steam and hot water indicators, as well as tracking water consumption indicators.

Generally, when running at nominal flow, the water in the level bottles must have slight oscillations at the normal level. If the necessities of the production process require the boiler to operate at a lower flow, the level must be slightly exceeded; Conversely, in case of high load operation, the water level should be slightly below the normal level.

In situations where the water level in the boiler is tracked on a control panel it is necessary to check the level at least three times per shift, directly on the indicators on the drum.

If the water supply is made by two independent pipes, it is necessary that both pipes be under pressure and be monitored permanently. Any drop in pressure on the supply lines must be signaled by the emergency at the pumping point to take the necessary action, as appropriate.

The backup feed pumps must be ready to operate whenever necessary.

Running control implies a permanent correlation between the amount of steam produced and the pressure in the smoke channels, which is generally achieved by the proper (closing or opening) operation of the combustion gas register and by the variation of the exhaust speed, if any.

If there is an increase in resistance on the flue gas ducts, measures must be taken to blow the heating surfaces, also for the slag cleaning of the first rows of boiler pipes. Blowing the heating surfaces will usually take place at least once per shift, at an enlarged depression in the furnace (3-7 mm water column).

Hot water boilers usually work with a constant flow of water, regardless of the thermal load, taking the variation of the load by varying the inlet and outlet temperature of the boiler.

Some hot water boilers operate in two regimes, both basic and top. In the basic regime, the water splashes the heating surfaces in series, and in the peak regime, by introducing some diaphragms, the water circulates in parallel.

Adjustment of the load is usually accomplished by maintaining a certain number of burners, namely one or two air fans, as the case may be. Air blowers have the ability, in turn, to adjust their flow through the action of some shutters located on the suction side.

Conclusions

An economic burning has to be characterized by the following indices:

- CO2% high in the outbreak and in the basket;
- O2% lack in the outbreak and lower in the basket;
- CO (or CO + H2)% lack both in the outbreak and in the basket;
- Gas temperature at the boiler: at the value indicated by the boiler manufacturer;
- Carbon content in ash and slag: as small as possible

- Appearance of the flame in the outbreak: bright yellow, no black peaks, no red dye
- Smoke appearance on the basket: uncolored

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