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CONTROL OF THE QUALITY AND QUANTITY OF FUEL AND HEAT AGENT

Asist.dr.ing. Daniela PANĂ
UNIVERSITY OF GALATI "DUNAREA DE JOS",
FACULTY OF ENGINEERING AND AGRONOMY,BRĂILA
daniela.pana@ugal.ro

ABSTRACT

Boiler installations are designed, and their optimal operating regimes are established for certain fuels with a certain working composition.
Any deviation from the composition of the fuel for which the firebox was built can lead to a different operation from that designed, both in terms of obtaining technical-economic indices, and in terms of safety and endurance in the operation of the boiler. To prevent these phenomena, it is necessary to carry out a permanent and systematic control of the quality of fuels.
Fuel samples must be taken according to STAS provisions.

KEYWORDS: boilers, operating regimes, calorific value, humidity, gaseous fuels, granulation, ash percentage

1. INTRODUCTION

The volume of air required for combustion is almost 2000 times greater than the volume of fuel, and in order to ensure the combination of oxygen in the air with the fuel elements, it is necessary for the air to come into contact with the surface of the fuel for the chemical reactions to take place.

Cannot ensure this perfect mixture with theoretical air alone, in order to achieve the combination of oxygen with the combustible elements, a volume of air for the unit of fuel greater than the theoretical one is introduced into the hearth. This surplus called excess air, together with the theoretical one, constitutes the real air required for combustion (L).

The greater the excess air, the more uneconomical the combustion plant, because the same amount of heat lost by combustion by 1 Kg of fuel will be contained by a greater amount of gases, and their heat content and temperature will be smaller, which will also reduce the transmission of heat to the heating agent surfaces of the boiler.

To raise the temperature of the gases to the working temperature in the boiler, in the case of excess air greater than the optimum, it is necessary to consume an increased amount of fuel to heat the excess air, bringing it to the operating temperature and then removing 1 together with the gases at the chimney.

During the operation of boilers, maintaining the air-fuel ratio within the established limits of excess air is of particular importance both for eliminating the possibility of incomplete combustion with the formation of carbon monoxide, a combustible element that can appear in the gases when operating below the optimal excess, and for eliminating the additional fuel consumption for heating the excess air and exhausting it to the chimney.

Running with excess air above optimum excess also results in additional electrical energy consumption, both for air and draft fans.

In natural draft installations, it can cause the draft to decrease, having negative influences on the combustion process in the hearth.

In the current stage of development of boiler aggregates, it is aimed that the mixture and the air-fuel ratio to be achieved in the burner, at the exit from the burner and in the hearth. In automatic burners, the command impulse to close or open the air and fuel flaps is generally given by the pressure or temperature of the heating agent. When the pressure rises above the nominal one, the given impulse leads through the drive system to reduce the air-fuel ratio.

In order for the combustion to be complete and economical, the value of the optimum excess air coefficient must be determined experimentally, taking into account the elemental composition and nature of the fuel being burned, as well as the combustion installation.

To ensure optimal combustion, with minimum specific fuel consumption required for the production of the thermal agent, a permanent control of the combustion process is required.

In order to be included in the economic indices of consumption, respectively the optimal operation of the boiler installation, combustion control is performed to determine:

- the quality and quantity of the fuel introduced into the firebox;
- the degree of combustion of the fuel and the excess of air with which the combustion is carried out, determined by the analysis of combustion gases, ash and slag;
- the values of the parameters of the heat agent and the products of combustion in different areas of the boiler, such as: the temperature of the combustion gases, excess air and draft in the hearth and at different points on the way of the gases to the chimney;
- the state of the air-fuel mixture when entering the firebox

From the samples collected, the following will be determined: caloric power, humidity; for solid fuels - granulation, percentage of ash and volatile matter, grinding fineness; for liquid fuels - specific gravity, viscosity, freezing temperature, sulfur percentage.

These values must be within the limits of the characteristics of the fuel with which the boiler installations were intended to operate.

In order to control the economic performance, it is necessary to know the amount of fuel consumed and the amount of heat agent produced in the unit of time.

Gaseous and liquid fuel are measured with different flowmeters, and solid fuel by weighing.

The heat agent is measured with steam flowmeters or gigacalorimeters, the impulse being taken from the measurement diaphragm, mounted on the heat agent pipes.

Depending on the laboratory tests, some fuel characteristics can be divided as follows:

- the degree of humidity higher than the one provided will be reduced until it is introduced into the hearth, by drying or additional preheating of the air that drives the coal dust over the hearth;
- fuel with a smaller grain size than the one provided will be mixed with a fuel having a different grain size, to reduce the percentage of improper grain size per unit weight;
- when the percentage of combustible elements is reduced, the composition of the fuel can be improved by mixing it with higher fuels;
- when the percentage of sulfur exceeds the allowed one, the fuel will be added to avoid premature corrosion of the metal surfaces of the boiler.

To achieve the optimal air-fuel mixture and its uniform injection into the hearth and in order to eliminate the possibility of producing different temperatures in certain areas of the hearth, the burners and injectors must be adjusted and permanently maintained in normal operation.

In case of obtaining specific consumptions below the normed ones, it is necessary to check the accuracy of the recording or indication of the heat and fuel flows by the measuring and control devices, an operation that is carried out by the specialized personnel of the enterprise and to metrologically control these appliances.

The elimination of the reported causes and deficiencies make the operation of the boiler occur at the designed technical-economical and safety parameters.

2. COMBUSTION GAS ANALYSIS

Deviations from the economical operation of a boiler plant are indicated by the carbon dioxide content in the flue gases.

According to the percentage of carbon dioxide, the excess air in the hearth and between the various heat exchange surfaces in the gas channels to the chimney can be determined, which depends on the quality of the combustion and the main heat losses produced with the combustion gases.

If the combustion were complete, without excess of air, as seen, the dry burnt gases should contain only carbon dioxide, nitrogen, and very little sulfur dioxide. In order to be able to achieve a complete combustion, an optimal air excess is necessary.

In this case, the burnt gases also contain a certain amount of oxygen, so the actual carbon dioxide percentage is lower than the optimal percentage.

The optimal percentage of carbon dioxide must be established for each type of fuel and for each type of firebox, taking into account the false air infiltrations, maximum admissible, on the path of the combustion gases to the chimney.

Lack of air leads to incomplete combustion and uneconomical operation. In case of lack of air, the combustion gases contain carbon monoxide or other unburned combustible elements.

From what is shown, it follows that the

percentage of optimal CO_2 can decrease both in the case of operation with excess air above the optimum, in which case the carbon dioxide is more diluted in the volume unit, and in the situation of operation with insufficient air, in the case of which, instead of the carbon being transformed entirely into carbon dioxide, part of it reaches the stage of carbon oxide - fuel element.

In the first situation, the volume of false air reduces the economic operation of the boiler, because it takes a quantity of heat from the combustible elements and removes it together with the flue gases. In the second situation, the carbon monoxide, entrained in the chimney, yields through complete combustion 3050 kcal/m3N, which, due to lack of air, does not burn and is eliminated in the chimney.

The readings of the CO_2 and CO monitors must be constantly monitored and the combustion adjusted so that the CO_2 is at the optimum value and the CO around 0. The maneuver is to reduce the air until the CO_2 indicator reaches a maximum value, and the CO meter shows zero or just above zero, as prescribed by the operating instructions.

If the value of carbon monoxide is higher than the maximum admissible (0-0.1) %, this means lack of air and the air valve should be opened or the fuel inlet should be closed.

If the air-fuel ratio is adjusted automatically, and the devices and analyzes for the determination of the percentage of CO_2 and CO indicate different values from the optimal ones, it follows that there has been a malfunction in the automatic air-fuel intake system.

For the correct adjustment of the amount of air required for combustion, the firebox must be equipped with electric gas analyzers, which permanently indicate the content of carbon dioxide and carbon monoxide + hydrogen, in order to maintain an economical operation.

The analysis of combustion gases can be done with electrical devices that are based on regime change and the imbalance of an electrical bridge; this, through calibration, indicates the percentages of the gases being analyzed.

Gas analysis can also be done chemically, a process by which the analyzed gas is absorbed by a certain solution, reducing the volume of sample gases by the volume of the gas absorbed by the chemical solution which comes into contact with.

The ORSAT device is the most widespread and gives good results in the analysis of combustion gases; with its help, the CO_2+SO_2 content can be chemically determined; O_2; Co. Every boiler owner must be equipped with such a device.

In the figure below (fig. 1), the operating diagram of the ORSAT device is presented. This apparatus is composed of the following parts: a vessel with a capacity of 100 cm3 (6) for measuring the sample gases (graded in cm3) which are absorbed using the vessel filled with colored water; three absorption vessels (5), which contain the chemical solutions for the absorption of carbon dioxide, oxygen and carbon monoxide. Each vessel is provided with a shut-off valve (4) and is connected to a common point (1) which connects it to the gas measuring vessel (6) when the valve is opened.

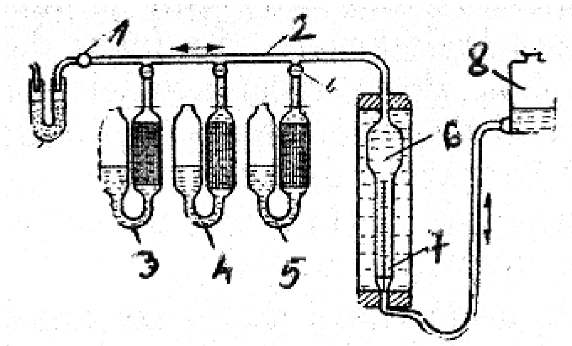

Figure 1. ORSAT gas analyzer 1 deck; 2 3-way faucet; 3-filter; 4-tap; 5-absorption vessels; 6-measuring vessel; 7-bowl with water; 8- work vessel

A three-way valve (2), placed on the common pipe, offers the possibility by maneuvering to close the bridge, to isolate the device from the ambient environment and, at the same time, to connect the bridge to the pipe through which the gases are sucked measured. The gases pass through the filter (3) to retain impurities. With the help of the working vessel (8) the bridge is connected to the environment.

The solution in the first carbon dioxide holding vessel consists of a potassium hydrate (KOH) solution with a weight composition of 33% KOH and 67% H_2O.

The oxygen holding solution in the middle vessel consists of pyrogallic acid $C_6H_3(OH)_3$ with a weight content of 13% $C_6H_3(OH)_3$, 29% KOH and 58% H_2O.

The carbon monoxide trapping solution consists of an alkaline mixture of copper chloride $(Cu_2Cl_2)_2$ of 17% by weight Cu_2Cl_2, 25% NH_4Cl (ammonium chloride) and 75% H_2O.

Before filling the absorption vessel with reagent, a 25% solution of ammonium chloride (NH_4Cl) diluted in water is added to 1/3 of the volume of water.

It should be noted that, after the retention of carbon dioxide by the solution in vessel 1, the volume of gases is reduced in vessel 6 by the percentage of CO2 absorbed. After passing the gases through the oxygen retention solution, the volume percentages of oxygen are added to the percentages of carbon dioxide with which the gases in the work vessel are reduced (6). By the difference between the two volumes in the work vessel (6), the percentage of oxygen in the combustion gases is obtained. The volume percentages of carbon dioxide are also determined in the same way; after passing the gases through the CO gas holding solution in the measuring vessel, a smaller volume of gases is obtained, if there is CO in the flue gases. Depending on the results obtained, it can be concluded whether the boilers work economically or not.

As an inconvenience of carrying out the analysis of the combustion gases by chemical means, it presents the fact that the analyses are discontinuous and the composition of the combustion gases cannot be monitored continuously, so that the stoker intervenes operatively manually or through the automation installations in order to regulate the combustion. To eliminate this shortcoming, the boilers are equipped with electrical analyzers, and in some cases, the parameters are indicated by recorders.

The electric device for determining the content of carbon dioxide in the combustion gases (fig. 2) is basically based on the difference between the thermal conductivity of carbon dioxide, which is about 60 times lower than the thermal conductivity of air and carbon dioxide. The thermal conductivity of carbon dioxide is about 60 times lower than the thermal conductivity of air. This leads to a different heat exchange between the platinum conductors of the device in contact with air and carbon dioxide respectively.

The device has two analysis chambers in which two pairs of thin platinum wires are mounted, electrically heated to a temperature of about 1000C. The burnt gases are passed through one of the chambers, and the air is passed through the other. The higher the CO2 content of the flue gases, the lower their thermal conductivity, and the wires heat up more than the wires in the room through which air with high thermal conductivity passes.

The higher the temperature of the platinum wire, the higher the electrical resistance.

The platinum wires in the chambers through which the air and gases circulate constitute the resistances of an electrical bridge. With the help of a galvanometer, the carbon dioxide content in the combustion gases can be determined. Before introducing the gases into the apparatus, the bridge is in equilibrium and the galvanometer pointer is at the zero position on the scale. When gases with a determined content of CO2 pass through , as shown, they alter the electrical resistances, the bridge becomes unbalanced, and the galvanometer indicates a certain value which is noted as the known quantity of the percentage of CO2.

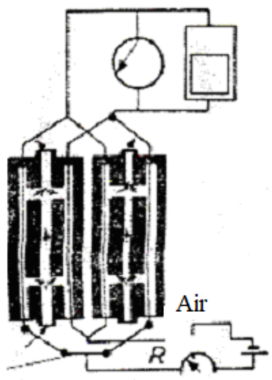

Fig. 2. Electrical device for determination carbon dioxide content in the burnt gases

In this way, the galvanometer is calibrated directly in percentage of CO2. The presence of hydrogen and carbon oxygen in the flue gases can give erroneous indications when measuring carbon dioxide, since hydrogen has a thermal conductivity of about 7 times that of air, and the low percentage of CO2 could be thought to come from combustion incomplete, in reality being, however, a lot of excess air with high thermal conductivity. To be able to establish the reality, it is necessary to determine the percentages of carbon oxide and hydrogen in the combustion gases.

The electric apparatus for determining the content of carbon oxide and hydrogen in the burnt gases figure (fig. 3) consists of two analysis chambers in which there are two electrically heated platinum resistors. The stream of burnt gases with about 30% air is passed into the analysis chamber over the electrically heated wire. In the presence of air, carbon dioxide and hydrogen burn, giving off a quantity of heat and, thus, the temperature of the wire increases, therefore its electrical resistance increases as well.

The platinum wire in the air chamber lowers its ignition resistance by cooling. And these platinum resistances are the resistances of an electrical bridge that goes out of balance, in the case of the existence and combustion of carbon dioxide and hydrogen in the combustion gases.

A constant and continuous stream of hydrogen, prepared by electrolysis, is introduced into the burnt gases in one of the hydrogen, prepared by electrolysis, is introduced into the burnt gases in one of the chambers of the device. The mixture is passed through the other chamber and burned. The oxygen content is determined with the help of measuring chambers, equipped with platinum wires, heated electrically up to about 800C. The burning of hydrogen indicates that oxygen has been found in the combustion gases.

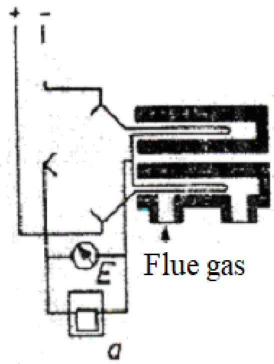

Fig. 3. Electric device for determination the content of carbon dioxide and hydrogen in the burnt gases

The heat released by the burning hydrogen heats the platinum iron, increases its electrical resistance and unbalances the bridge. The indicator device is calibrated, with a previously known gas, directly in percentage of oxygen.

The indicator device is calibrated, with a known gas, directly in percentages of what CO + H2. The device can give errors when there is steam in the combustion gases, which has a thermal conductivity of about 30% higher than air.

The oxygen meter is the electrical device for determining oxygen in combustion gases (fig. 4) that works according to the same principle as the electrical device for determining carbon dioxide.

If the nitrogen in the fuel is not taken into account and the combustion is complete, i.e. CO is zero, the oxygen is determined with the formula:

$$O_2 = 21 - \frac{21}{\alpha} \qquad (2)$$

The most widely used electrical devices are those for the determination of carbon dioxide, hydrogen and carbon monoxide.

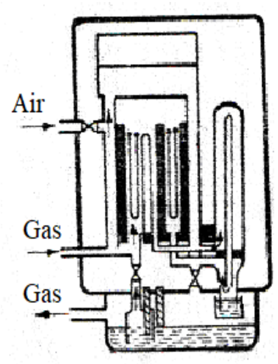

Fig. 4. Electric device for determination of oxygen in the burnt gases

Oxygen is determined from the Oswald diagram(figure 5) constructed for different fuels, depending on their working composition, or from the excess air formula:

$$\alpha = \frac{21}{21 - 79\,\dfrac{O_2 - \dfrac{CO}{21}}{N_2^{a}}} \qquad (1)$$

Knowing the temperature of the flue gases and their composition, the thermal balance of the boiler can be calculated by the indirect method, the heat losses through the walls being determined from different diagrams.

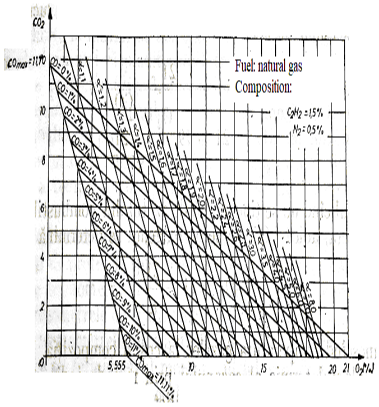

Fig. 5. Diagram Oswald
Fuel: natural gas

3. CONCLUSIONS

As an inconvenience of carrying out the analysis of the combustion gases by chemical means, it presents the fact that the analyses are discontinuous and the composition of the combustion gases cannot be monitored continuously, so that the stoker intervenes operatively, manually or through the automationinstallations in order to regulate the combustion. To eliminate this shortcoming, the boilers are equipped with electrical analyzers, and in some cases, the parameters are indicated by recorders.

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