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CALCULATION OF BURNERS

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ABSTRACT

Overall, one can not talk about a general method of calculating the burners, because the very different types of construction and the diversity of fuels used impose a special calculation method for each burner.
There is, however, a series of burner organs with a wide use in the construction of many types, for which a suitable calculation method can be established.

KEYWORDS: *Gas burner, fuel and combustion chamber, nozzle, combustion air*

1. INTRODUCTION

The combustion process is a physical and chemical phenomenon by which combustible substances combine with the oxygen produced by the combustion air, resulting in combustion gases and an amount of heat as the heat effect of the reaction.

The chemical aspect of the combustion takes into account the material balance that occurs during combustion and the release of the heat that takes place.

The physical aspect of combustion takes into account the aerodynamic factors that determine a certain rate of reaction and the thermal factors that determine the participation of certain heat flows in the various stages of combustion. Practically, the two aspects, both chemically and physically, can not separate, influencing each other.

On the other hand, if combustion is conditioned by aerodynamic and thermal factors, it is easy to understand that the combustion process can not be studied independently of the burner in which the combustion process takes place.

2. PHYSICAL APPEARANCE OF BURNING

The actual combustion process is not the one described by chemical oxidation reactions, they only mark the initial state and the final state of the system.

In fact, a very large number of intermediate reactants, in which they appear and transform with very high rate of unstable intermediate products (free radicals), characterize the burning process from the point of view of its evolution: speed, heat inputs, elements that inhibit the reactions . Such a process is called the chain reaction.

The burning process begins by heating a certain volume of the fuel mixture to the reaction temperature locally, after which the heat generated by the local reaction continues to prime the reaction in the surrounding volumes.

The large amount of heat released during the process leads to a strong rise in temperature, which in turn accelerates the combustion reactions following an exponential law. This phase is called ignition.

3. THE CHEMICAL ASPECT OF COMBUSTION

In a complete combustion, combustible elements C, H, S are transformed by oxidation into CO2, H2O and SO2.

In addition to the oxidation products, the N2 nitrogen from the combustion air and the water, in the form of vapors, derived from the fuel constituent and from the air humidity, are obtained in the combustion gases.

However, technical combustion does not occur with theoretical air necessary for combustion because incomplete combustion may occur due to inherent non-homogeneity in the mixing of the fuel and the air.

This leads to important energy losses because a fuel that does not burn completely or emit all the heat that it would give in the complete reaction. That is why in all combustion processes, an excess of air is set at a value that ensures complete combustion.

The burning is not done with excessively large excess of air because in this case there are increased losses through the enthalpy of the exhaust of the combustion gases.

Indeed, the combustion gases are evacuated from the plant at a temperature of 420-500 K, determined by the heat exchange conditions, and consequently the excess air will be evacuated with the combustion gases at the same temperature.

The method of calculating a burner will therefore consist in separating it from simple structural and functional elements and calculating them by known methods.

The organs common to all the burners are the air and fuel feed ducts, consisting of feed pipes and flow shut-off controls, air-fuel mixers, and combustion fuel inlets.

In the case of liquid fuel burners, the mixing system is preceded by a fuel spraying system.

4. CALCULATION OF PIPELINES

Based on the design of the bell pipe, it is divided into simple elements: straight sections of pipes, elbows, loudspeakers, valves, flaps, etc.

For each of these elements, the flow rate characteristic and the coefficient of resistance $\lambda \frac{l}{d}$ or ξ .

Then calculate the load on each element and it is appreciated if the value of the elemental and total fall is acceptable-corresponds to the available pressure-or if other dimensions have to be selected.

A particular case of calculation is that of the self-aspirating gas burner piping, which has an ejector in its construction.

The diagram of this ejector is shown in figure 2.1.

The gas enters the burner nozzle where it goes at high speed into the mixing chamber.

In this room, the air from the ambient air is sucked in on the gas jet energy.

In the mixing chamber, there is also the air-gas mixture, which then flows through a divergent nozzle into the combustion device.

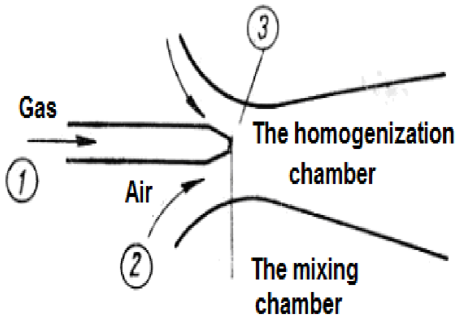

Figure 2.1. Ejector scheme.

The calculation of the ejectors aims at determining the various passages of the gases and the corresponding lengths.

Of particular interest is the calculation of the optimum size of the cylindrical section of the mixing chamber relative to the exhaust section of the entraining gas nozzle, which must correspond to an optimal efficiency of the ejector or a maximum pressure value at the end of the diffuser under the conditions of a Coefficient of injection μ.

A simplification that is adopted in the calculations is the neglect of the degree of unevenness of the gears at the beginning and at the end of the mixing chamber.

The basic relationship from which we start, resulting from the movement quantity theorem, is:

$$\omega_1 G_1 + \omega_2 G_2 - \omega_3 G_3 = \left(P_3 - P_2\right) S_3 \quad (1.1)$$

where:

- ω is the speed; G-mass flow; P- pressure; S- the section, and the indices correspond to the sections in the figure.

5. PREPARING THE FUEL AND BLENDING IT WITH THE COMBUSTION AIR

Fuel preparation is a process specific to liquid fuel burners, in which case it is necessary to spraying the fuel before mixing it with the air.

There are numerous researches that have pursued the establishment of the theory of pulverization by pressure or by air entrainment. All these theories use the law of impulse and energy conservation to deduce the final state from the original state.

However, because the phenomenon is very complicated, the method of calculating the spraying consists in adopting experimental coefficients and expressions in the formulas that link the theoretically deduced functional criteria.

Practical formulas for spray calculation follow the dmed definition and the maximum dmax diameter of droplets.

The main influential factors are presented below.

In the case of mechanical spraying:

$$d = f\left(k, \eta, \sigma, \frac{1}{\omega^2}\right) \tag{1.3}$$

Where: k - coefficient depending on the nature of the fuel;

η - fuel viscosity;

σ - superficial tension;

ω - exit nozzle speed

It is worth mentioning the possibility of intervention for the reduction of the diameter by increasing the temperature of the fuel, with effect on the decrease of the viscosity and the increase of the pressure, with effect on the increase of the exit speed.

In the case of spraying fuel by air, the calculation formula depends on the following factors:

$$d = f\left(k, \eta, \sigma, \frac{1}{\omega_{rel}}, \frac{D_c}{D_a}\right) \tag{1.2}$$

where: ω_{rel} - is the relative air velocity relative to the fuel;

D_c and D_a - are the flows of fuel and spraying air.

It is noticed the possibility of intervention for shifting the diameter d by increasing the temperature of the fuel, by increasing the relative speed of the spraying agent and by increasing the ratio of air-fuel flows.

Another characteristic of the jet is the spraying angle α, which is important because the mixing of the fuel droplets with the combustion air in the case of mechanical spraying is progressively made out of the burner, as the drop of the droplets escapes.

The angle of junction of the jet is calculated with the following formula:

$$\frac{\alpha}{\alpha_0} = C\left(\frac{R_c}{r_e}\right)^{-0,5} \cdot \pi_1^{-0,5} \cdot \pi_2^{-0,1} \tag{1.4}$$

where:

R_c - swirl chamber radius;

R_e - radius of the exit nozzle;

α_0 - the theoretical spraying angle for the ideal fluid;

π_1 - geometric invariant;

π_2 - the dynamic invariant

Figure 3.1 shows the characteristic dimensions of the injector.

The theoretical spraying angle is determined from:

$$\alpha_0 = f\left(A, \varphi, n\right) \tag{1.5}$$

where A is the geometric characteristic:

$$A = \frac{R_c \cdot r_e}{z \cdot r_t^2} \tag{1.6}$$

Knowing the geometric characteristics A allows further determination of the fill coefficient φ of the nozzle exit section:

$$\varphi = 1 - \left(\frac{r_a}{r_e}\right)^2 \tag{1.7}$$

where r_t is the radius of the tangential inlet of the fuel chamber and the radius of the outlet of the turbine.

In formula (1.5) the jet recirculation coefficient n appears, which is the ratio between the fuel flow entering the Q_e furnace and the total fuel flow introduced into the vortex chamber Q_t.

$$n = \frac{Q_e}{Q_t} \tag{1.8}$$

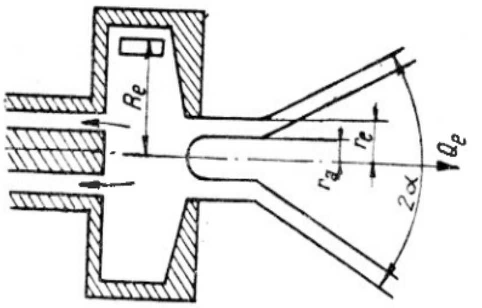

Figure 3.1. Swirl injector scheme.

The invariations in the relationship (1.4) have the following expressions:

$$\pi_1 = \frac{8\sigma \cdot f_e}{\mu^2}; \tag{1.9}$$

$$\pi_2 = \frac{\varpi_e \cdot \mu}{\sigma}; \tag{1.10}$$

For conventional exit speed, it is permitted:

$$\varpi_e = \frac{Q_e}{\pi \cdot r_e^2} \qquad (1.11)$$

In the case of gaseous fuels, the calculation of the mixing process is based on the application of pulse and energy laws.

If a gas vapor coming out of a diameter hole d with velocity ϖ_g has to travel through the air gap B/2 to achieve homogenization, then the length of the route A required according to figure 6.18 is calculated starting from the system of equations:

$$\begin{Bmatrix} l_g + l_a = l_{am} = const \\ E_g + E_a = E_{am} = const \end{Bmatrix} \qquad (1.12)$$

In the case of sprayed solid fuels driven by primary air, mixing with secondary air can be calculated from similar relationships with the above, of course, taking into account the density of the suspended air.

The homogenization calculations can be made only on the path preceding the entry of the mixture into the furnace because all the calculation formulas assume the isothermal flow hypothesis.

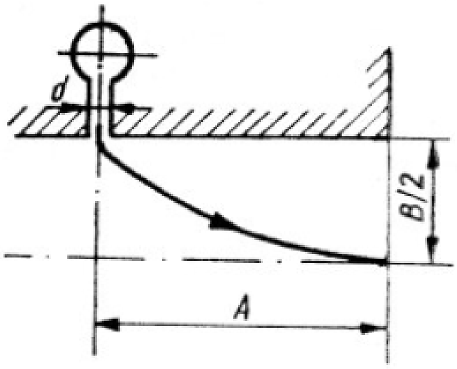

Figure 3.2. Scheme of gas vapor penetration in the air jet.

6. CONCLUSIONS

Inside the furnace homogenization proceeds at the same time as the burning process, if it has not been done before;

This complex process can only be studied experimentally on existing models or outbreaks.

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