PROPORTIONAL MIXERS
CHAPTER 4

LOW-PRESSURE FORCED-AIR COMBUSTION SYSTEMS

Most industrial heat processes rely on burners featuring a wide range of capacity and capable of burning in combustion chambers in different conditions of positive counter-pressure. Such conditions suggest relatively high mixture pressures and air-gas ratios in the range of 75÷100 be adopted.

In order to do this, particularly with low gas pressures, it is necessary to adopt forced-air combustion systems.

As we have already said (see Ch. 1) there are 10 m^3 of air per m^3 of natural gas in a 100% mixture of air and natural gas. As the quantity of air is greater than the quantity of gas it is convenient to exploit the energy supplied to the air by a blower to entrain the gas and obtain at the same time a mixture pressure suitable for the needs of the burner. "Proportional" or "forced-air" mixers (see fig. 6) utilize the energy obtained from the compression of the air to some hundreds of a millimetre of water column, to entrain the gas and create a 100% or less mixture and send it at high pressure to the burner. This mixer works exactly on the same fundamental principles of the venturi described in chapter 2.

In well-designed "proportional" mixers with an air pressure of 700 mm H_2O, mixture pressures (P_3) of 200÷300 mm H_2O at the nozzles may be obtained as well as some draft in P_2 of 25 mm H_2O and more.

In order to obtain a constant air-gas ratio at every capacity by changing the air pressure, it is necessary to bring the gas pressure in A_2 to "zero" that is the atmospheric value. There are equipments, the so-called zero governors capable of keeping such neutral value of gas pressure constant by regulating the capacity according to the capacity of the mixture air. With a view to keeping the air-gas ratio constantly in equilibrium, it is ncessary that the three pressures (the air, gas and mixture pressures) and the three areas (the air, gas and mixture pathways) stay adequately in equilibrium and in the correct ratio one to the other.

The number of burners applied to a specific heat process and their heat capacity are conditions which are typical of the process itself. Which mixer to use with the whole equipment depends on the correct dimensioning of the area A_1 of the mixer relating to the total area of the burners, thus the capacity of the mixer must correspond to the capacity of the burners. In other words, a mixer having a specific area A_1 is chosen when its capacity and the capacity of the area A_3 of the burners are known.

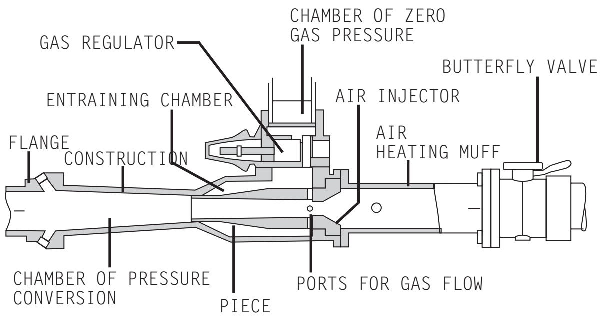

Fig. 06

FIG06

Usually, once the mixture pressure needed by the burners to obtain a specific heat capacity is known, the mixer which allows to obtain the same capacity as the burners at the desired mixture pressure is chosen. The choice of a mixer on the basis of the areas may sometimes be difficult, unless the discharge coefficients of the burners are known. As we have already described in Chapter 2, such coefficient accounts for the efficiency of an orifice. In practice it is as if it modified the real area of orifice A_3. A burner nozzle acts exactly as an orifice, as the fluid flowing through it is subject to a pressure drop right in that point.

Manufacturers of burners always supply their burners with all the technical data allowing to choose the best mixer in relation to the areas of the burners. These instructions should be followed accurately.

Proportional mixers are characterized by the fact that they allow for the regulation of the two fluids via the control over one of the two. Upstream of every mixer a butterfly valve is usually placed which is designed to control the pressure of the air sent to the injector of the mixer itself. A different valve is placed between the gas atmospheric regulator and the mixer to find out the area A_2 of the mixer; this valve is usually equipped with a locking device. Once the correct position of the valve has been decided, in order to obtain the desired air-gas ratio, it is not necessary to perform other regulations for the mixer over its entire flowfield. This type of equipments usually allow to obtain a very wide range of capacity, keeping the ratio of pressure P_1 to P_2 constant. For instance, with an initial air pressure of 700 mm H_2O, the flowfield may be 16 to 1.

ATMOSPHERIC REGULATORS OR ZERO GOVERNORS

I Zero governors (see fig. 7) are designed to reduce the pressure of a fluid to the value of the atmospheric pressure. They are 2-diaphragm units where the first diaphragm, which is called calibration or sealing diaphragm, is designed to separate the gas inlet chamber of the regulating body from the chamber under the main diaphragm; the second one, called main diaphragm, is designed to balance the outlet pressure in the lower chamber of the diaphragm with the atmospheric pressure in the upper chamber.

The spring of these regulators is only designed to counterbalance the weight of the internal mobile parts and possesses an additional voltage which is barely sufficient to close the valve.

The small sealing diaphragm is shaped in order that its surface is the same as the real area of the valve disc. In this way the variations in the boost are cancelled (as for the effects of the valve position) as they counterbalance on the 2 similar surfaces.

The upper chamber of the main diaphragm is usually in communication with the atmosphere, whereas the lower chamber is in communication with the chamber of the pressure regulated downstream of the valve via an impulse orifice. With equal pressures in the chambers under and over the main diaphragm, the valve stays closed. When a mixer starts working, the entraining created by the mixer decreases the pressure in chamber (2). The difference in the pressure which results between chambers (1) and (2) forces the valve to move downwards hence allowing the gas to flow through the system. The gas flow increases until the pressure downstream is the same as the atmospheric pressure in chamber (1). This is possible because the pressure downstream, through the impulse orifice, is transmitted to chamber (2) of the diaphragm.

When the entraining created by the mixer is increased, the pressure downstream of the valve decreases. This entails an insufficiency between the existing pressures in chambers (1) and (2), forcing the valve to open again until the system reaches some equilibrium.

If the spring is calibrated so as to compensate the weight of the internal parts, the pressure downstream of the valve will always be the same as the pressure in chamber (1) of the regulator.

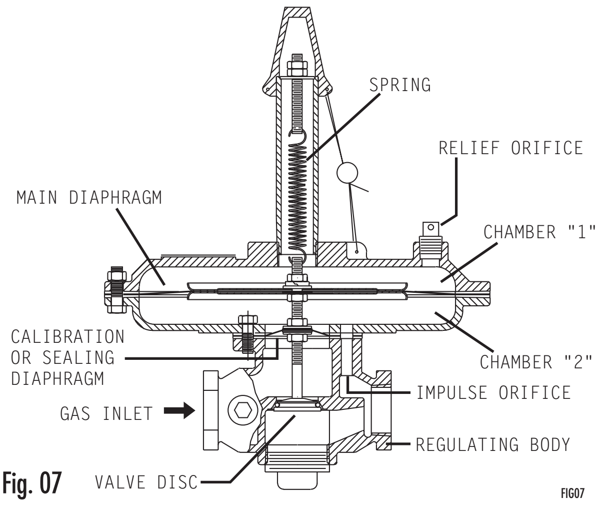

Fig. 07

Should we apply a positive or negative pressure in this chamber, downstream of the valve a pressure would result which would be exactly the same as the pressure applied to the upper part of the main diaphragm. That is why the relief orifice of cahmber (1) must never be connected via any exhaust pipe to the chimney, as is the case with standard pressure reducing valves.

Zero governors are precision equipments. They are built and assembled following severe criteria and little tolerance. The softness of the diaphragm and the spring tension are very delicate features of these equipments. It is difficult to repair them on the spot. Usually, manufacturers ask for the broken equipment to be given back in order to repair it at the factory.

No change or regulation on the spot are usually recommanded. A new calibration of the spring tension is not recommanded except for specific instructions from the manufacturer.

If we examnine fig. 07 we can understand how a slightly positive pressure downstream of the valve, forces the latter to close. 0.25 mm H_20 are enough to cause this phenomenon.

PROPORTIONAL MIXERS AND ZERO GOVERNORS: APPLICATIONS

When the air injector of a proportional mixer is well-shaped in relation to the area of the burners to which it is connected, good and stable negative values of pressure P_2 are always obtained. An excessive increase in pressure P_3 results in positive pressure P_2, hence causing anomalies when the zero governor is working.

No cock should ever be placed between the mixer outlet and the burners because any intervention on it changes pressure P_3 and consequently the working conditions of both the mixer and the zero governor.

Every pressure drop between the mixer outlet and the burners, results in an increase in pressure P_3. For this reason, the dimension of the mixture piping must be accurately calculated. Furthermore it is better to reduce the number of elbows, connections and necks to the minimum. Generally speaking we recommand all these pressure drops be kept under 25 mm H_2O (see fig. 08).

If you have not yet gained much experience with this type of equipments, we recommend pressure P_1, P_2 and P_3 be controlled. It is possible to verify whether the mixer works correctly by comparing the data obtained to what we have described above. If after some time some anomalies are detected, it is advisable to check the 3 pressures: this is the quickest and easiest way to find out the cause of the anomaly.

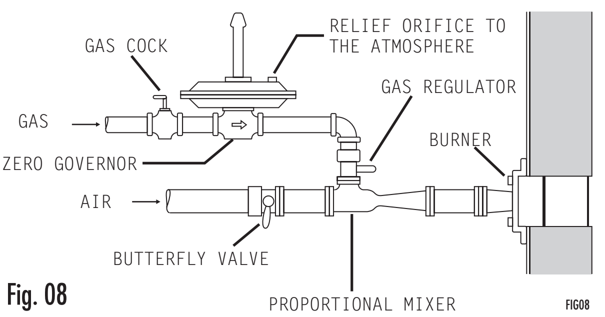

Fig. 08

HIGH-PRESSURE COMBUSTION CHAMBER

The use of the zero governors we have examined thus far was referred to combustion systems in neutral pressure, that is atmospheric pressure. When on the other hand they are used in combustion chambers with negative or positive pressures, the sytems is not balanced as such pressures affect the value of negative pressure P_2.

It is quite easy though to find the equilibrium again by connecting the upper (1) chamber of the main diaphragm of the zero governor to the combustion chamber (see fig. 9) via a "datum line".

Thus the positive or negative pressure in the combustion chamber is loaded on both faces of orifice A_2 and therefore its effect is cancelled. The datum line is necessary with pressures in the chamber of ±2.5 mm H_2O. It is advisable to use a copper tube featuring a diameter of 6÷8 mm for the datum line.

When this type of combustion systems are installed on combustion chambers with positive pressures exceeding 25÷50 mm H_2O, the boost to the zero governor must be such as to create a 100 mm H_2O pressure drop through the same zero governor.

For instance, if some burners are installed on a combustion chamber with a positive pressure of 150 mm H_2O, the minimum boost of the zero governor should be 250 mm H_2O.

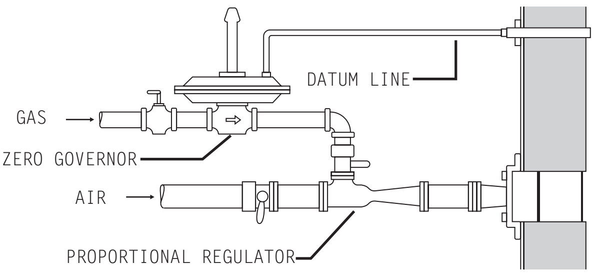

Fig. 09

OTHER PROPORTIONAL MIXERS

The types of proportional mixers we have examined thus far utilize some round air injector in A_1. The air inlet is coaxial to the mixture outlet. In these mixtures it is necessary to change the injector area every time the mixer is to be adapted to a different number of burners. This is necessary to keep the correct ratio of the mixture areas A_1 to the total burner areas A_3. This can be done by replacing the air injector called "piece".

There are though some proportional mixers where this operation is performed via a simple regulation of the injector area.

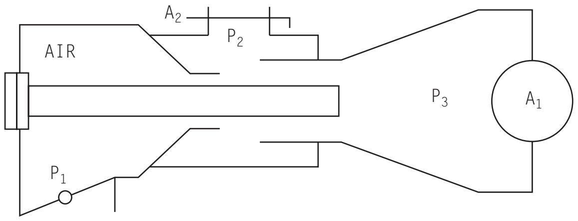

Fig. 10A

Figure 10A shows a mixer where the regulation of this area is done by replacing a cylindrical section adjuster. When some cylinders featuring different diameters are placed in the venturi throat, different capacities are obtained. In this case, the air injector is an annular injector .

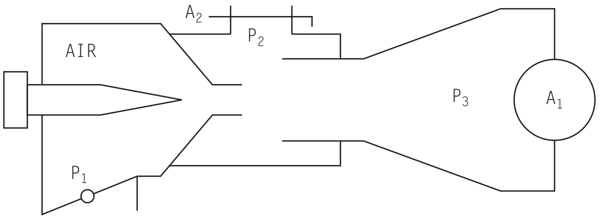

Fig. 10B

Figure 10B shows a mixer with a needle regulator placed in order to adjust the area of the air injector. In proportional mixers it is not possible to obtain satisfactory working conditions if at any change in section A_1 does not correspond a proportional change in the area downstream of the injector. Theoretically there exists only one ideal ratio between the area of injector A_1 and the area A_T of the mixer throat.

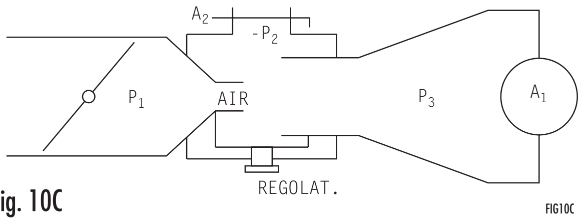

Fig. 10C

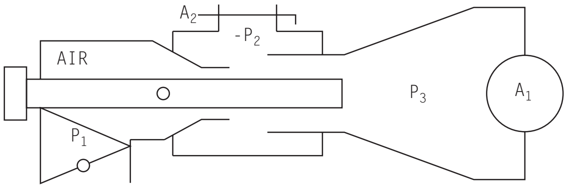

Fig. 10D

Figure 10C shows for instance a mixer featuring rectangular areas A_1 and A_T where the upper and vertical sides are fixed whereas the lower sides are mouvable and adjustable via a screw designed to act on the 2 areas at the same time by keeping the ratio constant.

One of the most recent models of proportional mixers is shown in figure 10D. In this case areas A_1 and A_T are fixed. The central tube is empty all through the length relating to the 2 areas. The holes in the tube allow for air to flow also inside the tube. The aim of the regulating tube is to change the pressure in P_3. If the tube is pushed inwards so as to have the holes close to area A_1 of the injector, pressure P_3 decreases. If the tube is pulled outwards, pressure P_3 increases.

As we have already underlined, when pressure P_3 is changed also the negative pressure P_2 is changed. In this way the mixer capacity is adjusted though the ratio between the areas is kept constant.

The 2 variable mixers shown in 10C and 10D are very flexible equipments capable of compensating accidental pressure drops in the mixture piping and may be used when some ball valves must be placed on each burner. They can adapt to wide changes of the outlet area of the burners.

All these equipments utilize atmospheric regulators for the gas supply at atmospheric pressure to orifice A_2. Once the capacity of orifice A_1 is decided, the combustion system may be adjusted via butterfly valves on the air piping. This operation is the same both for fixed capacity mixers and adjustable capacity mixers.