BASIC INFORMATION ABOUT FUEL OILS
CHAPTER 8

Just like gaseous fuels, fuel oils are composed mainly of hydrocarbons of different nature, that is of molecules made up of carbon as well as hydrogen atoms. Unlike gaseous fuels though, fuel oils contain hydrocarbon molecules featuring a very long chain, which is responsible for their liquid state.

PREHEAT OF FUEL OILS

The reason why fuel oils are preheated in combustion systems is often either not clear or misunderstood. At times fuel oil is overheated, at other times it is not sufficiently heated.
Many people dealing with combustion systems still think that the main reason for preheating fuel oils is to make them more liquid so as to make oil pumping easier. They also think that whatever temperature will do for this goal. In fact, preheating fuel oil to the correct temperature is of fundamental importance in order to obtain efficient as well as correct combustion, resulting in increased heat release, longer lasting fuel and in general more economical working of the combustion system.
An incorrect preheat temperature may on the other hand results in smoky emissions, release of free carbon and wasted fuel.

WHY FUEL OIL MUST BE PREHEATED

The combustion of fuel oil is a chemical reaction by means of which the oxygen of the air combines with the carbon and hydrogen contained in the fuel oil molecules. As it is the case with many other chemical reactions, an increase in the temperature fosters the reaction, in some cases just to start it, in many other cases to complete it.
Preheating fuel oil means not only favouring the chemical reaction of combustion, but also approaching the oil temperature to the oil ignition temperature and furthermore making the oil more fluid to ease its atomization.

ATOMIZATION

It is impossible to complete combustion if fuel oil is liquid; the function of the burner consists of breaking the fluid mass and reducing it into small drops which may be reached by the oxygen of the air more easily. This operation is called "atomization". There exist different systems to atomize fuel oil and the final result is also very different. In some cases fuel oil is mixed with combustion air before it reaches the atomizing nozzle; therefore the real atomization is easier because the air-fuel mixing has already been carried out.
This method though has some disadvantages: the use of an air compressor which together with the mixing system is an additional complication for the equipment and a source of frequent service and maintenance operations; the use of a nozzle whose area is quite large hence it results in a non completely satisfactory atomization.
Another wide-spread method for fuel oil atomization is the one resulting from the mechanical action of the pression exerted on the fuel oil approaching the atomizing nozzle against the walls of the small helicoid channels and holes of the nozzle itself. In this way as a result of a sharp change in the flow direction and the bumping into a metallic wall, the fuel oil is subdivided in small drops. The dimension of such droplets both depends on the shape of the atomizing nozzle and working pressure. However it has been demonstrated that with this method it is difficult to decrease the dimension of the droplets beyond a certain level. Yet, this system is commonly used all around the world successfully to atomize distillate fuel oils. In Italy it is also used for fluid fuel-oil burners. Nevertheless in our opinion good combustion and reduced maintenance operations may be obtained by mechanical atomizing oil burners only if distillate oils with no residues are used.
Last but not least there is a system which is by far more suitable for both heavy fuel oils and fuel oils containing residues. It consists of exploiting another high-pressure fluid, usually compressed air or vapour, to subdivide the small drops leaving the atomizing nozzle in

even smaller droplets. This system is called "pneumo-mechanical combined system". Although it is a complication for the burner, it is the only one which, if correctly realized, guarantees good results and low maintenance costs if fuel oils are used featuring a viscosity higher than that of diesel fuel.
We also want to mention an atomizing system which is very much similar to the ones of the previous group but differs in that the atomizing fluid is not vapour or high-pressure air but rather some of the combustion air supplied to the burner via a low-pressure fan. This method is very efficient and economical as for maintenance and service costs if distillate fuel oils are used.
As we have just said there are different ways to atomize fuel oils which characterize the type of atomizing nozzles and the burner as a whole.
No matter what system you choose, fuel oil must feature a sufficiently low viscosity in order to reach a good level of atomization.Usually distillate fuel oils feature a viscosity which satisfies this requirement at ambient temperature; when the fuel oil viscosity exceeds the viscosity of diesel fuel at ambient temperature it is necessary to preheat oil in order to reduce its level of viscosity.
If oil were not preheated it would be very difficult to obtain a sufficiently fine atomization and this would result in bad combustion and ignition problems.
It is quite obvious that the smaller the drops resulting from the atomization the easier the mixing of carbon with hydrogen; in this way the oxidation of hydrocarbons becomes easier.
The results of the atomization depend on the system adopted, the viscosity of the fuel oil and pressure.
A nozzle-mix burner produces bigger oil drops than a burner operating with a pneumo-mechanical system.
If we examine the combustion products of these two different types of burners carefully we see that in the first type it is difficult to obtain levels of CO2 exceeding 8÷9%, hence there is the problem of unburned substances; the second type, on the other hand, guarantees near stoichiometric combustion (CO2 about 15%) with no excess air and no unburned substances.
Even if the viscosity required for pumping sets is relatively high, the viscosity needed to obtain good atomization must be lower. In practice the temperature of preheat and of fuel atomization are exactly the same.
In order to regulate the temperature of preheat correctly it is necessary to know three characteristics:

1) the viscosity of the fuel oil which is being used;
2) the atomization temperature required by the burner;
3) the fire point of the fuel oil.

The first value depends on the fuel used, though it may vary from one supply to the other. Therefore we suggest every supply of fuel oil be checked carefully, and if possible, especially if oils are mixed, we recommend the viscosity be checked periodically (we would like to remind you that a quick method, though not very accurate, to find out the viscosity of fuel oil consists of finding out its A.P.T gravity).
The atomization temperature depends on the type of burner and atomizing nozzle. In order to find out the correct preheat temperature for a good atomization through some tables, it is worth remembering that generally speaking every atomizing nozzle requires a viscosity ranging from 2 to 5 °E. Clearly enough a fuel oil having a higher viscosity at ambient temperature will have to be preheated in order to obtain the corret viscosity at the atomizing nozzle. For instance a heavy fuel oil with a viscosity of 20 °E at 50 °C will have to be heated to 90÷100 °C if we want the effects of its atomization to be comparable to the effects of a diesel fuel.
The fire point of a fuel oil is important as for the temperature of preheat, because it would be dangerous to exceed the fire point.

SUPPLY CIRCUITRY OF FUEL OIL TO BURNERS AND THE DIFFERENT PARTS OF A COMBUSTION SYSTEM

Once you know that fuel oil must reach the atomizing nozzle or nozzles (if there are several nozzles) at a temperature corresponding to the atomization temperature required by the burner, now we must examine the methods to raise the original fuel oil temperature to the atomization temperature and to maintain such temperature in all working conditions, both in high- and low-fire position.

Electrical or steam preheaters of diesel fuel may be manufactured in different ways. Our experience has demonstrated that the requirements for a good preheater of diesel fuel are: to release the maximum amount of heat, that is to have a good thermal efficiency and at the same time to avoid that the oil temperature fluctuates too much above or below the regulation point.

Another fundamental precaution to observe when designing and manufacturing oil preheaters is that the amount of fuel oil flowing in the preheater must be as little as possible, so as to avoid any change in temperature between the upper and lower part of the tank. It is advisable not to heat fuel oil too much in order to avoid the formation of carbon and other vapours.

As for the location and hydraulic connection we give up giving any information due to the great variety of situations which exist in practical applications. It is important to underline though the fact that these elements are of fundamental importance to obtain good combustion.

It is worthwhile remembering that, particularly when the preheater is far from the burner, fuel oil must always, since the beginning of ignition, reach the nozzle when it is still warm. Clearly enough if the burner or burners are low rating ones and very distant from the preheater, the oil will cool down on the way to the burner as it cedes heat to the different parts of the hydraulic circuit.

For this reason if fuel oils featuring a viscosity higher than that of diesel fuel are used, we recommend the oil be left free to flow in great quantities as close as possible to the burners and return either to the preheater or tank. This operation guarantees that all the pipes and controlling devices will reach the working temperature before the ignition of the burner.

Another aspect which is of fundamental importance is that of the effects that a change in the oil flow to the burners (which may be requested by the combustion system itself) may cause on the temperature hence on the viscosity of the oil arriving at the atomizing nozzle.

Let's say that a 10/1 capacity ratio is required for a fuel oil burner, that is a 100/1 ratio on pressure. If for instance the atomizing nozzle operates at an (oil) pressure of 6 Kg/cm2 at maximum load, it will operate at an (oil) pressure of 600 mm H20 at minimum load.

Any engineer will immediately realize that such pressure is insufficient to break the fluid flowing out of the nozzle and subdivide it in drops, in other words it is insufficient to atomize the fuel oil. In order to keep the oil temperature constant over the whole flowfield, it is necessary to avoid heat losses. In low-fire conditions, both pressure and temperature affect the atomization of the fuel oil in a negative way.

That is why all designers, manufacturers and users of burners prefer adopting systems equipped with a low-pressure return circuitry.

The return circuit may be realized in different ways. The best thing is to make diesel fuel recirculate in a low-pressure ring which may either be connected to the intake tube of the fuel pump or be sent back to the feed tank.