CONTROL OF FURNACE AND FLARE OPERATION. FLAME FAILURE ALARM


UDC 665.63.041.454

Of the many fire and explosion hazards in refineries, the reheating furnaces occupy a special position. Explosions in furnaces have serious consequences. The most frequent cause is flameout due to unstable burning or feeding of fuel to a furnace where ignition has not taken place. This usually happens in starting up and stopping a furnace or in operating on small loads.

The causes of 156 explosions in furnaces and boiler burners in 44 boilers were analyzed in the USA. Of these explosions, 60% occurred in ignition and 32% occurred in operating on small loads. Of the equipment examined, 39% operated on gas, 16% on residual fuel oil, and 45% operated on coal. When liquid fuel was used, all of the explosions took place as it was being fed into the hot furnace, which could explain the identity of the properties of the fuel hydrocarbon vapors and natural gas.

In Germany, the causes of 85 explosions (backfires) were analyzed, and over half occurred in switching on the burners, including 25% due to incorrect ignition, 15% due to incorrect preliminary blowing, and approximately 15% were due to failures of fuel equipment. Nonignition of fuel after flameout was the cause of almost all of the other backfires.

There were 200 explosions on low-power boilers in Japan over 5 years, and 60% occurred during ignition. The causes of emergencies in oil refineries and petrochemical plants in Russia were similar.

The region of controllable parameters on reheating furnaces is relatively obvious based on the results of a statistical analysis and experience in direct use; for this reason, a competent engineering approach alone is required for an exhaustive solution of the problem and correct maintenance of safety and control equipment. Of this equipment, flame failure alarms (FFA), which check for the presence of a flame, signal its extinction, and control automatic fuel equipment, are most widely used.

In world practice, FFA of different designs and operating principles are used for protecting furnaces and boilers. Photoelectric FFA, which record intensity and fluctuations in the long-wave portion of the burner flame emission spectrum in the $0.6 - 0.8 \mu \text{m}$ range are widely used in Russia.

Susceptibility to parasitic emission from the walls and process fittings of furnaces and boilers is a fundamental drawback in devices of this type which reduce their operational reliability. In the indicated emission range, reliable operation of the devices is not really attained.

Two types of FFA are used abroad for protecting fuel-burning equipment: photoelectronic and ionization. Photoelectric FFA are universally equipped with ultraviolet (UV) sensors for the flame emission range: $0.2 - 0.3 \mu \text{m}$. These sensors reliably record the presence of a local burner flame due to effective absorption of UV radiation by the environment. The reflected flame emissions of other burners do not affect their operation. This is the main advantage of devices of this type.

However, the UV sensors also have drawbacks caused by their basic advantage. Very high requirements are imposed on the transparency and cleanliness of the entire optical path — from the source of emission to the detector, due to the high UV radiation absorption coefficient in different media. In servicing and operating these furnaces, these requirements are difficult to satisfy, which leads to frequent false alarms. This causes them to be distrusted and a corresponding decrease in the responsibility of servicing personnel.
FFA of the ionization type have recently been used relatively rarely because the fundamental electrode that senses the ion current of the flame rapidly corrodes in the aggressive medium of the flame and fails. The development of complex safety devices ensuring reliable control of flare burning, measurement of flame temperature, and control of the degree of rarefaction in the boiler volume furnace is promising.

The problem of reliably recording the burner flame is basically solved in the FFA 1.001 device (developer and manufacture: Shibbolet Limited Liability Company and Rutenii LLC, Ryazan’). A double-beam flame-emission recording system is used in this device, and this allows not only reliably determining the existence of a flame (from any type of fuel) after excluding the effect of the heat parts of the furnace fittings and walls but also measuring its temperature.

The temperature measurement is based on the Ornshtein method [1], which essentially consists of determining the ratio $r$ of the integral intensities $I_1$ and $I_2$ of two spectral lines belonging to the same emitting body, which is important for increasing the efficiency of burner operation, and the corresponding wavelengths $\lambda_1$ and $\lambda_2$:

$$r = \frac{I_1}{I_2} = \frac{A_1 g_1}{A_2 g_2} \left( \frac{\lambda_1}{\lambda_2} \right) \exp \left( \frac{E_1 - E_2}{kT} \right)$$

where $A_1, A_2, g_1, g_2, E_1, E_2$ are the probabilities of transitions, statistical weights of the initial levels and excitation energy corresponding to the spectral lines; $k$ is the Boltzmann constant; $T$ is the flame temperature.

In contrast to the absolute intensity method used in conditions sufficient for saturation of the emitting atom concentration lines, the relative intensity method can only be used in conditions of low concentrations. This restriction is due to the difference in the absolute intensities of different spectral lines and consequently degrees of their proximity to the state of saturation.

If we take the logarithm of the ratio of the signal intensities for two spectral lines, it is possible to determine the temperature and presence of a flame in the aperture visual field with sufficient accuracy with hardware.

The FFA parameters are selected from a calculation of the so-called “safety margin”, defined as the maximum acceptable time for stopping fuel feed into a furnace in the absence of a flame [2]. When the burner is turned on, the safety margin begins when fuel is fed into the burner and during its operation, from the time the flare is extinguished after closing of the cutoff valve.

The burner power, furnace volume, and system of forming the fuel mixture (with or without a blower) are taken into consideration in calculating the safety margin. The safety margin varies from 1 to 40 sec as a function of the factors listed.

In addition to indicating the presence of a burner flame, the given FFA can also measure its temperature, which can be effectively used for optimizing the burner operating regime. This possibility is due to the extremal character of the dependence of the flame temperature on excess air coefficient $\alpha$.

The maximum temperature is attained for $\alpha \approx 1$, which ensures independent adjustment of the burners for the optimum operating regime. This is important, since measurement of $\alpha$ in furnaces with a large number of burners based on the oxygen content in the stack gases does not allow individually setting and monitoring the operation of the different burners.

The reliability of operation of the device is ensured by continuous self-diagnosis with indication of the character of a malfunction (rupture of lines, reduction in the optical channel transmission coefficient, malfunction of an electrical circuit, etc.), which allows its timely elimination.

In large petrochemical plants, the reheating furnaces usually have a large number (from 20 to 100) of burners. Equipping all of the burners with FFA devices is naturally not rational, since extinction of one of the burners during stable operation of the furnace cannot cause an emergency.

In igniting a furnace when drying or going into normal operation, two to three burners are usually operating. Backfire is most probable in ignition of the furnace, where its drying or going into normal conditions take place. Due to regulation of the order of igniting the furnace and installing FFA only on burners from which ignition begins, the explosion hazard decreases significantly, and is even eliminated in the overwhelming majority of cases.

At Ryazan’ Oil Refinery, 40 FFA 1.001 devices have been installed on furnaces of different types. They have reliably monitored operation of burners in burning of different fuels, including hydrogen sulfide, for 4.5 years.