AUTOMATED CONTROL SYSTEM FOR THE SUPPLY OF LIQUID FUEL TO A TUBE FURNACE

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Abstract

For optimal control of technological processes in explosion- and firehazardous industries, which include oil and gas refining, chemical and petrochemical objects, one of the main and pressing issues is the effective control of the liquid fuel supply to tube furnaces. To automatically regulate the output temperature of the raw materials supplied to the furnace on the liquid fuel line, an appropriate actuator is used. At the same time, gas fuel is continuously supplied to the tube furnace. The main reason for the intermittent supply of liquid fuel is that it is used as a feedstock for other technological installations It is known that feeding fuel into a tube furnace is unsafe for the technological process as a whole, that is, it is a process of a certain increased danger. This can lead to unwanted fires and explosions in the workplace. Therefore, to reduce some technical and technological risks, it is important to use liquid fuel with appropriate breaks, since the use of dry gas in a technological system poses a certain danger.

Keywords: technological process, liquid fuel, technological risk, tube furnace, control system, gas fuel

I. Introduction

Oil refining is a large-scale production, consisting of a large number of complex technological installations, which are complexes of many interconnected technological apparatuses [1-11]. One of such important and complex oil refining technological apparatuses is tube furnaces. Tube furnaces are used in the following oil refining installations: primary oil refining as part of Atmospheric Vacuum Tube installations; reforming; hydrocracking; viscosity breaking; delayed coking installation; isomerization; hydrogen production by steam reforming, etc. [12, 13].

It is known that tube furnace is a technological apparatus for heating a flow or carrying out a high-temperature chemical reaction due to the heat that is released during the combustion of organic fuel, that is, it is intended for heating hydrocarbon raw materials by open fire heating of tubular coil with gases in the combustion chamber from the combustion of liquid or gaseous fuel. After heating hydrocarbons in tube furnaces, they are subsequently sent to distillation columns to separate them into components (diesel fuel, heating oil, gasoline, etc.).

Thus, tube furnaces are used in any oil refinery and petrochemical plant in all major refining processes [14-17]. This is due to the fact that a tube furnace is the most cost-effective and efficient process for heating oil fractions.

Due to the lack of fuel gas produced in oil refineries, liquid fuel is also used to heat raw materials in process tube furnaces.

Combustion of liquid fuel in tube furnaces at oil refineries is ineffective from an economic and environmental point of view, since, on the one hand, environmental pollution by flue gases increases, and on the other hand, the possibility of using liquid fuel (fuel oil) as a raw material is reduced. Therefore, rational use and saving of liquid fuel is a very important and pressing problem in similar industries and is of great importance for the entire economy as a whole.

For this purpose, thorough research work was carried out in the field of the raw materials heating process entering the tube furnace in an oil refinery and the following shortcomings were identified:

1) the existing fuel network management system (processing of gaseous fuel, as well as its use) does not meet the requirements of modern automated operational control systems (there is no effective and optimal automated control system between production and relevant consumers);

2) since the total amount of fuel gas used in technological installations cannot provide the amount of fuel required to heat raw materials in tube furnaces, they also use liquid fuel along with dry gas. At the same time, to control the required temperature of the product at the outlet of the tube furnace, dry gas is continuously supplied to the technological system. It is important to note that when gas is supplied to the system, there is a possibility of an explosion and fire hazard in a tube furnace. This circumstance turn, can lead to certain technological and technical risks when heating the raw materials used. Thus, this affects the correct and efficient functioning of the automated control system as a whole.

In addition, it should be noted that in oil refineries regulate the temperature of the feedstock leaving the tube furnaces and select the gas fuel flow rate. On the other hand, adjusting the temperature of the raw material at the outlet of the tube furnace with gas flow leads to the fact that part of the dry gas is released into the flare line to equalize the pressure in the fuel network to a given value.

II. Development of an automated control system for the supply of liquid fuel to a tube furnace

From the factors mentioned above, it is clear that to eliminate the corresponding technological and technical risks arising in the gas and fuel technological network, it is necessary to create an automated control system for liquid fuel processing. At the same time, the automated control system for emergency situations must ensure that the following conditions are met:

- the pressure in the gas distribution point must be maintained constant (stable) according to the set point value;
- the discharge of dry gas from the gas distribution point to the flare line of the technological system should be minimized;
- the temperature of the raw materials at the outlet of the tube furnaces must be maintained constant (stable) in following the set point value.

An automated control system that meets the above requirements is presented in Fig. 1. When the gas pressure (position 5-1) coming from the gas distribution point increases, (position 5-2) and the pressure regulator (position 5-3) acts on the valve (position 5-4) located at the entrance to the tube furnace, according to a command received from the setting device, increasing its throughput.

In this case, the pressure of the gas supplied after the gas separator to the tube furnace (position 6-1) drops. In this case, to stabilize the pressure of the fuel gas supplied to the tube furnace according to the set point value, it acts on the secondary device (position 6-2), from there on the regulator (position 6-3), the control valve (position 6-4), increasing the capacity of this valve. In this case, the temperature of the raw material at the outlet of the tube furnace by the set point value is realized as follows.

Signals from thermocouples installed on the ridge wall and the outlet of the tubular furnace (position 1-1) and (position 2-1) are supplied, respectively, to temperature converters (position 1-2) and (position 2-2), and then they go to electric-pneumatic transducer (position 1-3) and (position 2-

3), and from them they are further sent to secondary devices (position 1-4) and (position 2-4).

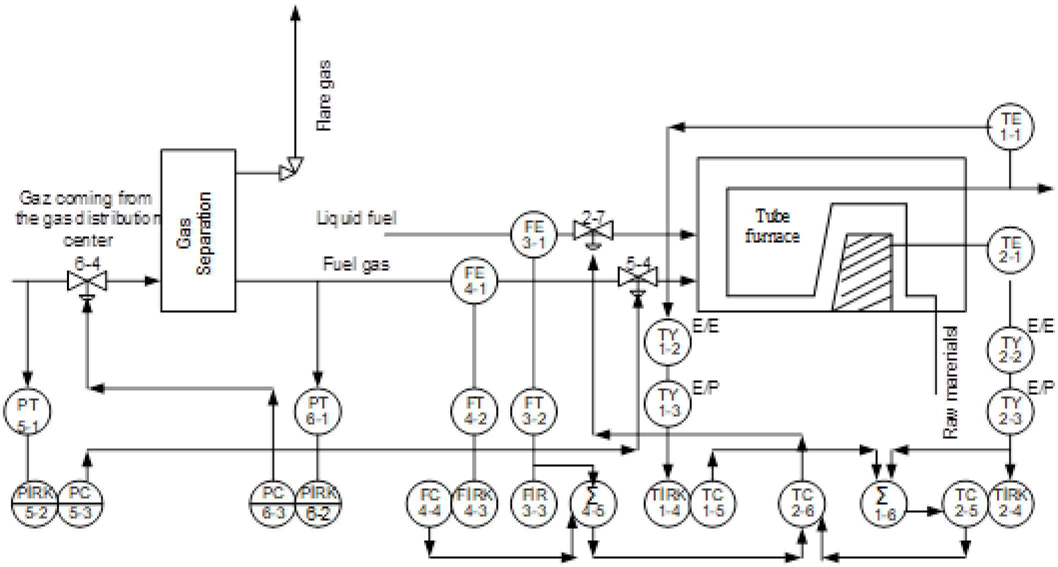

Figure 1: *Structural scheme of an automated system for the supply of liquid fuel to a tube furnace*

Having received a set point value from the output of the device (position 1-4), the controller signal (position 1-5) goes to the summator (position 1-6).

At the same time, the input of the summator (position 1-6) also receives a signal from the output of the electro-pneumatic transducer (position 2-3). At the same time, the output signal of the summator (position 1-6), as a variable value, is supplied to the temperature controller (position 2-5) by the set value coming from the secondary device (position 2-4).

The output signal of the temperature controller (position 2-5) is fed to the input of another temperature controller (position 2-6) as a set point value. The temperature controller input (position 2-6) receives signals from flow sensors (position 3-1) and (position 4-1) as variable values. The output signal of the temperature controller (position 2-5) is fed to the input of another temperature controller (position 2-6) as a set point value.

The temperature controller input (position 2-6) receives signals from flow sensors (position 3-1) and (position 4-1) as variable values. Pneumatic signals from local devices (position 3-2) and (position 4-2) are accumulated in the summator (position 4-5) and then the output signal of this summator in the variable value form is supplied to the input of the temperature controller (position 2-6). As a result, the temperature controller output (position 2-6) acts as a force on the control valve (position 2-7), reducing its flow capacity.

It should be noted that if the pressure in the gas distribution center drops below the set point value, the automated control system presented above has the opposite effect.

Let's look at a microprocessor system for controlling the process of heating raw materials in tube furnaces.

It is known that heating raw materials in tube furnaces during primary oil refining is a very complex heat engineering process, the correct implementation of which depends on the correct control of numerous technological parameters of the apparatus under study. Therefore, it is necessary to create a control system in tube furnaces that ensures stable maintenance of operating parameters under technological requirements. The structural scheme of such a system is presented in Fig. 2.

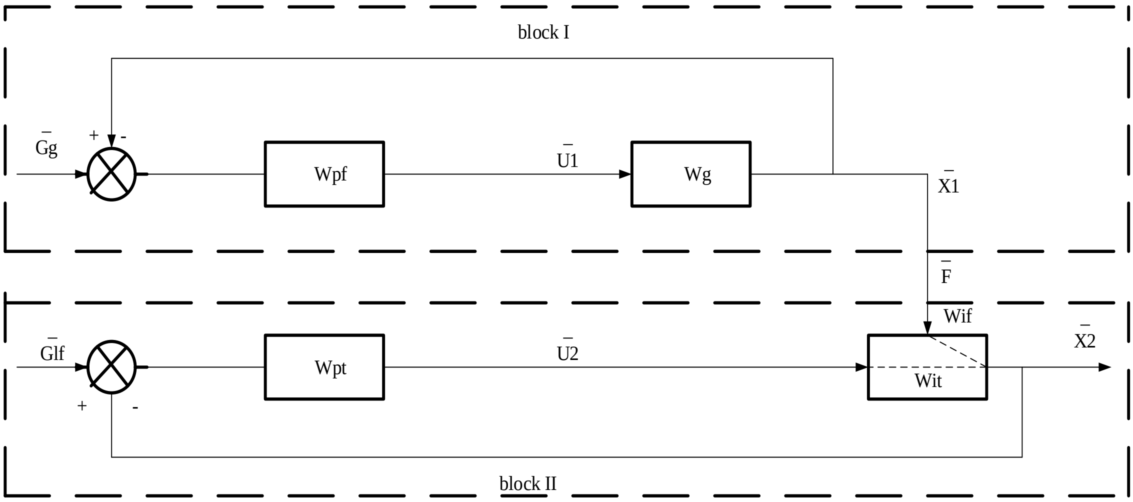

Figure 2: *The structural scheme of a microprocessor control system*

Here W_{pf} and W_{pt} are the diagonal matrices for the transfer functions of the multichannel flow and temperature controller, respectively. W_{if} and W_{it} – transfer functions matrices of the technological object for gas flow and between the temperature channels of the raw material at the tube furnace outlet. $\bar{G}_g$ and $\bar{G}_{lf}$ are vectors of set point values for gas and liquid fuel consumption. $\overline{X1}$ and $\overline{X2}$ are the vectors of output parameters (temperature). $\overline{U1}$ and $\overline{U2}$ are vectors of regulatory actions. As can be seen from Fig. 2, the control system consists of two control blocks – I and II. With the help of block I, the optimal gas fuel division between technological tube furnaces is realized, and with the help of block II, a constant (stable) temperature at the outlet of the tube furnaces is maintained. Analysis of this structural scheme shows that, on the one hand, a change in vector G1 along the direct channel has a disturbing effect on the output parameter $\overline{X1}$. On the other hand, since block I is powered by the collector, changing the regulator in it causes a change in the adjacent controlled parameter in the same block. Therefore, in technological tube furnaces, disturbing influences arising in the system for regulating mode parameters are transmitted not only through a direct channel but also through a transverse channel.

Therefore, to improve the quality of regulation, it is necessary to create an autonomous regulation system in block I and an invariant regulation system in block II, based on the above principles.

It is known that when controlling technological processes in oil refineries, not one, but several tube furnaces are used. Therefore, to correctly and effectively regulate the temperature at the outlet of tube furnaces, a combined computer control system has been created.

The structural scheme of the proposed combined computer control system is shown in Fig. 3. The system operates in the following order: changing the set point value of the regulator in accordance with the optimal price of fuel gas is carried out by the dispatcher (operator). But after converting the current values of regulating and disturbing influences into a direct current signal with a 4-5 mA strength, through the appropriate electronic type converters, they are supplied to the input of an analog-to-digital converter located in the control computer complex. The analog-to-digital converter, in turn, converts the analog signal into codes. After the analog-to-digital converter, the signal through the multi-channel control software module also determines the magnitude of the control action, and this signal is sent to the input of the digital-to-analog converter located in the computer. The direct current signal (4-20) mA, which appears at the output of the digital-to-analog converter, is converted through an electro-pneumatic converter into a pneumatic signal (0.2-1) kg/cm² and acts on certain actuators. Current technological parameter values characterizing the heating process raw materials in tube furnaces are displayed on the display screen, and the operator enters into dialogue with the control computer complex to complete the task.

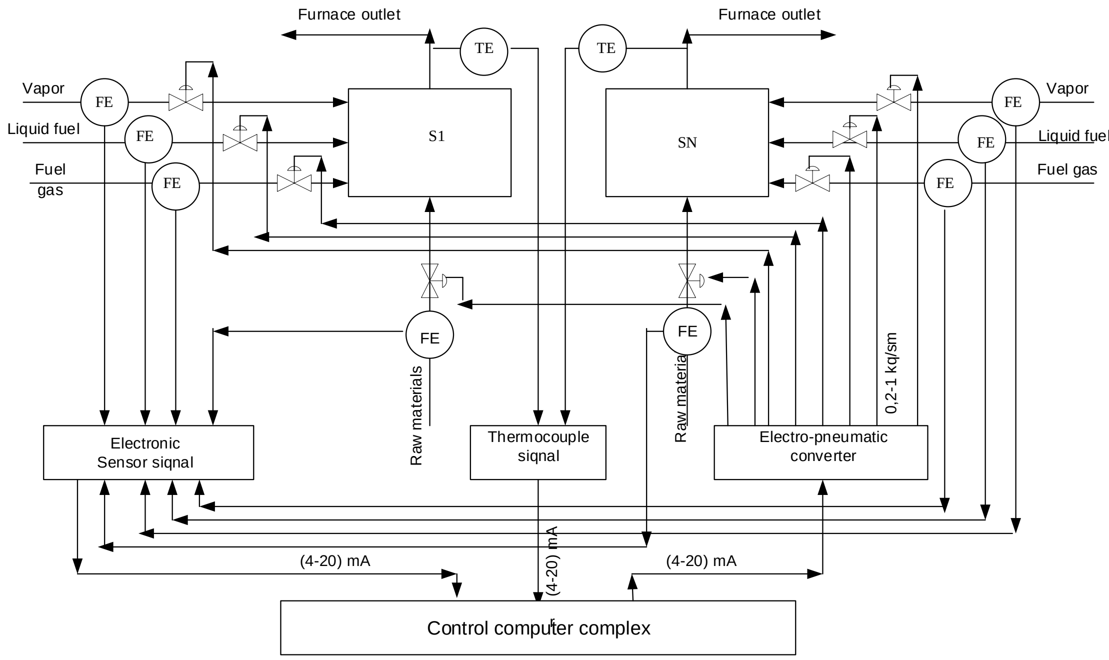

Figure 3: *Structural scheme of a combined computer control system*

III. Conclusion

An automated control system for the supply of liquid and gas fuel to a tube furnace has been developed. When supplying gas from a gas distribution center to a tube furnace, a system has been developed to regulate the flow and fuel gas pressure. To regulate the temperature of the raw material supplied to the tube furnace, which is important for the technological process, an actuator installed on the liquid fuel line is used.

Heating raw materials in a tube furnace is a complex process. In this process, stable preservation of the many mode parameter values must be ensured by the set point value. In this regard, the proposed microprocessor system for controlling the consumption of liquid and gaseous fuel, quality indicators, temperature, and pressure has been developed.

To maintain a stable temperature of the output raw material in tube furnaces, a control computer complex is proposed in a combined computer control system.

Thus, based on the above, various types of automated control systems have been developed to maintain the necessary and required temperature of the technological process under study.

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