A method of reducing the amount of fuel gas during operation of the oil fire furnaces

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Abstract. The rational use of resources and energy in the oil refining process is largely determined by the efficiency of the technological equipment. In the conditions of the Far North, with a sharply continental climate, at low negative temperatures, the operation of technological furnaces is carried out with very high energy consumption, which indicates the use of equipment in suboptimal conditions. Loss reduction is possible due to heat recovery through the use of heat from combustion products, through heat exchange between product streams and the use of low potential waste heat. In this work, an analysis of the operation of a technological oil heating furnace was carried out, the main parameters affecting the consumption of fuel gas were identified, a method for reducing the cost of natural fuel gas by introducing a recuperator was proposed.

The oil refining industry is an important link in a single fuel and energy complex that determines the efficiency of the use of oil raw materials. The efficiency, rationality of their use in oil refining processes is largely determined by the operation of the plant’s technological equipment. The main equipment of these plants are: tube furnaces, distillation columns, heat exchangers [1], [2], [3], [4].

Technological tube furnaces with fire heating are the main consumers of energy in the oil refining, petrochemical and chemical industries. Their share in energy consumption in large-scale production of oil refineries reaches 70%. In a technological furnace, raw materials and petroleum products are heated to a predetermined temperature in coil tubular surfaces. When using the equipment in non-optimal mode, the operation of technological furnaces is carried out with the greatest energy consumption [5], [6]. The aim of the work is to increase the energy efficiency of a fire oil heating furnace (process furnace).

The technological furnace consists of two types of chambers - radiant and convection. Radiant chamber - is a hollow metal cylinder insulated from the inside. The cylinder is mounted vertically on racks. Inside the cylinder, a food coil is placed on the periphery. Directly above the radiant chamber, a box-shaped convection chamber is installed, inside of which horizontal coils are placed. The product is heated in the furnace coil by burning fuel gas in a radiant chamber on 3 working burners located in the hearth of the furnace (figure 1). Also, three ignition burners are installed in the hearth of the furnace for firing up working burners. The natural draft of the chimney ensures the removal of flue gases and vacuum in the furnace. In the furnace coils, the raw material partially evaporates, so that a two-phase vapor-liquid flow with a temperature of no more than + 370 °C is output, which is then sent for fractionation to an atmospheric distillation column.
Currently, there are four main areas of energy conservation in tube furnaces of the oil refining industry:

- technological energy saving (consists in replacing obsolete energy-intensive technological furnaces with more modern, energy-efficient ones, as well as in clearly regulating the quality of raw materials and operating parameters);
- thermotechnical energy saving (increasing the efficiency of furnaces by optimizing the combustion of fuel, improving burners, applying special coatings to the lining of the furnace to intensify heat transfer; using the heat of the exhaust gases to heat the air and generate steam for the company’s own needs);
- energy saving (cogeneration of electric and thermal energy at oil refineries by adding process furnaces to gas turbine units) [1].

Technological energy saving is the replacement of obsolete energy-intensive tube furnaces with modern ones. We consider in more detail the application of the most common two types of furnaces: tent and vertical tubular furnaces.

The main disadvantages of tent stoves are low efficiency, high metal consumption, large footprint, outdated control systems. The condition of these furnaces is often such that the efficiency is lower than the design by 10% or more due to inefficient use of the furnace space and poor sealing of the furnace. The disadvantages of the furnace can also include underground chimneys, often filled with water, pumping which increases the downtime of the installation. Therefore, it is necessary to develop and implement a long-term program for the gradual replacement of these furnaces with modern ones, taking into account the technological features of each installation.

Since the mid-60s, vertical tubular furnaces with horizontal, vertical, spiral coil arrangements have been designed and widely used in the oil refining industry. Efficiency of these furnaces is 10-20% higher than tent, and material consumption and occupied space are much less.

Each furnace has its own individual characteristics (requirements for hydraulic resistance of the coil, flow temperature, heat recovery task).
Thus, the main ways of developing the design and manufacture of tube furnaces in the oil refining industry are:

- replacement of furnaces of old designs (tent) with modern furnaces of a new design, taking into account the optimization of heating conditions, maintainability;
- the choice of recycling units that provide high economic performance;
- elevated laying of chimneys [1].

Most of the furnaces operated at the enterprise are characterized by very high values of the coefficient of air flow and flue gases. This leads to large heat losses with flue gases, low efficiency of furnaces and excessive fuel consumption.

Large suction of cold air from the environment into the working chambers of the furnaces also leads to high heat loss. On old tent stoves that work without a smoke exhaust, one has to maintain a very high vacuum in the working chambers, since pressure drops in the furnaces occur when the vacuum decreases. High vacuum increases the suction of air into the furnace.

Reducing the magnitude of heat loss (taking into account suction cups) can be achieved by equipping the furnaces with additional gas analyzers, sealing, as far as possible, the external enclosures of the furnaces, and adjusting the aerodynamic regime that ensures operation at a small positive pressure [1].

The most important for optimizing the modes of fuel combustion in furnaces is the improvement of burner devices. For example, the «Neftekhimekologiya» company developed the ECO-FLAME burner. The design of the burner implements the idea of recirculation of combustion products, which allows to reduce the oxygen content, reduce the temperature of the flame and reduce the formation of thermal NOx without deterioration of the combustion process. Advantages of the burner are: reduction of specific fuel gas consumption by 10-15%, expansion of the range of regulation of burner productivity; 2-4 times reduction in the number of burners installed in the furnace [2].

To reduce the heat loss from external cooling, components of 5-10%, use special heat-insulating materials that increase the tightness of the furnace. The use of lining made of fibrous refractory materials of chamotte products allows you to create new, lightweight construction of the lining of walls and arches, while being a refractory and thermal insulation. Low thermal conductivity allows to reduce the dimensions of the furnace due to the thickness of the lining, which in combination with low density makes it possible to reduce the weight of the lining of the furnace up to 10 times. The heat accumulated during heating is thus also reduced several times. The heating time of the furnace is drastically reduced, saving not only energy resources, but also reducing unproductive working hours of the furnace and maintenance personnel. Therefore, fibrous materials are also called low inertia.

One of the reasons for the insufficiently high thermal efficiency of a number of process furnaces is their lack of a system for utilizing the heat of the exhaust gases. The consequence of this is high flue gas temperatures of the order of plus 300 to plus 400 °C, a significant level of flue gas losses and low furnace efficiency [7].

An important direction in reducing energy consumption in primary oil refining plants is the modernization of furnaces by adding gas turbine devices to them. Such developments use the exhaust gases of a gas turbine engine as a coolant and an oxidizing agent in atmospheric and vacuum tube furnaces operating on gaseous and liquid fuels. The introduction of such a large energy unit is advisable at 100% loading of crude oil by primary processing.

Based on the foregoing, we can conclude that the most effective and appropriate is the application of the principle of heat engineering energy saving, which includes increasing the energy efficiency of furnaces by optimizing the combustion modes of the fuel, improving burners, and using the heat of the exhaust gases to heat the air.

When heated air is supplied to the burners, the fuel combustion process intensifies, the temperature of the flue gases increases, and the heat transfer to the tube coils increases by radiation. Air heating is also beneficial because it allows you to burn fuel with a minimum excess of air and reduce the formation
of sulfur dioxide from fuel containing sulfur compounds, which in turn helps to reduce equipment corrosion [7].

In order to reduce fuel consumption, tube furnaces are equipped with equipment for heating air, which is used to burn fuel. Heated air with flue gas will allow fuel to be burned with a minimal excess of air and reduce the formation of sulfur dioxide from fuels containing sulfur compounds. The heat transfer of flue gases is assumed by introducing a heat exchanger (figure 2).

![Figure 2. Upgraded work scheme technological furnace.](image)

Currently, there are several types of heat exchangers, each of which has its own field of optimal application. Heat exchangers are divided into: regenerative; mixing; recuperative [8].

Regenerative heat exchangers are very efficient devices that are advisable to use in cases of large volumes and high temperatures. However, the dimensions, weight, technological and structural difficulties make their use very limited [8].

It is advisable to use a mixing heat exchanger for such coolants that are easy to separate after the heat exchanger. For example, such a pair of coolants is water and air. The most important factor in the working process of the mixing heat exchanger is the size of the contact surface of the coolants, which depends on the degree of crushing of the liquid. To increase the heat transfer surface, a nozzle, which is a layer of lumpy material (for example, pieces of ceramics, coke, etc.), or wooden grates, can be placed on the path of the heat transfer media. The liquid film on the surface of the nozzle is an additional contact surface, which sometimes can be the main heat transfer surface. These devices have very limited use in certain technological processes [8].

In recuperative heat exchangers, heat carriers wash the wall from two sides and exchange heat. The heat exchange process proceeds continuously and is usually stationary in nature. The wall, which is washed on both sides by coolants, is called the working surface of the heat exchanger. Structurally, recuperative heat exchangers can be performed with tubular (shell-and-tube heat exchanger) and plate (plate heat exchanger) working surfaces.

Of all the types of heat exchangers discussed above, the most widespread and versatile use is found for regenerative heat exchangers. Since recuperators have the greatest advantages, such as simplicity of
design and the greatest safety in operation. It is supposed to use a plate recuperator, according to the type of coolant movement - counterflow.

Advantages of a plate heat exchanger:
- high energy efficiency, expressed in a minimum level of heat loss;
- the possibility of heating the incoming air in cold or damp seasons;
- minimal power consumption with a high efficiency;
- the absence of moving parts greatly facilitates the maintenance of the system and extends its working life and the durability and compactness of the entire system, which allows it to be mounted in almost any environment;
- ease of modernization (depending on the tasks, the power and efficiency of the unit can be easily increased or decreased by adding or removing plates).

The plate heat exchanger is a cassette called a heat exchanger, equipped with many thin sheets, which are made of galvanized steel with corrugated sheets. The type of coolant movement is counterflow. This is due to the fact that, for effective heat exchange, the flows should ideally not be in contact with each other and mixed. Using this principle of operation, the plate heat exchanger ensures uninterrupted heating of the incoming air in the cold season with the flue gases of the technological furnace. A general view of the heat exchanger (plate heat exchanger) is shown in figure 3.

![Figure 3. General view of the heat exchanger (recuperator).](image)

Loss reduction is possible due to heat recovery through the use of heat from combustion products, through heat exchange between product streams and the use of low potential waste heat.

Conducted experimental studies found:
- Thus, preliminary air heating due to the flue gases of the oil-fired heating furnace can reduce the amount of fuel gas, reduce the volume of harmful emissions into the atmosphere, as well as reduce equipment corrosion.
- Regulation of energy consumption should become an integral part of the technological process at all enterprises of the oil refining industry, in order to achieve the optimal level of energy consumption.

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