CONSTRUCTION OF A MULTI-CONNECTED CONTROL SYSTEM FOR SAFE COKE PRODUCTION

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Abstract

Efficient processing of crude oil in the oil refining industry develops the economy. To improve the oil products quality and increase its productivity, it is necessary to use minimal energy consumption. The release of harmful substances into the environment during technological processes of production has a certain negative impact on the ecological situation. The risks that may arise from all waste types in production objects are identified and controlled. According to the oil company's policy, reducing the impact of waste on the environment determines its recycling. In the technological processes course, environmental protection and safety personnel constantly monitor installation for gas safety, inspect the air and toxic environment, and ensure gas safety at work. When the raw material is heated to the required temperature in the furnace, the gas fuel supplied to the furnace creates a fire hazard. Technically, oil products coking makes it possible to cost-effectively and expediently increase and improve oil refining.

Keywords: technological process, coking process, oil products, coke, control process

I. Introduction

Efficient processing of raw oil in the oil refining industry develops the economy. To improve the quality of oil products and increase its productivity, it is necessary to use minimal energy consumption.

The release of harmful substances into the environment during technological processes of production has a certain negative impact on the ecological situation. The risks that may arise from all waste types in production objects are promptly identified and controlled. Thanks to the efficient crude oil processing, the impact of waste on e environment as a whole is reduced.

During the technological process, environmental protection and safety personnel constantly monitor oil installation (technological apparatuses) for gas safety at the object, inspect the air and toxic environment, thereby ensuring gas safety at work. When the raw material is heated to a certain temperature in the kiln, the fuel gas supplied to the kiln may create a fire hazard [1-7].

An emergency situations analysis in explosive and fire hazardous industries showed that a tube furnace is one of the most dangerous objects with increased risk parameters compared to other technological apparatuses. In addition, accidents at tube furnaces are a source of equipment ignition and explosion located in the immediate vicinity of the furnace. Therefore, it is currently relevant, on the basis of approved regulatory documents and acts in the industrial safety field, to create and improve the implemented automated process control systems that operate at risk and in explosive and chemically hazardous industries, which include objects of oil production, transport, oil refining and gas, chemicals and petrochemicals [8-18].

Currently, the oil refinery uses: an oil pretreatment installation, a catalytic cracking installation, a catalytic reforming installation, modern installations for the production of oil coke and gas fraction.

The main research object is the technological process of obtaining oil coke. At the same time, cascade and multi-connected automatic systems are mainly used to control the regime parameters. In the process of obtaining coke, the installation for the gradual coking of heavy oil products in unheated chambers is designed to produce electrode coke. In addition to coke, the installation receives dry gas, a stable liquefied gas head, coke oven gasoline, coke oven light gas oil (component of domestic heating oil) and coke oven heavy gas oil (boiler fuel component). The installation has two streams in the coke chamber section and one stream in the distillation section.

The gradual coking installation operates continuously by supplying raw materials and intermittently by discharging coke. During the coking process, technological apparatuses are connected to each other in series, in parallel and mixed. The pressure of 0,6 MPa and the temperature of 450÷500 °C are maintained in the coke chambers. As a result of the reactions taking place in the technological apparatus under study, from liquid and gaseous decomposition products, after intermediate compounds, the ready product coke is obtained. More deeply liquefied products are formed during the continuation of hydrocarbon condensation processes.

II. Investigation of the technological process for obtaining petroleum coke

Characteristics of products entering and receiving at the installation under study are given in Table 1. Let us consider a brief explanation of the technological process for obtaining oil coke. Installation for gradual coking of heavy oil products in unheated chambers type 21-10/5 is designed to produce electrode coke. In addition to coke, the unit receives dry gas, stable liquefied gas “head”, stable gasoline, light gas oil (a component of domestic heating oil) and heavy gas oil (a component of boiler fuel). The device operates continuously due to the supply of raw materials and periodically (cyclically) due to the discharge of coke.

The process of coking heavy oil products is carried out at a gradual coking installation. The raw material (tar) is supplied for installation from the tanks of the commodity park. Furnace S-303, designed for heating raw materials, is a vertical-flame furnace type GS1650/17, two-stream, serpentine tubular. The temperature at the inlet to the furnace is 170÷190 ^{0}C, at the outlet 280÷360 ^{0}C, the maximum pressure in the pipes is 2,5 MPa. At the exit from the S-303 furnace, the heated raw material is combined into one stream and enters the K-301 column. The supply of the raw material part to the plate of the 1st stage is designed to regulate the recirculation ratio. The gas fuel pressure in the S-303 furnace is controlled so that when the pressure drops below 0,01 kgf/sm^2, the shutter closes and the S-303 furnace is turned off.

The pressure in the upper part of the K-301 column is adjustable. The level in the middle part of the column is controlled by a valve located in line to the evaporator, the temperature in the middle part is controlled by the reflux returning from the evaporator and the flow is controlled. The level and temperature in the lower part of the column are regulated, the flow rate is controlled. In both cases above, there is a cascading relationship between temperature and consumption, and level and consumption. The cubic column product is sent to the S-301 furnace for reheating. Here, the intermediate product is reheated and fed into the R-301/1,2 reactors. At this time, the temperature is monitored and signaled. The pressure inside R-301/1,2 reactors is controlled. Extraction of the resulting coke is carried out with water, and the pressure of the high-pressure washing water supplied to the reactors is regulated.

In furnaces, when heated vapors of light or heavy gas oil (coolant) and a mixture of secondary raw materials enter the coke chambers, as a coke formation reactions result, coke accumulates in the chambers, and the coking products vapors are fed under the plate of the 1st stage of the bottom for the rectification column K-301. Here the consumption is controlled and the temperature is regulated. There is a cascading relationship between consumption and temperature. At this time, the second chamber is being prepared for operation, freed from coke, checked for tightness and heated to 100 °C with steam. The electric shutters in the helmet tube of the chamber being prepared for operation are gradually opened, the chamber is heated by blowing vapors from the working chamber from top to bottom into the K-310 scrubber, and the pressure in the chamber is equalized with the pressure of the working chamber.

Table 1: *Characteristics of products entering and receiving at the installation*

№	Name	% mass	min ton/year
Enter:			
1	Tar - is obtained from low-sulfur Azerbaijani oils	79,0	1053,0
2	Heavy phlegm - obtained at a catalytic cracking installation at a temperature of more than 420 ⁰C	21,0	280,0
Total:		100,0	1333,0
Receive:			
1	Dry gas	6,1	81,3
2	Stable liquefied gas head	2,4	32,0
3	Coke oven gasoline	14,1	188,0
4	Coke oven light gas oil, fraction 180÷300 ⁰C fraksiya	43,4	578,5
5	Coke oven heavy gas oil, fraction above 300 ⁰C	9,4	125,3
6	Coke	22,8	303,9
7	Technological losses	1,8	24,0
Total:		100,0	1333,0

At a chamber heating temperature of 160÷220 °C, the purge vapors are sent to the K-301 column and connected to the K-310 scrubber. The chamber filled with coke is separated from the feed stream. To do this, a valve opens at the entrance to the chamber, and the fourway valve turns towards this chamber. This process takes 40÷60 minutes. The inlet lines of the coke chamber are purged with steam, the inlet valves are closed. To remove volatile hydrocarbons from the coke pores and cool the coke, heated or hot steam is supplied to the isolated chamber at a 4 ton/h rate, and the chamber is blown into the K-301 column.

When the temperature of the reactor top (coke chamber) drops to 340÷360 °C, its blowing with water vapor is gradually directed towards the K-310 scrubber for 40÷60 minutes and blowing is continued for 6÷7 hours, increasing the flow rate of water vapor to 10 ton/h according to the schedule. After completion of the purge, the supply of water vapor to the reactor is stopped and cooling water is introduced within 6 hours.

The consumption of water into the reactor is controlled according to the schedule. When the temperature at the top of the reactor drops to 80÷90 °C, the top cover is opened, cooling with water is stopped, and water is drained from the reactor. After draining the water from the coke chamber, open its lower covers, install the telescope and start cutting the coke.

Coke cutting is carried out within 5-6 hours with water supply under pressure of 18÷23 MPa (180÷230 kgf/sm^2). For preparation after heating with water vapor, the reactor is checked for sealing with water vapor to a pressure of 4,5 kgf/sm^2, then the steam is passed through a filter to a pressure of 3,3÷3,5 kgf/sm² and discharged into the K-310 scrubber and the operation of equalization with the pressure of the working chamber is started. This operation lasts 30÷40 minutes, and during this time the pressure drop in the reactors should not exceed 0,2 atm.

When the temperature of the reactor bottom rises to 180÷220 °C , its purge with oil products vapors continues in the column K-301. This process takes 6 hours. When the temperature of the reactor bottom reaches 350÷360 °C, it is put into operation according to the coking scheme.

From the top of the K-301 column, oil gas, gasoline and water vapors, being cooled in air-to-water coolers, enter the Sp-301 gas separator. The separator separates gas, gasoline and water. Fraction 180÷350 °C - light gas oil from the column K-301 is discharged into the evaporation column K-302 with its flow from the 19th solid plate (accumulator) of the column. The low-boiling components of the fraction are evaporated with superheated steam and returned from the top of the K-302 column to the cube of the 19th plate K-301 column.

The gradual coking process carried out in unheated coke chambers at 450÷500°C temperature and 0,6 MPa pressure 0,6 MPa (6 kgf/sm²) can be considered as a deep thermal cracking process.

III. Multi-connected tar heating control system

The technological process essence is the implementation of the coking process by collecting (accumulating) its heat by blowing raw materials heated to a high temperature (495÷520°C) into unheated reactors (coking chambers) isolated from the outside. For complete coking, light gas oil heated to 515÷520°C is injected into the chambers.

The technological scheme of the oil coke production process is shown in Figure 1.

The raw material (tar) passes through the heat exchangers with the help of the H-104 pump, enters the S-303 furnace, heats up to 360÷380°C and is fed into the K-301 rectification column. The heating raw materials (tar) process in the S-303 furnace is carried out under such difficult technological conditions that any excitatory impact force acting on the system can upset the system balance and amplitude changes in the mode parameters that characterize the heating raw materials occur process.

Gas fuel is used for heating tar in an industrial furnace. When using gaseous fuels, there are certain hazards and risks for the process. This technological process is a very complex process. Because under heating conditions, external influences (exciting influences) are applied to this system, which upsets the control system balance. If the balance is disturbed, the technological parameters of this process change, that is, the difference in amplitude values. This disrupts the correct operation of the heating the raw material process to the required temperature. One of the disturbing influences is the frequent and wide range of changes in the density of the feedstock entering the installation.

In such cases, the positions of actuators 7 and 8 placed in the feed lines entering the C-303 furnace will often change, resulting in violation of the technological process quality characteristics. To overcome these shortcomings, the development of a multi-connected automatic control system for tar heating is a very actual and important problem.

On Fig. 2 shows a scheme of a multi-connected automatic control system for tar heating.

The pneumatic signal from the 1-position level sensor located at the K-301 column bottom is simultaneously fed to the input of the 2 and 3-position consumption controllers. At the input of these regulators, a signal is simultaneously received from 4 and 5-position consumption sensors and a 6-position density sensor. The outputs of the 2 and 3-position consumption controllers are connected to the 7 and 8-position actuators, on which the line of raw material (tar) entering the S-303 furnace is located. The temperature of the raw material leaving the oven is measured by a 9-position temperature sensor. The output signal passes through a 10-position temperature controller and is transmitted to an 11-position totalizer. A 12-position temperature sensor measures the temperature in the gravity wall of the furnace, and the output signal passes through a 13-position temperature sensor and simultaneously goes to a 14-position setpoint sensor and a 15-position temperature controller. The 14-position setpoint sensor is connected by its output signal to its 11-position totalizer.

The output signal of the 4 and 5-position consumption sensors is fed to the input of the 16-position consumption totalizer. The output signal of the consumption totalizer passes through the 17-position consumption controller and is fed to the 11-position totalizer input. The output of this totalizer is connected to a 15-position temperature controller, the output of which acts on an 18-position actuator. Table 2 shows the mode parameters normative values.

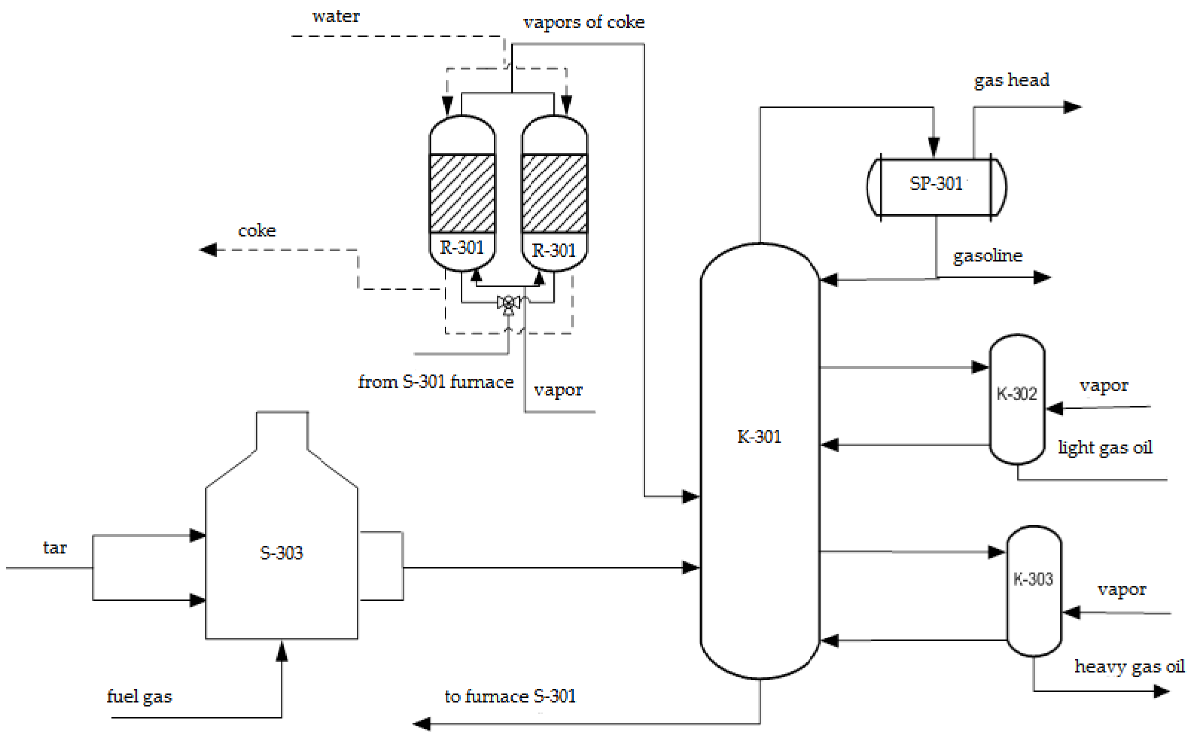

Fig. 1: *Technological scheme of the obtaining petroleum coke process*

Table 2: *Normative values of mode parameters*

№	The process stages names and mode indicators	Unit of measurement	Permissible parameter limits
1.	Raw material preparation block		
	Tar consumption	m^3/h	70÷170
	Tar temperature	°C	shouldn't be higher than 90
2.	S-303 FURNACE		
	Raw material consumption at the entrance: I.flow / II.flow	m^3/h m^3/h	35÷125 35÷125
	Raw material temperature at the outlet	°C	300÷360
	Raw material pressure at the inlet: I.flow / II.flow	kgf/sm^2 kgf/sm^2	shouldn't be more than 12
	- raw material pressure at the outlet:	kgf/sm^2	5.0÷6.0
	- flue gas temperature at the gravity wall	°C	shouldn't be higher than 830
3.	REKTIFICATION COLUMN K-301		
	- pressure at top of column	kgf/sm^2	3.3÷3.6
	- temperature at top of column	°C	on the quality of gasoline
	- column bottom temperature	°C	380÷395
	- heavy gas oil level	%	30÷70
	- light phlegm temperature	°C	350
	- light phlegm level	%	30÷70
	- heavy phlegm irrigation consumption	m^3/h	shouldn't be higher than 50
	- light phlegm irrigation consumption	m^3/h	shouldn't be higher than 80
	- level at the bottom	m^3/h	30÷70

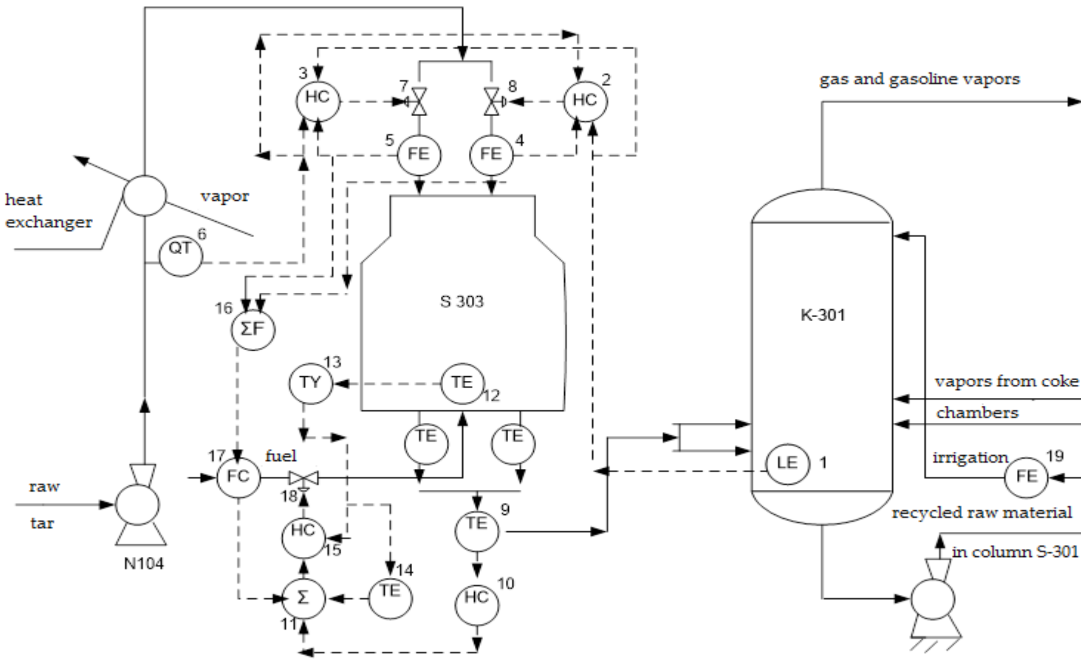

Fig. 2: *Scheme of a multi-connected tar heating control system*

IV. Conclusion

Based on numerous studies in the oil and gas processing, chemical and petrochemical industries, tube furnaces have been identified as the riskiest and most dangerous objects according to the results obtained when compared with other technological apparatuses. The technological process of obtaining petroleum coke was studied as an object of management.

All controlled and managed technological parameters that can affect the technological process have been selected and justified, metrological support has been developed. Based on this, a multi-connected automatic control system for the considered tar heating technological process was built. With this multi-connected automatic control system, the risk of explosion, fire and other existing hazards to the facility is eliminated.

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