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ENERGY SAVING TECHNOLOGIES IN THE PETROLEUM REFINING PROCESSES

*Yurii Danilov, Irina Sinkevich, Inna Lavrova, Aleksey Mardupenko, Alena Tulskaya**

National technical university "Kharkiv polytechnic institute", Kharkiv, Ukraine

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Abstract

This article describes the compounds of energetic material costs of the oil refining at the refineries and some tendencies of energy – saving technologies. It also shows the possibility of applying heat pumps, refrigeration machines, heat pipes for refining plants modernization and reduction in energy consumption.

Keywords: : temperature; pressure; energy-saving; heat pumps; refrigeration machines; heat pipes; heat recovery; screw compressor.

1. Introduction

Oil refining industry has defined the direction of development which stipulates deeper oil processing and increase of light products output, the requirements for motor oils quality increase as well. All these obstacles lead to considerable complication of the technological schemes and sharp increase of the refining expenses. Decrease of the energy costs is one of the most relevant problems, and its solving is connected with upgrade of equipment, integration of heat flux by using Pinch analysis. Also of interest is implementation of the modern hi-tech designs such as the absorbing heat inverter (AHI), compressor heat pump and heat pipes, which found a wide application in the nuclear and many others branches of industry [1].

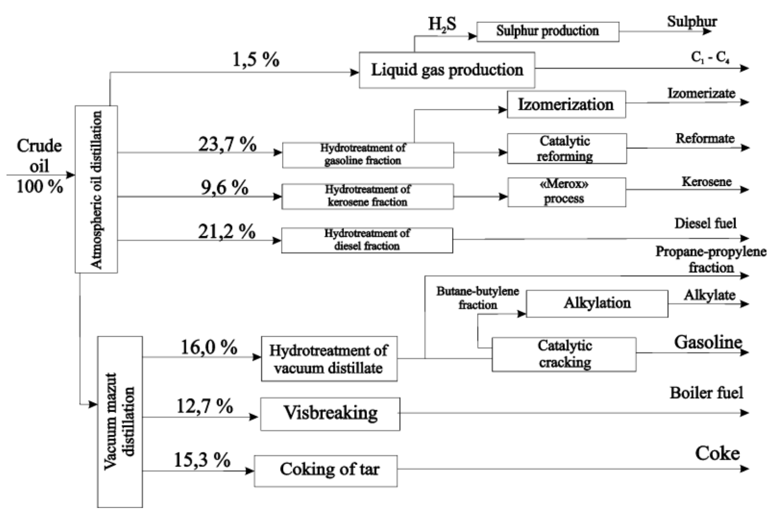

Fig. 1 presents typical structure of oil processing according to the fuel scheme.

Analysis of this scheme has shown that summary energy costs of oil processing reach from 15 to 17 % of extracted oil (fig. 2). That means not only immense material expenses but also a large amount of atmospheric emmisions.

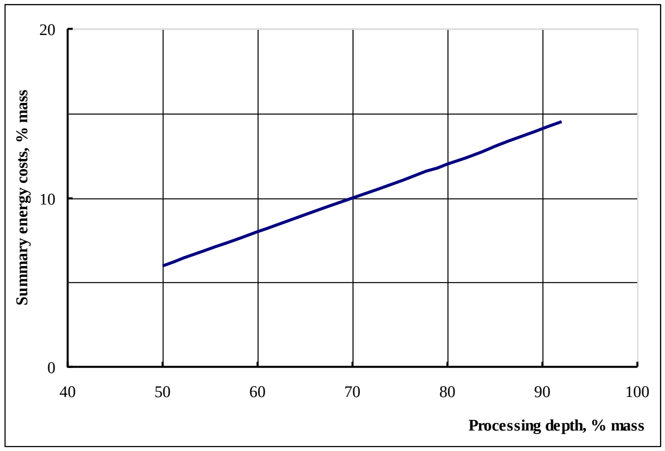

Fig. 2. Summary energy costs of oil processing

The primary oil processing facility is very energy-intensive due to the large amount of raw products. It is followed by hydrotreating and reforming facility, then – catalytic cracking and hydrocracking. The distinctive feature of these processes is the comparative low temperatures for their implementation (about 423 – 473 K). The raw is heated, as usual, by water vapour or high-temperature coolant, that has been heated previously in a furnace. The low temperature of output products does not allow to achieve high level of heat level of heat recuperation. The specific energy consumption is 70-100 kg of fuel per 1000 kg of refining materials.

One of the most perspective hi-tech designs are the absorbing heat inverter (AHI), compressor heat pump and heat pipes, how it was already mentioned before.

The AHI has these following advantages: ability to work in coolness production mode and heat production mode at the same time, herewith secondary products may be used as the sources of energy. The secondary products are water vapour under pressure 0,15 – 0,17 MPa, hot water with the temperature about 360-370 K etc.

The most popular among the AHI's are absorbing lithium bromide refrigeration machines (ABRM). The production cost of the cold, produced by these machines is 2-3 times lower than the production cost of the cold, produced in compressing cold machines. Applying the ABRM allows to reduce energy consumption and the capital expenditures pay off in less than 2 years [2].

Domestic and foreign manufacturers propose the wide range of screw compressors for compressing the hydrocarbon gases, including oil gas, torch gases etc. Screw compressors do not become fouled because compressed vapour takes the impurities out.

Heat pump is the advice, which is able to transfer a large amount of power at the low temperature gradient. It has encapsulated design which is partly filled with liquid coolant [2-3].

In the heating zone liquid coolant evaporates with absorption of heat. The movement of vapour from the evaporation zone to the condensation zone occurs due to the gradient of pressure of saturated steam in these zones. The liquid moves back to the evaporation zone through the capillary structure (wick), which is located inside the heating tube, mainly on its walls, by the gravity force or capillary pressure gradient. The effective thermal conductivity of heat pipe is 10 times more than thermal conductivity of copper, silver or aluminum and reaches 10^7 W/m·K.

The wick heat pipes, in which the transfer of liquid phase occurs due to the capillary forces, have wide application in nuclear, space and electronic industry, in the environment where the gravity is low or absent. The most perspective for applying in petroleum industry are smooth gravity tubes with phase transition – they are also called thermosiphon. The wick-fed structures of inner surface of the pipe produce additional hydraulic resistance for the condensate flow. As a results, the heat flux in wick pipes is less than in thermosiphons.

The heat pipes may be also applied for utilization of heat of exhausted gases, cooling of the liquid flux, warming of the thermolabile liquids at the constant temperature etc.

Several ways of application of the AHI, compressing heat pumps, screw compressors and heat pipes in the oil processing are given below.

2. Primary oil processing

As it was mentioned above, the primary oil processing equipment is the most energy-intensive. There is two possible ways of cost reduction: increase of the recuperation level of waste products and optimization of the technological schemes and parameters of the oil distillation.

The first way deals with the optimization of heat-exchange scheme and decrease of temperature of oil that comes to the heating furnace. In the modern equipment this temperature reaches 540-550 K. At the same time, waste products with the temperature lower than 420 K may transfer its heat to the air in numerous air-cooling units (ACU), but they're not practically applied at all. Therefore, we have great possibility to decrease the amount of ACU and reduce the energy consumption [4].

The second way deals with the optimization of the separation scheme, decrease the pressure level in atmospheric and vacuum columns. All these obstacles allow to reduce the heat load in furnace and reduce the heating temperature in atmospheric and vacuum columns to 630 and 650 K respectively, reduce the raw decomposition level and coking of furnace coil. Due to the decrease of pressure the conditions of steam condensation at the top of the column get worse. The screw compressor may be used to support the pressure to supply the gas to the hydrotreating unit and the liquid gas emission unit [5-6].

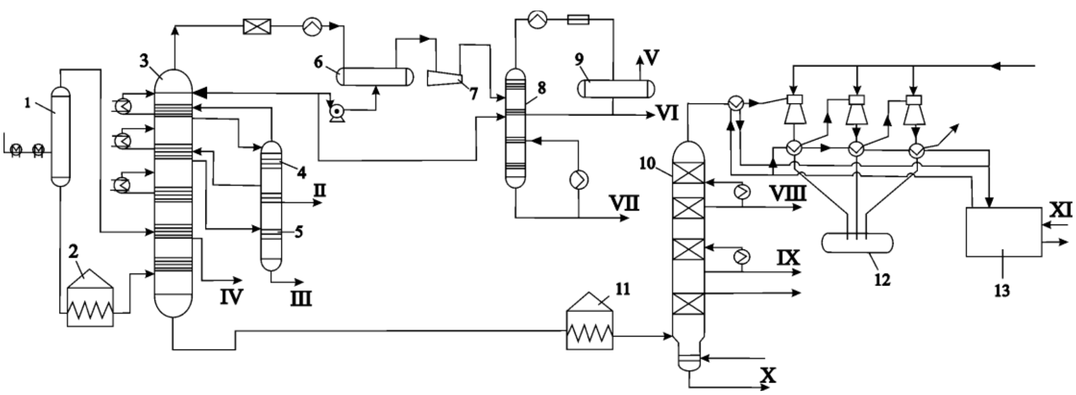

Fig.3 – The principal scheme of atmospheric distillation unit: 1 – preliminary separator; 2,11 – heating furnaces; 3 – atmospheric column; 4,5 – stripping-sections; 6,9 – reflux vessels; 7 – screw compressor; 8 – stabilizer; 10 –vacuum column; 12 – barometric vessel; 13 – ACU; I – oil; II – kerosene fraction; III – light diesel fraction; IV – heavy diesel fraction; V – fuel gas; VI – liquid gas; VII – stable gasoline fraction; VIII – diesel fuel compound; IX – vacuum gasoil; X – tar; XI – low-pressure water vapour

Fig. 3 presents the technological scheme of the primary oil processing with applying the power saving technologies. It has the following features:

- The temperature of oil after the desalter unit rises up to 550 K due to the effective heat-exchange scheme
- The furnace has a separator to decrease the pressure drop 1
- The excessive pressure on the top of the atmospheric column 3 is about 0,14 MPa
- The temperature of oil at the furnace exit is 630 K
- The screw compressor 7 has been installed to feed the stabilizer 8 with the steam. Pressure in the compressor raises up to 0,9 MPa

The calculations have shown that due to the decrese of pressure in atmospheric column by 0,8 MPa, specific energy costs decrease by more than 10 %.

In vacuum unit due to the low pressure drop at the top of the vacuum column (3,99 kPa) and low pressure drop inside the column and transfer pipeline it is possible to decrease the temperature of fuel oil heating at the furnace exit to 650 K. To support the required pressure of 3,99 kPa in vacuum column, the water steam is injected into the cube and it is also necessary to keep the temperature at 293 K. These conditions are provided by ABRM 13, in which the circulating water is cooled down to 288 K. Pressured steam (0,15 MPa) may be used in ABRM as a coolant.

In general, application of energy-saving technologies in the primary oil processing may provide the decrease of effective energy costs, the recoupment of capital expenditures is approximately 1,5 years [5].

3. Hydrotreatment of medium distillates

The hydrotreatment of medium distillates is widely used in modern technology of oil processing and takes the second place by the energy expenditures (after the primary processing). The main ways of the energy expenditures reduction are:

- Improving of the catalysts' system
- Decrease of the hydrogen concentration (integration of the concentrated hydrogen unit into the plants)
- Combination of the cold and hot separation for more effective hydrogen emission and maximal extraction of the liquefied gas
- Optimization of the heat-exchange scheme, exclusion of the air-cooling units, which use refrigeration machines

4. Izomerization, production of Methyl tert-butyl ether (MTBE) and fractioning of gases

These processes are performed at relatively low temperatures with clear rectification of fractions, at are required high energy expenditures. For reduction of these expenditures it is reasonable to use the heat pump and ABRM

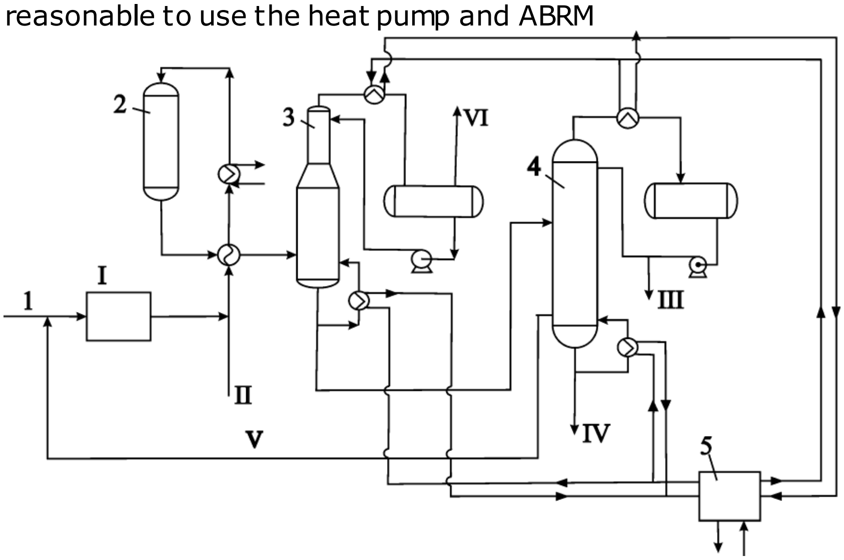

Fig. 4 – Principal scheme of isomerisation unit: 1 – dryer; 2 – reactor of isomerisation; 3 – stabilization column; 4 – deisohexanizer; 5 – ACU; I – raw material, II – hydrogen; III – isomerizate; IV – C_{7+} fraction; V – recycled material; VI – fuel gas.

Fig. 4 presents the principal technological scheme of isomerization unit with ABRM, which is able to produce cold and hot water at the same time. Cold water is used for reduction the temperature of recycling water and in rectification columns and hot water is used for heating of the columns' cubes. The water steam of fuel gas may be used as coolants.

The application of AHI provides the reduction of energy expenditures in more than 1,5 times.

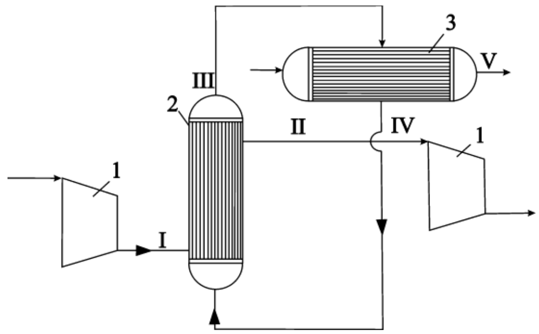

Fig. 5 – Principal scheme of gas cooling with the heat pipe: 1 – compressor; 2 – evaporator of heat pipe; 3 – condenser of heat pipe; I – hot gas; II – cold gas; III – vapour; IV – condensate; V – water

Fig. 5 presents the principal scheme of gas cooling between the compressor stages with application of heat tube. The hot steam after the first compressor's stage goes to the tubular or plate evaporator 2 where it transfers the heat to the intermediate coolant, that boils in the tubes. Then, steam goes to the condenser 3 through the heat pipe, and the condensate goes back to the evaporator by the gravity. As a result the heat-transfer process is closed.

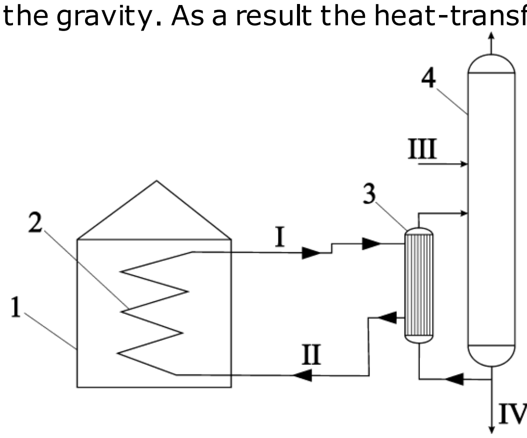

Fig. 6 Principal scheme of heating of the column cube with the heating pipe:
1 – heating furnace; 2 – evaporator of heat pipe; 3 – condenser of heat pipe;4 – rectification column; I – coolant vapour; II – coolant condensate; III – raw material; IV – bottom stream

Fig. 6 presents the principal scheme of heating of the column cube with application of heat pipe. The evaporator of heat pipe (2) is placed into the heating furnace 1, and the condenser 3 is used for heating of the column cube (4). The heating tube can be up to tens meters long and requires the relevant support. And it is also necessary to calculate the hydraulic resistance of the whole system.

The choice of coolant depends on temperature level of heat transfer, physical and chemical properties and other. Therefore, as a coolants we may use alcohols, freons, distillated water, metals etc.

The heat pipe provides effective heat transfer with the minimal temperature drop and maximal heat transfer coefficients due to the phase transitions. And due to the absence of pumps the operation and capital costs are reduced to a minimum.

Symbols

AHI	*absorbing heat inverter*
ABRM	*absorbing lithium bromide refrigeration machines*
ACU	*air-cooling units*
MTBE -	*methyl tert-butyl ether*

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To whom correspondence should be addressed: prof. Alena Tulskaya, National technical university "Kharkiv polytechnic institute", Kharkiv, Ukraine, fuel.khpi@gmail.com