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The Precise Definition of the Payload Tube Furnaces for Units of Primary Oil Refining

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The article considers the primary oil refining unit AVDU A12/2 in the mode without vacuum unit. In this paper carried out extraction of data on process flows and equipment, tabulated streaming data. It is performed modelling of primary oil refining unit in the software package Unisim Design to refine the data. It was determined the potential energy savings through the using methods of the pinch analysis, done the project of reconstruction of AVDU A12/2 with the modelling in program Unisim Design to confirm the performance of the project. The amount of heat loss in the heat exchange equipment and pipes was calculated, have developed a method for the accurate determination of the payload tube furnaces.

1. Data extraction for integration of the process of primary oil refining

Collecting process data at AVDU A12/2 was carried out using portable and stationary thermometers and flow meters. To improve the information about the composition of the circulating flows and for calculating of heat balance and material balance of AVDU A12/2 in the mode without vacuum unit used the program Unisim Design, which is a software package designed to model in the steady mode, design of chemical engineering industries, productivity monitoring equipment and optimization of the extraction and processing of hydrocarbons and petrochemicals (Plesu, 2001b).

Modelling was done in this case is for the process of refining oil, after the desalting and dehydration of crude oil in electric dehydrators and heat exchangers in the network (Plesu, 2005). Obtained data by modelling allowed tabulating streams data, which is digitally image of process. It contains all the necessary technological data for further thermal and energy integration of process primary oil refining (Tovaznyansky et al., 2010a).

2. The definition of energy-saving potential of the installation AVDU A12/2

To represent the connections of heat exchange is used grid diagram constructed on the basis of data from table of stream data. On the diagram marked all the process data and heat exchangers (Plesu, 2001a).

In the system of heat recovery dominated counter flow scheme of heat between the hot and cold process streams. In such systems, there may be a large heat loss as explained by Bagirov (1974) and elaborated more recently (Klimenko, 1985), leading to an overestimation of the surface area of heat transfer.

We can determine the thermal power, which is recovered in the heat exchange system AVDU A12/2 in the mode without vacuum unit with grid diagrams and the measured temperatures of the process streams and the values of their heat capacity. At the moment, the system is recovered heat capacity value of 33 MW.

Using data of process from a table of data streams (Table 1) and a grid diagram, on the temperature-enthalpy diagram was build Hot and Cold Composite Curves that represent the total change in enthalpy of consumable hot and cold process streams circulating in the AVDU A12/2. Composite Curves on the chart should be placed so that the interval of overlap between them was the amount of power 33 MW heat recovery (Figure 1).

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Table 1: Table of data streams

№	The name of the stream	Type	T_S, °C	T_T, °C	G, t/h	C, kJ/(kg K)	r, kJ/kg	CP, kW/K	ΔH, kW	α, kW/(m^2 K)
1	Cross flow K-1,1a in K-3	hot	173	54	8.20	2.11		4.81	571.93	0.4
2.1	Cooling gasoline vapors K-1,1a	hot	145	50	29.69	2.52		20.78	1,974.36	0.1
2.2	Cooling gases from K-1,1a	hot	145	40	2.78	2.52		1.95	204.33	0.1
2.3	Condensation gasoline vapors K-1,1a	hot	50	50	29.69		75		618.53	1
2.4	Cooling gasoline K-1,1a	hot	50	40	29.69	2.11		17.40	174.01	0.4
3.1	Cooling gasoline vapors K-3	hot	157	46	17.40	2.52		12.18	1,351.98	0.1
3.2	Condensation gasoline vapors K-3	hot	46	46	17.40		75		362.50	1
3.3	Cooling water vapors K-3	hot	157	100	1.05	2.00		0.58	32.96	0.12
3.4	Condensation water vapors K-3	hot	100	100	1.05		2256		658.00	2
3.5	Cooling water K-3	hot	100	46	1.05	4.19		1.22	65.99	0.8
4	Diesel fuel	hot	229	200	71.11	2.70		68.29	1,980.27	0.2
		hot	200	100	71.11	2.42		58.81	5,880.67	0.2
		hot	100	58	71.11	2.10		51.76	2,174.05	0.2
5	Pump around K-3	hot	165	74	75.79	2.11		55.87	5,083.79	0.15
6	Pump around K-2,2a	hot	295	144	30.73	2.11		29.85	4,507.90	0.15
7	Fuel oil	hot	360	300	133.08	2.90		150.01	9,000.85	0.15
		hot	300	250	133.1	2.71		135.78	6,789.08	0.15
		hot	250	200	133.1	2.54		122.99	6,149.54	0.15
		hot	200	150	133.1	2.36		109.87	5,493.37	0.15
		hot	150	90	133.1	2.17		95.69	5,741.42	0.15
8	Salt solution	hot	115	40	15.05	4.21		17.14	1,285.61	0.8
9	Crude	cold	10	50	250.85	1.95		142.55	5,701.96	0.1
		cold	50	118	250.85	2.10		170.22	11,574.78	0.1
10	Desalted crude	cold	112	150	248.34	2.28		192.17	7,302.34	0.15
		cold	150	200	248.34	2.47		214.40	10,720.07	0.15
		cold	200	214	248.34	2.65		231.36	3,239.06	0.15
11	Reduced crude in atmosphere part of furnace 1	cold	214	250	56.00	2.75		54.87	1,975.49	0.15
		cold	250	300	56.00	2.84		59.75	2,987.44	
		cold	300	371	56.00	3.18		66.73	4,737.86	
	Reduced crude in vacuum part of furnace 1	cold	214	250	26.00	2.75		25.48	917.19	0.15
		cold	250	300	26.00	2.84		27.74	1,387.03	
		cold	300	310	26.00	2.97		29.42	294.16	
12	Reduced crude in the left part of furnace 2	cold	214	250	64.00	2.75		62.71	2,257.71	0.15
		cold	250	300	64.00	2.84		68.28	3,414.22	
		cold	300	370	64.00	3.18		76.17	5,331.73	
	Reduced crude in the right part of furnace 2	cold	214	250	64.00	2.75		62.71	2,257.71	0.15
		cold	250	300	64.00	2.84		68.28	3,414.22	
		cold	300	370	64.00	3.18		76.17	5,331.73	
13	Fuel oil through the vacuum part of furnace	cold	360	407	53.29	2.90		65.68	3,086.84	0.15
14	Water for electric desalting unit	cold	10	80	12.54	4.20		14.60	1,021.87	0.8
15	Steam superheating in the furnace 1	cold	135	450	1.05	2.69		2.60	819.88	0.6
16	Gas for furnaces	cold	31	80	3.00	2.52		2.10	102.90	0.1
17	Fuel oil in the furnaces	cold	49	80	3.79	2.05		2.32	71.80	0.1

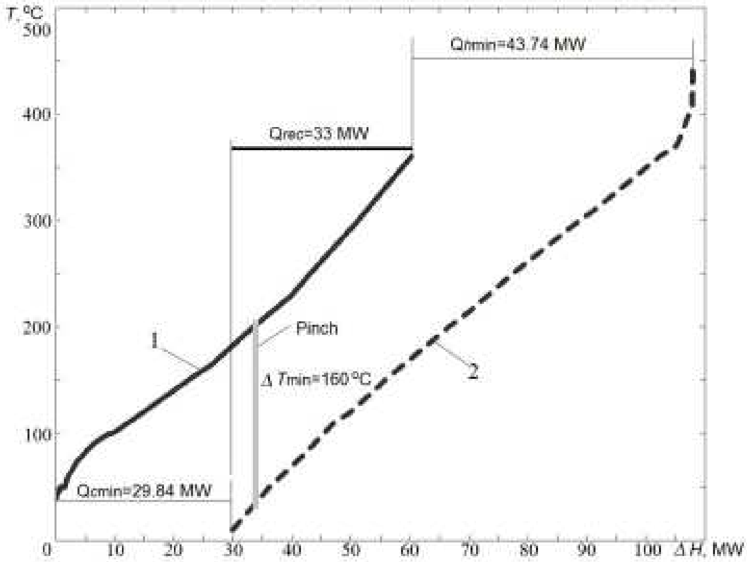

Figure 1: Composite Curves of the existing process. 1 – Hot Composite Curve; 2 – Cold Composite Curve; Q_{hmin} – minimum of hot utilities; Q_{cmin} – minimum of cold utilities; Q_{rec} – energy of recovery; T – temperature; ΔH – heat capacity; ΔT_{min} – minimum of temperature difference

In this case pinch is localized at the temperatures: T_{hot} = 200 °C and T_{cold} = 40 °C. Minimum temperature difference in the pinch is 160°C. This difference would be really minimal, if the conditions of vertical heat transfer was complied, but is now in the heat exchange system much of the heat energy is transferred between the heat transfer agents in terms of cross-exchange and on heat exchangers observed temperature difference between the heat carriers less than minimum (Stepanov, 1989).

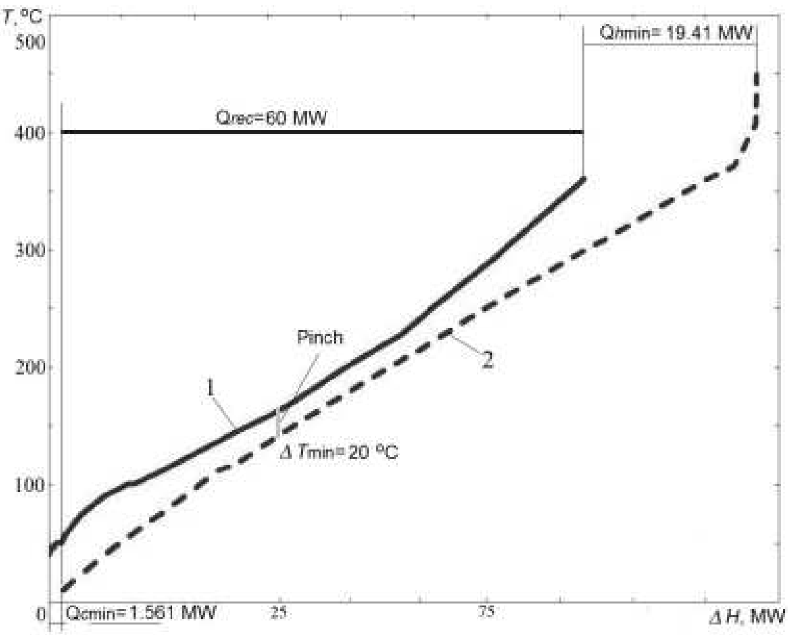

Figure 2: Composite Curves of the integrated process. 1 – Hot Composite Curve; 2 – Cold Composite Curve; Q_{hmin} – minimum of hot utilities; Q_{cmin} – minimum of cold utilities; Q_{rec} – energy of recovery; T – temperature; ΔH – heat capacity; ΔT_{min} – minimum of temperature difference

These calculations with Composite Curves allows to determine minimum temperature difference 20 °C, which will be taken as the minimum optimum temperature difference when building on enthalpy-temperature diagram of composite curves (Figure 2).
Applying Composite Curves allow fairly accurately estimate the required heat exchange surface area for the designed or reconstructed process. Furthermore, using the price of heat transfer equipment provided by the manufacturer, even before the completion of the reconstruction allows us to estimate the number of the necessary capital investment and estimated payback period (Kitipat et al., 2012).
Composite Curves show that when the ΔT_{min} = 20 °C cold utilities of 1.6 MW, and hot utilities assume significance 19.4 MW, which is 2.5 times less than the process now receives from utility system.

3. The reconstruction project

Using the rules and methods of pinch analysis assumes a separate project implementation of heating networks above and below the pinch, which are then sewn together at the pinch temperatures , if none of the connects do not violate the principle of ΔT_{min}, and all flows are satisfied in their energy requirements (Feng et al., 2011a).
Total power of hot utilities in the network is 19.4 MW and only 43 kW is transferred through the pinch. The power of cold utilities was reduced to a value of about 1.6 MW and that allows eliminating the majority of refrigerators. In the resulting heat transfer network uses 22 recuperative heat exchange communication. Assessment of the overall surface area of heat transfer is 31.052 m^2, but in the existing scheme already installed 12.658 m^2 of shell and tube heat exchangers, so the will be need only 18.394 m^2 surface.
Using data was built the model reconstruction project AVDU A12/2. This will test the proposed project and confirm the appropriateness of its design and implementation in production (Tovaznyansky et al., 2010b).
Comparison of the energy performance of existing and proposed in the project of reconstruction of heat exchange network installation showed that the project will reduce the energy consumption of hot utilities by 56 %, and the cold – by 95 %.

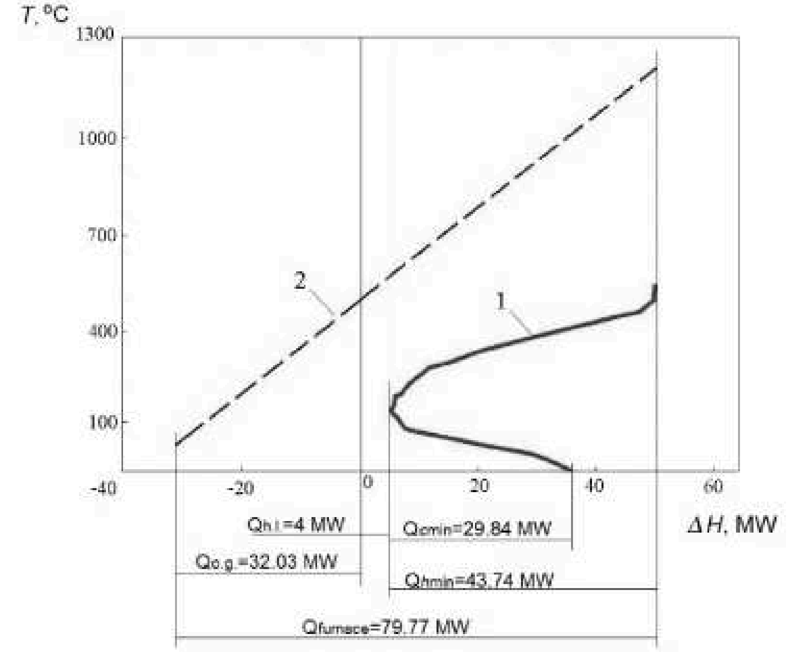

Figure 3: Grand Composite Curve without heat losses: 1 – Grand Composite Curve; 2 –profile of the furnace off-gases; Q_{hmin} – minimum of hot utilities; Q_{cmin} – minimum of cold utilities; $Q_{h.l.}$ – heat loss; $Q_{o.g.}$ – power of off-gases; T – temperature; ΔH – heat capacity

4. Amount of heat loss on the heat exchange equipment and pipes AVDU A12/2

In the process of primary oil processing at AVDU A12/2 heat transfers is not a vertical, so utility heating can occur at the big part of Cold Composite Curve, as well as recuperative heat exchange. At the same time, the payload on utility system includes not only the hot utilities, but heat loss to the environment (Mohammad Rozali et al., 2013). These losses occur in the system heat transfer directly to the heat exchangers and pipes and have a value of about 4 MW of thermal energy.

5. Accounting of the thermal losses in the construction of grand composite curve

For the most accurate data to the process of interaction it is necessary to construct a Grand Composite Curve. In addition, to determine the exact value of the payload tube furnace it must be build a diagram of grand composite curve with the profile of flue gas furnaces (Smith et al., 2000). In this case, the off-gas profile advisable to build as part of the curve.

In figure 3 is shown a Grand Composite Curve of the existing process of primary oil refining at AVDU A12/2 in operation without the vacuum unit and a profile of the furnace off-gas installation without the flow of heat losses in the heat exchangers. In this process, as is evident from the figure in furnaces stands out 79.77 MW of thermal power, payload kiln is 43.74 MW and thermal power of flue gas is 32.03 MW.

It should be noted that the flow of heat loss does not exist as material flow. His accounting in building Grand Composite Curve diagram of the process is a means to accurately determine the payload furnace. Based on the fact that the load corresponds to a load of hot utilities, it is advisable to make the accounting of the thermal losses in the range with the highest target temperature (Ulyev amd Melnikovskaya, 2011).

A Grand Composite Curve with the flow of heat losses and profile off-gas are shown in figure 4. As can be seen, the payload of furnaces in this case is 47.74 MW. Thus, accounting of the thermal losses in the installation with the construction of a Grand Composite Curve of the process allows determining a more precise value of the payload tube furnaces.

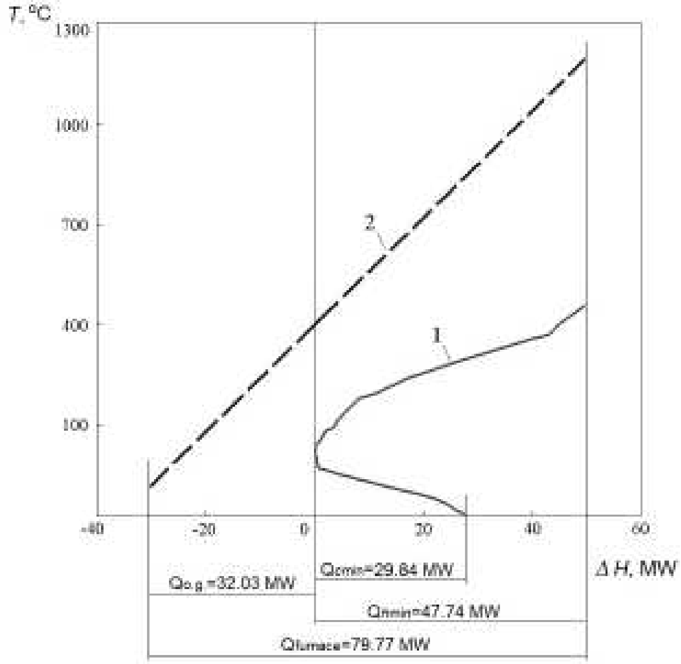

Figure 4: Grand Composite Curve with heat losses: 1 – Grand Composite Curve; 2 –profile of the furnace off-gases; Q_{hmin}, Q_{cmin} – minimum of hot and cold utilities; $Q_{h.l.}$ – heat loss; $Q_{o.g.}$ – power of off-gases

6. Conclusions

Simulation of the primary oil processing at AVDU A12/2 using the software package Unisim Design led to getting more accurate streaming data and allows to built a table of streaming data, which is a digital model of the process. Further application of pinch analysis to the integration of thermal processes of the installation will reduce energy consumption by more than 2-fold compared with the level of consumption in the present.

Building a grid diagram of the reconstruction project has allowed making its simulation program Unisim Design, which confirmed the integrity of the project and the feasibility of its implementation.
Accounting heat loss heat exchange equipment and pipes of 4 MW in the construction of Grand Composite Curve of the process provides more accurate values furnace payload and off-gas, and allows understanding the utilities interaction with the process.

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