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CONTENTS

МАЗМҰНЫ

СОДЕРЖАНИЕ

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IMPROVING THE ENERGY EFFICIENCY OF OIL TREATMENT AND STABILIZATION UNITS IN THE FIELD

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Abstract. The article discusses improving the energy efficiency of an oil treatment and stabilization facility in the field using pinch analysis methods. Pinch analysis as a methodology for minimizing the energy consumption of a process involves calculating thermodynamically justified amounts of energy consumption and approaching them by optimizing heat transfer processes, energy supply methods, and process characteristics. Pinch analysis is used in various industries, in particular in oil and gas processing, petrochemistry and the chemical industry, and can be used both in designing new technological facilities and in solving problems of optimizing the operation of existing industries, taking into account the principles of energy conservation. The Total Site energy system is a complex facility that is part of large industrial enterprises or industrial parks. As a rule, these are energy production facilities that convert various types of fuels into heat and electricity, providing basic processes. The main scientific hypothesis is to find a compromise between full energy recovery at facilities, taking into account operational and capital costs. In this paper, the object of research is the heat exchange system of an oil stabilization unit located in a field with production of 34200 thousand tons of crude oil per year. The thermal and energy integration of the oil stabilization and treatment plant has been carried out. As a result of the project's implementation, the energy consumption of external hot energy sources will decrease by 213.4 MW, or 55%. Greenhouse gas emissions will decrease by about 71%. The discounted payback period is about 11 months from the moment the reconstruction project reaches its target capacity.

Keywords: Heat exchangers, composite curves, energy efficiency, Pinch analysis, cost optimization, crude oil

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© Б.М. Калдыбаева[1*], Д.М. Кенжебеков[1], Д.Ж. Джанабаев[2], Л.М. Ульев[3], А. Жолшыбек[1], 2025.

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КӘСІПШІЛІКТЕ МҰНАЙДЫ ДАЙЫНДАУ ЖӘНЕ ТҰРАҚТАНДЫРУ ҚОНДЫРҒЫСЫНЫҢ ЭНЕРГИЯ ТИІМДІЛІГІН АРТТЫРУ

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Аннотация. Мақалада пинч-талдау әдістерін қолдана отырып, кәсіпшілікте мұнайды дайындау және тұрақтандыру қондырғысының энергия тиімділігін арттыру қарастырылады. Пинч-талдау процестің энергия тұтынуын азайту әдістемесі ретінде жылу беру процестерін, энергиямен жабдықтау әдістерін және технологиялық процестердің сипаттамаларын оңтайландыру арқылы энергия тұтынудың термодинамикалық негізделген көлемін есептеуді және оларға жақындауды қамтамасыз етеді. Пинч-талдау әртүрлі салаларда, атап айтқанда мұнай және газ өңдеу, мұнай - химия және химия өнеркәсібінде қолданылады және жаңа технологиялық объектілерді жобалауда да, энергияны үнемдеу принциптерін ескере отырып, қолданыстағы өндірістердің жұмысын оңтайландыру мәселелерін шешуде де қолданылады. Total site энергетикалық жүйесі ірі өнеркәсіптік кәсіпорындардың немесе индустриялық парктердің құрамына кіретін күрделі нысан болып табылады. Әдетте, бұл әр түрлі отынды жылу мен электр энергиясына айналдыратын, негізгі процестерді қамтамасыз ететін энергия өндіретін объектілер. Негізгі ғылыми гипотеза операциялық және күрделі шығындарды ескере отырып, объектілерде энергияны толық қалпына келтіру арасында ымыраға келу болып табылады. Бұл жұмыста зерттеу объектісі жылына 34 200 мың тонна шикі мұнай өндіретін кәсіпшілікте орналасқан мұнайды тұрақтандыру қондырғысының жылу алмасу жүйесі болып табылады. Жұмыста мұнайды тұрақтандыру және дайындау қондырғысының жылу-энергетикалық интеграциясы орындалды. Жобаны енгізу нәтижесінде сыртқы ыстық энергия тасымалдаушылардың энергия тұтынуы 213,4 МВт-қа немесе 55% - ға төмендейді. Парниктік газдар шығарындылары шамамен 71% - ға төмендейді. Дисконтталған өтелу мерзімі қайта құру жобасы берілген қуатқа шыққан сәттен бастап шамамен 11 ай шамасын құрайды.

Түйін сөздер: Жылуалмастырғыш аппараттар, құрама қисықтар, энергия тиімділігі, Pinch талдауы, шығындарды оңтайландыру, шикі мұнай

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ПОВЫШЕНИЕ ЭНЕРГОЭФФЕКТИВНОСТИ УСТАНОВКИ ПОДГОТОВКИ И СТАБИЛИЗАЦИИ НЕФТИ НА ПРОМЫСЛЕ

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Аннотация. В статье рассматривается повышение энергоэффективности установки подготовки и стабилизации нефти на промысле с использованием методов пинч-анализа. Пинч-анализ как методология минимизации энергопотребления предусматривает расчёт термодинамически обоснованных объёмов потребления энергии и приближение к ним путём оптимизации процессов теплопередачи, методов энергоснабжения и параметров технологических процессов. Данная методика находит широкое применение в различных отраслях — в нефте- и газопереработке, нефтехимии и химической промышленности — и может использоваться как при проектировании новых технологических объектов, так и при решении задач оптимизации работы действующих производств с учётом принципов энергосбережения. Энергосистема Total Site представляет собой сложный объект, являющийся частью крупных промышленных предприятий или индустриальных парков. Как правило, это теплоэнергетические комплексы, преобразующие различные виды топлива в тепло и электроэнергию и обеспечивающие ключевые технологические процессы. Основная научная гипотеза исследования заключается в поиске компромисса между максимальной рекуперацией энергии и необходимыми операционными и капитальными затратами. В данной работе объектом исследования является система теплообмена установки стабилизации нефти, расположенной на промысле с добычей 34 200 тыс. т сырой нефти в год. Проведена теплоэнергетическая интеграция установки стабилизации и подготовки нефти. По результатам анализа показано, что внедрение проекта позволит снизить потребление внешних горячих энергоносителей на 213,4 МВт, что составляет около 55 %. Выбросы парниковых газов уменьшатся примерно на 71 %. Дисконтированный срок окупаемости составляет около 11 месяцев с момента выхода проекта реконструкции на проектную мощность.

Ключевые слова. Теплообменные аппараты, составные кривые, энергоэффективность, Pinch-анализ, оптимизация затрат, сырая нефть

Исследование выполнено при финансовой поддержке Комитета науки Министерства науки и высшего образования Республики Казахстан (ИРН AP26104837–Повышениеэнергоэффективностиобъектовнефтегазодобывающей промышленности путем интеграции процессов при подготовке и добыче)

Introduction. To increase energy efficiency and reduce costs in the oil refining industry, it is necessary to develop comprehensive methods for integrating industrial processes and start directly with oil and gas production. It is necessary to develop an energy-efficient method of targeted energy delivery to the well to prevent oil paraffination, and it is also necessary to develop energy-efficient methods for preparing and stabilizing crude oil during production and energy-efficient integrated methods for liquefying associated petroleum gas (Smit et al., 2000; Khusanov et al., 2017). When solving the problems of increasing the energy efficiency of technical systems, the issues of thermodynamic optimization of processes occurring in the elements of thermal power equipment and in thermal power systems themselves are primarily considered. One of the most effective methods of parametric optimization of thermal energy processes is pinch analysis or the method of integration of thermal processes (Tovar-Facio et al., 2020; Carmona-Martínez et al., 2023). However, one of the main limitations of the pinch method is its focus on the enthalpy approach to the analysis and optimization of heat fluxes in the system under consideration.

In connection with the above, there is a need to develop such a method of thermodynamic analysis and improvement of technical systems that would combine the advantages of the exergetic method and the method of structural and parametric optimization of thermal processes based on pinch analysis. Increased energy efficiency in the manufacturing industry can be achieved through new processes, production chain upgrades, better process integration, etc. But inter-factory integration (Klemeš et al. 1997) and inter-industry integration are still under development, and some results may be applicable to the low-carbon industry (Kuznetsov et al., 2022). The concept was first established (Dhole et al. 1993) and later updated by many authors and various aspects of biomass integration (Amiri et al. 2021), including centralized cooling (Liew et al., 2015), process modification (Chew et al., 2015), modernization of the heat exchanger network (Čućek et al., 2015) and others.

The use of exergetic analysis is important for assessing the stability of chemical processes, as it demonstrates potential losses in the energy system. This has been proven for the Total Site with the Omega Total Site Profile for calculating exergetic fracture and losses in individual processes (Mehdizadeh, et al., 2022). Combined with the general optimization algorithm, this resulted in a 24% reduction in exergy destruction in the specific example. The exergetic approach has also been used for multiple back-pressure steam turbines and optimal design of heat and electricity cogeneration systems (Pirmohamadi et al., 2019). The cogeneration potential of Total Site energy systems is crucial because it determines the amount of heat that can be converted to electricity. Varbanov et al. He presented methods for modeling steam turbines and gas turbines, which were integrated into models of utility cogeneration systems and synthesis of individual utility systems (Klemeš et al. 1997). Targeting for cogeneration was evaluated using commercial software and proved the feasibility of the approach (Ren et al., 2018). The efficiency of steam turbines should be improved, for example, optimization of the model has demonstrated high energy savings, shaft productivity and profitability of the bio-processing plant (Pyrgakis et al., 2020). The potential of cogeneration can also be used by the local energy sector to reduce energy consumption and improve energy efficiency and cogeneration of electricity (Lee et al., 2020). Optimization of the local energy sector is mainly carried out using mathematical programming (MP) to use seasonal total energy storage at the facility (Liew, et al., 2018), increase efficiency in conditions of uncertainty (Sun et al., 2017), etc.

The article (Boldyryev et al. 2023) presents a new extension of the common site method, which takes into account the optimal amount of energy that can be saved at the inter-factory level. The approach uses the construction of general profiles of an object with a real temperature, takes into account heat transfer with intermediate utility and determines the potential of cogeneration within the enthalpy blocks of the total heat recovery of the object. The total annual cost was determined based on the Total Site Pinch concept, which makes it possible to find the optimal temperature regime between the temperature profiles of the facility. The results can be used for detailed design of the facility's energy system and further development of Total Site methods.

In (Boldyryev et al. 2023), an update of the super-targeting procedure is proposed, taking into account the separation of flows and mixing in the compression problem. An original algorithm for constructing composite curves is proposed for analyzing the distribution of technological flows and flow separation in subsystems above/below compression before designing a network of heat exchangers. This was then used in the super target planning procedure to refine capital expenditures. The proposed methodology can be used for preliminary design of the heat exchanger network in order to better determine the optimal ΔTmin, capital cost targets and verify the optimal change for various energy prices.

The document (Boldyryev et al., 2023) presents a methodology for evaluating electrified options for the processing industry based on methods of systematic process integration. Improved heat recovery and focus on electrified utilities were achieved using a Large Composite Curve and analysis of the main technological flows. The processing of liquefied natural gas is analyzed and the electrified heating network is evaluated. This approach can be used to further develop options for decarbonization of industry and targeting of electricity in processing industries.

Materials and methods

The main methods (Smit et al., 2000) of optimizing energy consumption in an industrial enterprise are as follows: – operational improvements that optimize the technological process; – a higher percentage of heat recovery due to increased thermal integration of the technological process (this includes pinch analysis); - the introduction of new technologies that increase the efficiency of equipment operation.

To assess energy efficiency and increase it at oil and gas treatment and processing enterprises, a number of methods and techniques are used to achieve the target values of optimal energy consumption. These include: pinch analysis; energy efficiency benchmarking methodology; hyperstructure optimization; stochastic optimization. The methods of pinch analysis find the greatest application in relation to the industries of the industry (Kuznetsov et al., 2022).

Total Site is a concept that covers the management and optimization of all aspects of work in a field or production facility, including extraction, processing, storage and resource allocation. When using the Total Site concept, all operations — from oil production to its refining — are considered as a single system (Boldyryev et al., 2023).

Pinch analysis as a methodology for minimizing the energy consumption of a process involves calculating thermodynamically justified amounts of energy consumption and approaching them by optimizing heat transfer processes, energy supply methods, and process characteristics. Pinch analysis is used in various industries, in particular in oil and gas processing, petrochemistry and the chemical industry, and can be used both in designing new technological facilities and in solving problems of optimizing the operation of existing industries, taking into account the principles of energy conservation (Boldyryev et al., 2023).

The Total Site energy system is a complex facility that is part of large industrial enterprises or industrial parks. As a rule, these are energy production facilities that convert various types of fuels into heat and electricity, providing basic processes. There is also heat distribution, cogeneration, and cooling. The utility can be supplied to the main processes from the utility system of the facility or another process due to the utilization of waste heat. The main scientific hypothesis is to find a compromise between full energy recovery at the facilities, taking into account the operational and capital costs of TSHR. This method extends the supertargeting procedure, which is used for individual processes and at the Total Sites level. However, TSHR is a more complex system and requires additional consideration to reformulate the overall objectives and systemic consideration. The initial idea was to apply the concept of supertargeting (Linnhoff et al., 1986) to shared profiles (TSP), but some functions limit such an extension. These are heat exchange using intermediate utilities (IMUS), the presence of zones for generating electricity, shifted temperature TSP, unified ΔTmin of utility systems, and others. This study will determine the total annual cost (TAC) of TSHR as a function of the total ΔTmin at the site and investigate the behavior of this function over a wide range of arguments and provide recommendations for cost-effective design of the TS heat exchange network.

The method is based on the decomposition of TSP into enthalpy blocks, taking into account real temperatures. Real temperatures make it possible to use certain IMUS in enthalpy blocks and maximize TS heat recovery (Boldyryev et al., 2023). In addition, heat and electricity (CHP) cogeneration will be considered within the framework of enthalpy units that maximize electricity generation. The next steps involve combining enthalpy blocks to reduce the number of IMU levels (Boldyryev et al., 2023), and hence heat exchangers and cogeneration zones. Capital expenditures and TAC targeting are applied to find the most cost-effective solution for TSHR.

When applying process integration, the following rules should be followed:

- heat transfer through pinch should not be carried out;
- for the area above the pinch, there should be no external cooling system.;
- for the area below the pinch, there should be no heat supply to the system from external sources.

In this case, the technological object is considered as a system with the allocation of structural units and the establishment of relationships between them. The above example, in particular, is characterized by the presence of a number of parallel operating devices of the same type – separators, settling tanks, and electric dehydrogenators; at the same time, the stages of the target process are carried out sequentially.

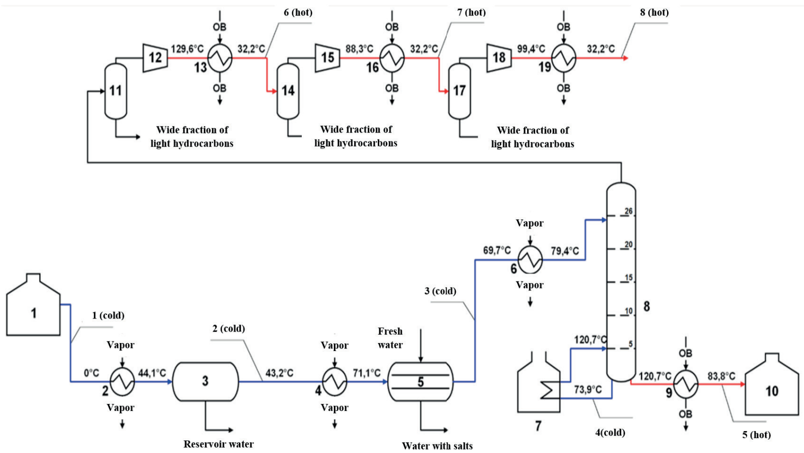
When analyzing the schemes, it is necessary to determine all the flows of matter and energy – internal (within the system) and external (flows going beyond the system and coming from systems external to the system under study), followed by determining the energy characteristics of internal and external flows. To do this, perform material calculations and, based on knowledge of the temperature parameters of the processes, determine the enthalpies of the flows with the release of hot and cold flows. The analysis of the heat exchange system and the collection of data on technological flows, obtaining flow properties and data on operating and capital costs will be carried out directly at the research facility (in the field), using an instrumental survey (measurement, survey, monitoring) and statistical analysis of historical data on resource consumption.

Results and discussion

The oil-bearing reservoir fluid extracted from oil fields has a complex composition. It contains: oil itself; associated petroleum gas; reservoir waters; drilling mud; various mechanical (Smit et al., 2000). It is unprofitable to transport such a mixture through main oil pipelines. Therefore, special oil treatment and stabilization units (OTSU) are being built and operated directly at the fields. These installations carry out the processes of degassing, dewatering, desalination and stabilization of extracted raw materials, and these processes, like most processes in the oil refining and petrochemical industries, are among the most energy-intensive processes among all industries. Therefore, the search and synthesis of systemic technological solutions to reduce specific energy consumption in these areas of industry is an urgent task.

Currently, the most effective methods of improving the energy efficiency of oil refining plants are process integration methods, and, in particular, the pinch analysis method (Khusanov et al., 2017).

In this paper, the object of research is the heat exchange system of an oil stabilization unit located in a field with production of 34,200 thousand tons of crude oil per year (Fig. 1).



1 – tank with raw materials; 2, 4, 6, 9, 13, 16, 19 – heat exchangers; 3– sump; 5 – electric dehydrogenator; 7 – furnace; 8– stabilization column; 10 – reservoir of prepared oil; 11, 14, 17 – separators; 12, 15, 18 – compressors.

Figure 1- Schematic technological diagram of the existing process at the OTSU

Crude oil with an initial temperature of ~ 0^0C from the reservoir 1 of the central collection point is pumped through a heat exchanger 2 and at a temperature of about 44 ° C enters the sump 3. In the sump, reservoir waters are diverted from the target stream, and the dehydrated oil, after heating in the heat exchanger 4, is fed into an electric dehydrogenator 5, in which, mixing with a stream of prepared fresh water with with a flow rate of 13.89 kg/s, it is re-dehydrated and desalinated. Further, the prepared oil, passing through the heat exchanger 6, is fed under the upper plate of the stabilization column 8. The temperature of the bottom of the column is maintained between 110-130 ° C due to the heat of stable oil circulating through the coils of the tubular furnace 7. The overpressure in the column is maintained at values from 0.1 to 0.2 MPa, which creates the best conditions for fractionation of gasoline vapors – a wide fraction of hydrocarbons – in the cascade of separators 11, 14, 17 and in refrigerating condensers (the diagram shows separately 12, 15, 18 – condensers and 13, 16, 19 – cooling heat exchangers). Stable oil leaving the bottom of the column is cooled in the heat exchanger 9 and enters the reservoir of the prepared products. Hot steam circulates in the heating heat exchangers, and cooling water circulates in the cold ones.

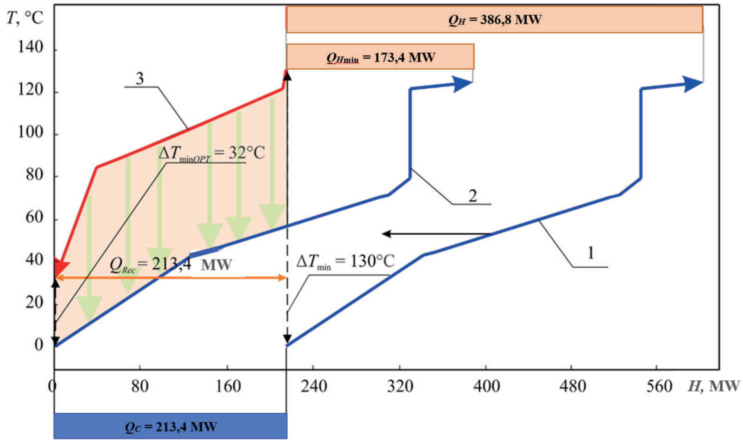
The study of the technological regulations of the process, the technological scheme and the synthesis of the engineering model (Fig. 2) of the installation using the mathematical software of Honeywell UniSim® Design allowed us to form a flow table for the process under consideration (Tovar-Facio et al., 2020) (Table 1).

Table 1 -Table of streaming data of the oil treatment and stabilization unit

№	Stream name	Type of stream	T_s,°	T_t,°	*C*, kW/(kg Ч	*G*, kg/s	*CP*, kW /°	α, kW/(m2°
1	Power	cold	0	44	2.35	1257.5	2957.7	0.3
2	Power supply for the electric dehydrator	cold	43	71	5.0	1257.5	6304.8	0.25
3	Power supply of the stabilization column	cold	70	79	1.9	1257.5	2333.1	0.25
4	Heating of the column cube	cold	121	124	20.2	958	19380.7	0.25
5	Flow from the separator of the 3rd stage	hot	99	32	4.62	916.9	4235.9	0.02
6	Flow from the separator of the 2nd stage	hot	88	32	0.93	340.6	316.1	0.02
7	Flow from the separator of the 1st stage	hot	130	32	0.97	163.44	158.3	0.03
8	Bottom of the stabilization column	hot	121	84	3.37	77.65	261.8	0.25

Stream numbers in the table. 1 coincide with the numbers of technological flows on the basic technological scheme (Fig. 1.). The following designations are used in the flow table: T_s – initial flow temperature, °C; C, – specific heat capacity, kW/(kg · °C); G is the mass flow rate, kg/s; CP is the flow heat capacity, kW/ °C; α is the heat transfer coefficient characteristic of the flow, kW/(m2· °C

It follows from the regulations and technological scheme of the OTSU (Fig. 1) that only utility heat exchangers are used in the technology, and the heat energy recovery capacity is zero. Using the Pinch 2.02 software package, we will construct composite curves of technological flows of USPS so that they do not overlap along the axis of flow enthalpy (Fig. 2).



1 – cold composite curve of the initial process; 2 – cold composite curve of the initial process after thermal energy integration; 3 – hot composite curve; Q_H – useful capacity of the hot utility before thermal energy integration; Q_C - useful capacity of the cold utility before thermal energy integration; Q_{Rec} – heat energy recovery capacity; ΔT_{minOPT} - economically optimal the value of the minimum driving force in the heat exchange system

Figure 2- Composite curves of technological flows of OTSU

In this case, the cold process streams are heated in utility heat exchangers and the useful power used for this heating is equal to Q_H = 386.8 MW. Hot process streams are cooled in utility heat exchangers and heat output from them is equal to Q_C = 213.4 MW. In this case, the value $\Delta T_{min}=130^0C$ C is not the driving force of heat transfer, but simply shows the distance between the curves along the temperature axis.

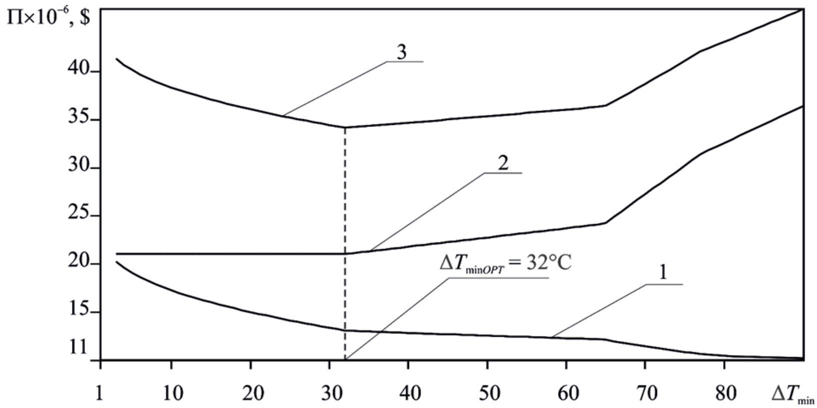
With a known power consumption and output and the specific cost of energy resources, it is easy to calculate the total cost of energy resources consumed by a thermal power system. However, to determine the optimal value of ΔT_{min} it is necessary to know the cost of reconstructing the heat exchange system. The cost of reconstructing the heat exchange system is calculated using the dependence of the cost of installed heat exchange equipment, which is obtained using a regression analysis of the cost of heat exchangers at oil refineries [A.A. Carmona-Martínez, et al. 2023]:

$$\Pi_{HE} = A + B(S)^c, \tag{1}$$

where A = 40000 USD is the cost of installing the heat exchanger together with fittings and delivery; B = 1000 USD is the cost of 1 m^2 of the heat exchange surface, S; c = 0.87 is an indicator of the nonlinear dependence of the cost of the heat exchanger on its heat exchange surface. The typical cost of hot utilities at oil refineries is ~ 120

USD per 1 kW per year, cold ~ 10 USD per 1 kW per year, and the loan rate is 20% for a period of 10 years.

Using the Pinch-2.02 software package, taking into account the cost data, we construct cost curves for the reconstruction project of the OTSU heat exchange system (Fig. 3).



1 – The dependence of the present value of the installed heat exchange surface on the minimum driving force of heat exchange; 2 – The dependence of the annual cost of surface utilities on the minimum driving force of heat exchange; 3 – The total dependence of the present value of the reconstruction project on the minimum driving force of heat exchange.

Figure 3- Cost curves of the OTSU reconstruction project

And the optimal value of the minimum temperature difference, i.e. the difference, at which the discounted cost of the reconstruction project will be the lowest, is ΔT_{minOPT} = 32°C.

The construction of composite curves for ΔT_{minOPT} = 32°C (Fig. 2) shows the payload of hot utilities Q_{Hmin} = 175390 MW, cold utilities – Q_{Cmin} = 0 MW and thermal energy recovery capacity – Q_{Rec} = 213.4 MW. Thus, by completing the reconstruction project, it is possible to reduce the consumption of hot utilities by 55%, and to abandon cold ones altogether and put all refrigerators in reserve. The energy values obtained during the construction of composite curves for the optimal value of the driving force of heat transfer are the target energy values that must be achieved during the implementation of the pinch reconstruction project of the OTSU heat exchange system. In our case, we need to create a regenerative heat exchange system at the installation in question.

Next, using the laws and rules of pinch analysis to build optimal heat exchange systems, we synthesize a grid diagram of the OTSU reconstruction project (Fig. 4.)

In the grid diagram, the net capacity of the hot utilities is 173.4 MW, which is 45% of the currently existing hot utilities. All hot streams are brought to their target temperatures by cooling them in a regenerative heat exchange system with cold process streams. Summing up the thermal loads of the regenerative heat exchangers shown in the grid diagram, we obtain the value of the hot utility, which we obtained when constructing composite curves for ΔT_{minOPT} = 32°C. Thus, by placing regenerative heat exchangers on the grid diagram, we have shown the possibility of achieving target energy values in the project of creating a new OTSU regenerative heat exchange system.

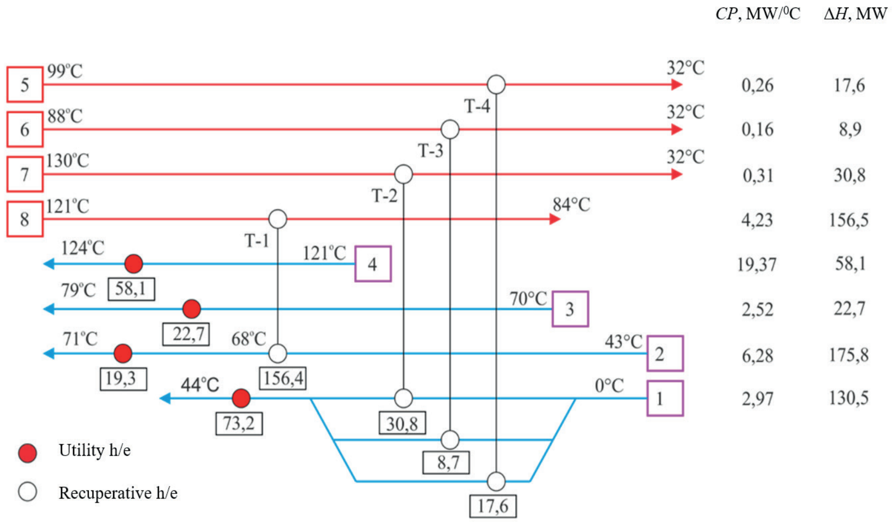


Figure 4- Grid diagram of the OTSU heat exchange system reconstruction project. The flow numbers correspond to the numbers in the Flow Table 1. The circled values below the image of the heat exchangers show their thermal load

It should be noted that the synthesized grid diagram of the OTSU heat exchange system project should serve as a technical specification for designing a regenerative heat exchange system and preparing working documentation for the reconstruction project.

Conclusions.

The paper performs thermal energy integration and presents a grid diagram of a regenerative heat exchange system for an oil stabilization and treatment plant. As a result of the project's implementation, the energy consumption of external hot energy sources will decrease by 213.4 MW, or 55%. You can completely abandon cold utilities. Greenhouse gas emissions will decrease by about 71%. The discounted payback period is about 11 months from the moment the reconstruction project reaches its target capacity.

References

Smit R., Klemesh J., Tovazhnjanskij L.L., Kapustenko P.A., Ul'ev L.M. (2000) Osnovy integracii teplovyh processov [Fundamentals of thermal process integration]. Har'kov. NTU "HPI". — 458 p. (in Eng.).

Khusanov A.E., Ul'ev L.M., Kaldybaeva B.M., Sabyrhanov D.S., Boldyrev S.A. (2017) Modelirovanie i optimizacija jenergopotreblenija, snizhenie urovnja zagrjaznenija promyshlennyh predprijatij na osnove integracij processov s primeneniem metodov pinch-analiza [Modeling and optimization of energy consumption, reducing pollution levels in industrial enterprises based on process integrations using pinch analysis methods.]. – Shymkent: SKSU named M. Auezov. — 266 p. (in Eng.).

J. Tovar-Facio, M. Martín, J. María Ponce-Ortega (2020) Sustainable energy transition: modeling, optimization. Sensor Actuator B Chem, Article 129129, 10.1016/j.snb.2020.129129. (in Eng.).

A.A. Carmona-Martínez, A. Fresneda-Cruz, A. Rueda, O. Birgi, C. Khawaja, R. Janssen, B. Davidis, P. Reumerman, M. Vis, E. Karampinis, P. Grammelis, C. Jarauta-Córdoba (2023) Renewable power and heat for the decarbonisation of energy-intensive industries. Processes, 11. — 18 p. 10.3390/pr11010018. (in Eng.).

J. Klemeš, V.R. Dhole, K. Raissi, S.J. Perry, L. Puigjaner (1997) Targeting and design methodology for reduction of fuel, power and CO2 on total sites. Appl Therm Eng,17. — P. 993-1003p., 10.1016/S1359-4311(96)00087-7 (in Eng.).

M. Kuznetsov, S. Boldyryev, D. Kenzhebekov, B. Kaldybaeva (2022). Improving inter-plant integration of syngas production technologies by the recycling of CO2 and by-product of the fischer-tropsch process. Int J Hydrogen Energy, 47. — P. 31755-31772, 10.1016/j.ijhydene.2021.12.184 (in Eng.).

V.R. Dhole, B. Linnhoff (1993) Total site targets for fuel, Co-generation, emissions, and cooling. Comput Chem Eng,17. — P. S101, 10.1016/0098-1354(93)80214-8–S109 (in Eng.).

H. Amiri, A.F. Sotoodeh, M. Amidpour (2021) A new combined heating and power system driven by biomass for total-site utility applications. Renew Energy, 163. — P. 1138-1152, 10.1016/j.renene.2020.09.039 (in Eng.).

P.Y. Liew, S.R.W. Alwi, Z.A. Manan, J.J. Klemeš, P.S. Varbanov (2015). Incorporating District Cooling System in Total Site Heat Integration. — P. 19-24, 10.3303/CET1545004 (in Eng.).

K.H. Chew, J.J. Klemeš, S.R. Wan Alwi, Z.A. Manan (2015). Process modifications to maximise energy savings in total site heat integration. Appl Therm Eng,78. — P. 731-739, 10.1016/j.applthermaleng.2014.04.044 (in Eng.).

L. Čućek, V. Mantelli, J.Y. Yong, P.S. Varbanov, J.J. Klemeš, Z. Kravanja (2015). A Procedure for the Retrofitting of Large-Scale Heat Exchanger Networks for Fixed and Flexible Designs Applied to Existing Refinery Total Site, 45. — P. 109-114, 10.3303/CET1545019 (in Eng.).

F. Mehdizadeh, N. Tahouni, M.H. Panjeshahi (2022). Total site exergy analysis, using a new conceptual method. Energy,250, Article 123790, 10.1016/j.energy.2022.123790 (in Eng.).

A. Pirmohamadi, M. Ghazi, M. Nikian (2019). Optimal design of cogeneration systems in total site using exergy approach. Energy,166. —P. 1291-1302, 10.1016/j.energy.2018.10.167 (in Eng.).

X.-Y. Ren, X.-X. Jia, P.S. Varbanov, J.J. Klemeš, Z.-Y. Liu (2018). Targeting the cogeneration potential for total site utility systems. J Clean Prod, 170. — P. 625-635, 10.1016/j.jclepro.2017.09.170 (in Eng.).

K.A. Pyrgakis, A.C. Kokossis (2020). Total site synthesis: selection of processes to save energy and boost cogeneration. S. Pierucci, F. Manenti, G.L. Bozzano, D. Manca (Eds.), Computer aided chemical engineering, 30 European symposium on computer aided process engineering. — vol. 48. — P. 1345-1350, 10.1016/B978-0-12-823377-1.50225-1 (in Eng.).

P.Y. Liew, S.R. Wan Alwi, W.S. Ho, Z. Abdul Manan, P.S. Varbanov, J.J. Klemeš (2018). Multi-Period energy targeting for total site and locally integrated energy sectors with cascade Pinch analysis. — Energy, 155. — P. 370-380, 10.1016/j.energy.2018.04.184 (in Eng.).

L. Sun, L. Gai, R. Smith (2017). Site utility system optimization with operation adjustment under uncertainty. Appl Energy, 186. — P. 450-456, 10.1016/j.apenergy.2016.05.036 (in Eng.).

Boldyryev S., Gil T., Krajačić G., Khussanov, A. (2023) Total site targeting with the simultaneous use of intermediate utilities and power cogeneration at the polymer plant. — Energy, 279. — 128034 p. https://doi.org/10.1016/j.energy.2023.128034. (in Eng.).

Boldyryev S., Kuznetsov M., Ryabova I., Krajačić G., Kaldybaeva B. (2023) Assessment of renewable energy use in natural gas liquid processing by improved process integration with heat pumps. e-Prime - Advances in Electrical Engineering, Electronics and Energy. — Vol. 5. — № 100246. doi: 0.1016/j.prime.2023.100246 (in Eng.).

B. Linnhoff, S. Ahmad (1986). SUPERTARGETING: optimum synthesis of energy management systems. J Energy Resour Technol, 2 (1). — P. 1-13, 10.1115/1.3231413 (in Eng.).

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