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THE SUBSTANTIATION OF CONSTRUCTION, PECULIARITIES OF ASSEMBLING AND CALCULATING MULTI-LEVEL SYSTEM OF HEATING OF RESERVIOR PRODUCTS CONDUCTED ON THE BASIS OF "DTH"DEEP PIPE HEATERS

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ОБГРУНТУВАННЯ КОНСТРУКЦІЇ, ОСОБЛИВОСТЕЙ КОМПОНУВАННЯ ТА РОЗРАХУНКУ БАГАТОРІВНЕВОЇ СИСТЕМИ ПІДІГРІВУ ПЛАСТОВОЇ ПРОДУКЦІЇ, ЩО ВИКОНАНА НА БАЗІ ГЛИБИННИХ ТРУБНИХ ПІДІГРІВАЧІВ „ПЕТ"

Purpose. Substantiation of construction, peculiarities of assembling and calculating the main parameters of a multi-level system of reservoir production heating that has been made on the basis of "DTH" deep tubular heaters, which are placed in the oil well and improve the production conditions of reservoir fluid with a high content of asphalt-resin-paraffin (TSA) by heating products within specified intervals.

Methodology. The methodological basis of the research is a complex analysis and synthesis of the literature, as well as the positive experience in combating with asphalt-resin-paraffin deposits (ARPD) while extracting hydrocarbons with high content of asphalt-resin-paraffin (ARP) using expert analysis and assess of the results obtained.

Findings. The research resulted in substantiation of the construction of heater of "DTH" pipe deep type, and elaboration of a multi-level system of heating the reservoir production on its basis, which is integrated into the complement of a lifter made from pump-compressor pipes. The calculation model has been substantiated to define parameters of work of the multi-level system of heating reservoir products performed on the basis of pipe electrical heater of "DTH" type. Methods of determining power required for the operation of the multi-level system of heating of reservoir production have been developed.

Originality. For the first time the following items have been developed: the model of work of the multi-level system of heating of reservoir products; the methodology of determining the coefficient of heat loss of pipe deep warm-isolation multi-layers heaters equipped with different types of casings.

Practical value. The construction of the pipe deep heater of "DTH" type has been substantiated and shown; the principle of assembling and calculating the multi-level system has been also offered of heating reservoir products, which are integrated into the composition of NKT heater and allow reducing the level of ASP deposits on work surfaces of deep equipment. The construction of multi-level warm-isolation casing has been suggested which is used in the composition of construction of a pipe deep heater of "DTH" type.

Keywords: *asphalt-resin-paraffin (ARP), deep heater, system or heating of the reservoir products, pump-compressor pipes*

Introduction. The process of well drilling of liquid hydrocarbons fuels, using fountaining, self-streaming or one of deep-pump ways of oil drilling in certain cases is characterized by the availability of higher content of paraffin or asphalt-resin-paraffin deposits (short - ARPD) in the fluid, the composition of which includes paraffin, which is a series of methane hydrocarbons from C_{16H34} to $C_{64}H_{130}$ as well as seliko-gel tar, asphalt-resinous compounds and others. These substances complicate and in some cases make impossible the process of drilling liquid products of wells since they tend to create deposits on work surfaces of deep pump equipment and walls of pump-compressor pipes (PCP). Under such conditions the usage of diverse methods and ways of dealing with deposits of high-viscosity compounds is becoming even more topical. Nowadays in Ukraine, the moving steam-generating sets are used, which heat the well trunk for dilution of asphalt-resin-paraffin deposits (ARPD) and other high-viscous substances. However, this method is characterized by high level of expenditures on deparaffinization and, in the majority of cases, the necessity of interrupting of the process drilling hydrocarbons products of wells.

The other variants (the usage of scrapers and magnetic devices, the introduction of chemical diluents, and the usage of borehole inductive heaters) have not been commonly used due to insufficient efficiency and reliability as well as necessity of the usage of considerable nomenclature of technological equipment.

Considering this, the urgent task is to project modern native highly efficient system of dealing with ARPD and development of a scientifically based model of its work that will allow choosing the optimal correlations of constructive and exploiting parameters of this system even at a projective stage and providing the maximal efficiency of its exploitation.

Analysis of the recent research. The analysis and research of factors of paraffin production and ways of their prevention are shown in works [1–4]. The research resulted in projecting and introducing diverse ways of dealing with ARPD and special equipment for their usage into the manufacture. It is important to take into account the devices for electrical deparaffinization (heating, induction) as being the equipment that has certain advantages, compared to analogical ones:

- it does not change the chemical composition of the environment;
- it can be used in periodical or permanent modes;
- it does not require considerable expenditure on providing the process implementation;
- it can be applied simultaneously with lifting of reservoir fluid.

An NKT lifter equipped with deep inductive heater (Fig. 1) [1, 5], and one of the variants of constructive performance of inductive well heater (Fig. 2) can be taken as examples.

The construction of inductive heaters has both advantages and disadvantages of constructive and exploiting nature.

The advantages are:

- the possibility to include reservoir products to the composition of a pump-compressor lifter with simultaneous implementation of their selection;
- the possibility of locating a tubing column within any interval.

Disadvantages are:

- the inductive coils that are sensitive to the circumstances of implementation of mounting-demounting works and exploitation since even little shakes or vibration during the work or lowering-lifting tubing columns can stop their work;
- the usage of inductive principle of work of reels increases the overall diametrical sizes that narrows the range of their usage;
- this construction allows applying the inductive heaters only on one tubing interval that cuts down their efficiency;
- high complication and cost of production.

Considering the disadvantages of inductive ones, it is advisable to pay more attention to analogical heaters [1], which have easier construction, for instance, electrical one, heaters on cable-rope (Fig. 3).

This heater has certain advantages and disadvantages. The advantages are:

- the simplicity of constructive performance;
- the ability to elaborate the wide range of temperature work modes.

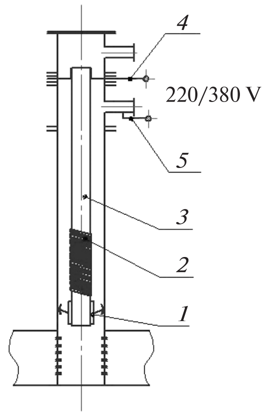

Fig. 1. The lifter tubing equipped with a well inductive heater:

1 — rolling contact; 2 — inductive winding; 3 — pump-compressor pipes (core); 4, 5 — electrical connecting terminals

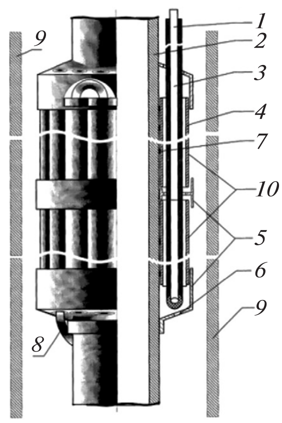

Fig. 2. The well inductive heater of construction by Ufa scientific and research, projecting and engineering center "Nafto-gas—2":

1 — wireway; 2 — casing pipe; 3 — cable with low electrical resistance; 4 — ferromagnetic tube; 5 — a protective casing; 6 — opening of the protective casing; 7 — intermittent interrupting welding; 8 — grounding; 9 — production casing; 10 — ferromagnetic section

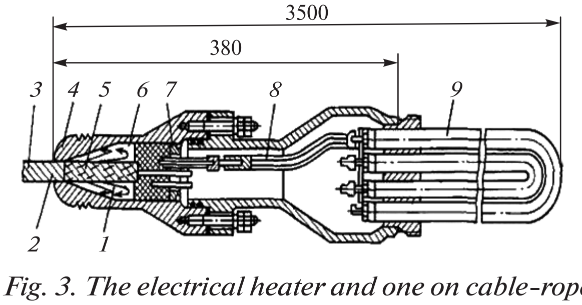

Fig. 3. The electrical heater and one on cable-rope:

1 — fastening cable; 2 — wire bandage; 3 — cable; 4 — head; 5 — asbestos braid; 6 — lead pouring; 7 — a nut; 8 — terminal blocks; 9 — ten-heater

The disadvantages of such a heating element are:

- the complication (sometimes even impossibility) of being used with deep pump techniques simultaneously;
- the impossibility of being located within the intervals of the tubing column length;
- the necessity of applying valuable electrical cable with wire bandage;
- it is used in complex with sets: UES-1500, SUEPS-1200 or SUEPS-1500, which are equipped with winch that puts down the heater to a depth of 1200–1500 m on cable-rope and it complicates and makes the exploitation more expensive.

Nowadays, there are practically no references to multi-level stationary systems of heating of lifter tubing, which could provide the necessary temperature balance of trunk of reservoir fluid during mining of hydrocarbon stuff along the whole length of the field of pump-compressor pipes where a high level of ARPD is observed.

That is why there is a necessity of developing multi-level system of heating of wells products that would combine all the advantages of inductive and ten-heaters, have high level of unification and construction simplicity and also exclude a great number of disadvantages, which occur in existing types of deep well heaters.

Objective. The provision of effective counteraction to negative consequences of deposits of ARPD on work surfaces of well equipment during drilling of hydrocarbon stuff and the absence of oil industrial equipment of sufficient nomenclature of corresponding machines, devices in the national market put a task to project and research work efficiency of deep electrical well pipe heaters that connect permanently to the multi-level system of well products as part of tubing lifter will allow carrying out the permanent or periodical choice of production at the same time with their usage, will have the constructive feasibility to be applied as part of ground complexes for heating products, pumped by pipelines, and will have the maximal level of unification with standard equipment and high performance efficiency. Thus, the construction of the devised heater has to give the possibility to use produced pipe heaters as part of multi-level lifter of products of oil wells with feasibility to insert of warm energy into the columns of pump-compressor pipes at an optimal depth.

Presentation of the main research. According to performed probations [1–5], (oil mining enterprises PAT "Ukrnafta" (Ukraine), NGVU "Pivdenorenburgnafta", NGDU "Ufaneft" (Russia)), the deposits of ARPD usually begin within the interval of 1200–750 m and higher along the length of well trunk. At the same time there appears a necessity of using equipment for heating the tubing trunk within this interval.

The author has offered a multi-level system of heating a lifter tubing (Fig. 4) carried on the base of pipe electrical heater of "DTH" type (Fig. 5), which is characterized by the following features:

- it has the electrical consumption that allows exploiting it in permanent or periodical modes;
- it is set stationary in the framework of the lifter tubing as its composing element;

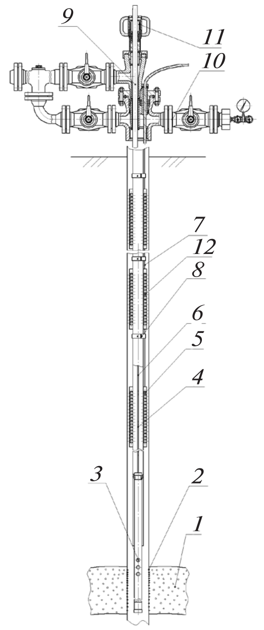

Fig. 4. The multi-level system of heating a tubing lifter performed on the basis of pipe electrical heater of "DTH" type:

1 – the productive reservoir; 2 – perforation zone; 3 – universal gas sand anchor; 4 – depth rod pump NSV-1U; 5 – shaft electric heater DTH-1X; 6 – sucker rod column; 7 – electric cable; 8 – clamp; 9 – polished rod; 10 – wellhead equipment; 11 – stuffing knot

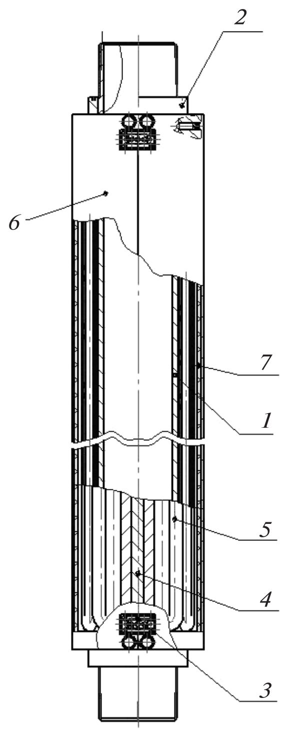

Fig. 5. The construction of an engineered deep pipe heater of "DTH" type:

1 – the pipe shell; 2 – the cramping puck; 3 – the plug nest; 4 – the electrical cable; 5 – the heating element; 6 – metal internal casing; 7 – the warm-isolation multi-layers casing

- it is characterized by the analogy principle of actions (direct heating of the environment with electroheating elements) that gives the possibility to simplify its constructive performance and reduce the production value;
- it has multi-level order of heaters setting, 3 (3-6-9-12)-fold, according to the number of power feed cables of KRBK unified with the power feed cable of UEVN (3 cores) that allows supporting the balance of heating temperature of reservoir fluid within the interval of deposits of high-viscous substances;
- it could be used as part of fountain lifter of oil and gas well and at the same time with deep pump methods of oil mining;
- it has the maximal degree of unification with existing oil and gas industrial equipment.

The construction of an engineered deep pipe heater of "DTH" type is shown in Fig. 5. The shell of the heater is an NKT pipe, equipped with screw shafts for attaching to the standard NKT clutches on both sides.

The heating element 5 is a power provider with high resistance, made of nichrome wire disposed in quartz sand or molten magnesium oxide (an electrically insulating heat conductor), which is situated in the protective refractory casing that is put along the axis of the pipe shell. The heating element *5* is fixed on the pipe shell *1* with help of cramping pucks *2*. There are plug nests *3* on the pipe shell that allow moving the power feed cable and removing it farther for feeding "DTH" heaters which follow. The plug nests have withdrawals for feeding the heating element *5* and are also connected between each other with three-core electrical element *4*, the cores of which are situated in the thermo-isolated casing. To provide mechanical protection of heating element *5* from negative influence of external factors there is a metal external casing *6*, between the casing *6* and heating element *5* the extra-fine multi-layers warm-isolation casing *7* is situated that minimizes the heat loss from the work of deep pipe heater of "DTH" type.

To determine main work characteristics of "DTH" heater and the multi-level system of heating reservoir products accomplished on their basis, relevant calculative and research models were developed and probations were performed.

The calculation model for defining the coefficient of heat loss of deep pipe heaters of "DTH" type is shown in Fig. 6.

The coefficient that considers heat loss while of a work agent is moving along the "DTH" pipe heater

$$\varepsilon = 0,5\left(1 + \left[1 - \frac{R_1}{R_2}\right]\right), \qquad (1)$$

where R_1 is the heat transmission of pipe shell; R_2 is the heat transmission of heat-insulating multi-layer casing with external casing of the heater.

According to Fig. 6

$$R_1 = a_1 d_2 + 2\frac{\lambda_1}{\ln\frac{d_1}{d_2}} + a_2 d_1; \qquad (2)$$

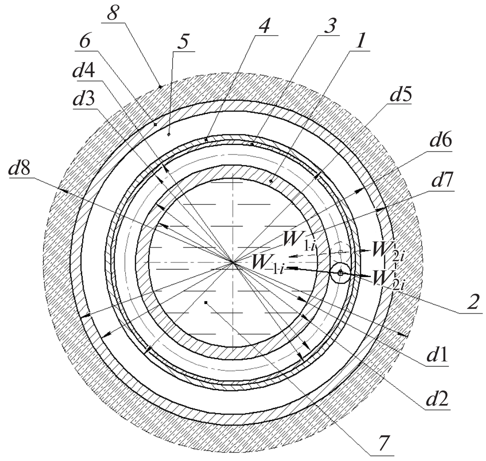

Fig. 6. The calculation model for defining the coefficient of heat loss of deep pipe heaters of "DTH" type:

1 — the casing pipe; 2 — the heating element; 3 — the heat-insulating casing; 4 — metallic external casing; 5 — inter-column space; 6 — the casing column; 7 — reservoir products; 8 — trunk breed; d_i — the diameter of a corresponding element of the computational model (i = 1—8); w_{1i} — heat flows from heating elements, which are used to perform useful work to the internal cavity tubing; w_{2i} — scattered outside heat flows

$$R_2 = a_3 d_3 + 2\frac{\lambda_2}{\ln\frac{d_4}{d_3}} + 2\frac{\lambda_3}{\ln\frac{d_5}{d_4}} + 2\frac{\lambda_4}{\ln\frac{d_6}{d_5}} + 2\frac{\lambda_5}{\ln\frac{d_7}{d_6}} + 2\frac{\lambda_6}{\ln\frac{d_8}{d_7}} + a_4 d_8, \qquad (3)$$

where a_i is the coefficient of heat transmission of i-element material, Vt/m^2 · K; d_i is the diameter of a relevant element of calculation model (i = 1—8), m; λ_i is the coefficient of thermal conductivity of i-element material, Vt/m · K.

The power that will be consumed by the deep pipe heater in the process of warm preparation of reservoir fluid, Vt

$$N_H = \frac{c \cdot G(T_K - T_П)}{t \cdot \varepsilon}, \qquad (4)$$

where c is the specific heat capacity of reservoir fluid, Dj/(kg · Grad.); G is the mass of the environment within the internal space of the heater, kg; T_K is the final temperature of reservoir fluid at the output of the heater, °C; $T_П$ is the initial temperature of reservoir fluid at the input to the heater, °C; t is the time of liquid flow passing the heater, s.

Thus, we can define the power, which will be consumed by the deep pipe heater according to the temperature characteristics of fluid at the output of it which are to be supplied under these or those conditions of exploitation; it will allow perform the calculation of work parameters of the multi-level system of heating reservoir products complied on their basis according to calculation models (Fig. 7).

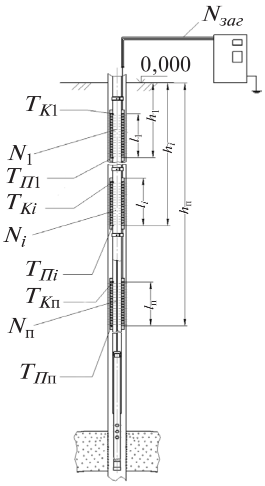

Fig. 7. The calculation model for determining the work parameters of the multi-level system of heating the reservoir products performed on the basis of the pipe electrical heater of "DTH" type for the number of heaters i = 1...n:

$T_{\Pi i}$ – the initial temperature on the input to i-heater; T_{Ki} – the final temperature of reservoir fluid on the output of i-heater; N_i – the power that consumes i-heater; l_i – the length of i-heater

The number of pipe heaters n, the power of each one and distance between them are selected under the conditions of providing the average temperature within the interval of the tubing lifter where ARPD is not lower than the level of temperature of deposits chilling defined in the laboratory. According to [1], the value $T_{сер}$ ranges from 60 to 76 °C.

The general power, which is to be provided by the ground electrical stations to feed the multi-level system of heating the reservoir products within the interval of deposits, will be calculated by the equation

$$N_{заг} = \sum_{i=1}^{n} N_i + N_{к.е.}, \quad (5)$$

where $\sum_{i=1}^{n} N_i$ is the total power of n-number of heaters in the well, кVt; $N_{к.е}$ is the loss of power in the electrical cable, кVt.

The useful power of i-heater DTH, Vt

$$q_{vi} = \frac{4 \cdot N_i \cdot \varepsilon_i}{\pi \cdot d_i^2 \cdot l_{ei}}, \quad (6)$$

where N_i is the power, consumed by the deep pipe heater, Vt; d_i is the average diameter of disposing of electrical spins of the deep pipe heater, m; l_{ei} is the effective length of a heating part, m.

According to the research conducted using the methods suggested, the following results were obtained:

1) the effective number of heaters along the length of a tubing column rangers from 3 to 6 ones for the field with ARPD deposits (the interval –850...–50 m [1];

2) the power of heaters, disposed in the well on the field with ARPD deposits, is within the interval from 5 to 30 кVt with loss of 2–3,5 кVt in the cable along its length;

3) the largest efficiency of the multi-level system of heating the reservoir products, performed on the basis of the pipe electrical heater of "DTH" type, is provided under the condition of speed of raising trunk of liquid well products $u_р \leq [u_{р.п.}] = 1{,}5$ m/s;

4) the obtained values of the coefficient of heat loss of "DTH" pipe heaters for different types of heat-insulating of multi-layer casings (the constructive thickness is 4,5 mm), closed with metal external casing with thickness of 3 mm, are given in the Table.

Table

The values of coefficient of heat loss of "DTH" pipe heaters for different types of heat-insulating of multi-layer casings

№	The type of construction	The value of coefficient of heat loss, ε
1	Two layers of aluminum foil with thickness of 0.5 mm with the layer (3.5 mm) of asbestos between them	0.85
2	Two layers of aluminum foil with thickness of 0.5 mm with the layer (3.5 mm) of mineral wool between them	0.87
3	The internal layer of aluminum foil with thickness of 0.5 mm and "Armofol" layer of NG type with thickness of 4 mm	0.88
4	The metal multi-layer list "K-SHIELD FIREWRAP" with thickness of 4.5 mm	0.90

* the values of the coefficient of heat loss are given, considering the usage of metal external casing

Conclusions. The article substantiates and suggests the construction of a pipe deep heater of "DTH" type; it also provides the multi-level system of heating the reservoir products based on it, which is integrated into the composition of a tubing lifter, that will allow improving the conditions of mining of reservoir fluid with high content of asphalt-resin-paraffin deposits (ARPD), by heating the products within given intervals of high viscosity substance deposits.

The engineered equipment differs favourably from its analogies due to its simplicity and construction efficiency.

The developed methodology, being necessary for feeding the multi-level system of heating the reservoir products, will give an opportunity to calculate its required amount at the stage of projecting and constructive work implementation.

The developed methodology of defining the coefficient of heat loss of "DTH" pipe heaters for different types of warm-isolation of multi-layer casings will permit determining the optimal content and the construction of heat-insulating layers according to the "price-quality" principle at the stage of projecting.

The multi-level system of heating the reservoir products, made on the basis of "DTH" pipe heaters, will give the feasibility to realize the trunk heating of liquid along the interval of ARPD deposits in a more qualitative way compared to analogies, using the possibilities of the heater location in any place along the length of a tubing column and effectively bringing the power to the intervals with the highest level of deposits.

The perspective prospects of further research is the modernization of probed complex of multi-level system of heating reservoir products on the basis of pipe deep heaters of "DTH" type with extra magnetic sections to increase the efficiency of ARPD prevention.

References / Список літератури

1. Persiiantsev, M. N., 2000. *Dobycha nefti v oslozhnionnykh usloviiakh* [The oil drilling in complicated circumstances]. Moscow: OOO "Nedra-Bisnesscenter".

Персиянцев М. Н. Добыча нефти в осложненных условиях / Персиянцев М. Н. — М.: ООО „Недра-Бизнесцентр", 2000. — 653 с. — ISBN 5-8365-0052-5.

2. Tronov, V. P., and Guskova, I. A., 1999. The mechanism of formation of asphalt-resin-paraffin deposits at a later stage of developing the deposits. *Neftianoie khoziaistvo*, No. 4, pp. 24–25.

Тронов В. П. Механизм формирования асфальтосмолопарафиновых отложений на поздней стадии разработки месторождений / В. П. Тронов, И. А. Гуськова // Нефтяное хозяйство. — 1999. — № 4. — С. 24–25.

3. Kopei, B. V., Martynets, A. B., and Stefanyshyn, A. B., 2014. The composition and properties of asphalt-resin-paraffin deposits. *Rozvidka ta rozrobka naftovykh ta gasovykh rodovysch*, No. 2 (51), pp. 46–50.

Копей Б. В. Склад і властивості асфальтосмолистих речовин / Б. В. Копей, О. Р. Мартинець, А. Б. Стефанишин // Розвідка та розробка нафтових і газових родовищ. — 2014. — № 2(51). — С. 46–50.

4. Urazakov, K. R., Bogomolnyi, Ye. I., Seitpagambetov, Z. S., and Gazarov, A. G., 2003. *Nasosnaia dobycha vysokoviazkoy nefti iz naklonnykh i obvodnennykh skvazhyn* [The pump mining of high viscous oil from angled and flooded wells]. Moscow: OOO "Nedra-Bisnesscenter".

Насосная добыча высоковязкой нефти из наклонных и обводненных скважин / Уразаков К. Р., Богомольный Е. И., Сейтпагамбетов Ж. С., Газаров А. Г.; под ред. М. Д. Валеева. — М.: ООО „Недра-Бизнес-центр", 2003. — 303 с.

5. Vakhitov, M. F., Khalimov, R. H., Vakhitov T. M., Farkhulin, R. G., and Derevianko, R. V., OOO Ufa scientific and research, projecting and engineer center "Neftegas-2", 2005. *Scvazhiniy electronagrevatel*. Ufa. No. 2004106111/03

Пат. 2249096 Российская Федерация. Скважинный электронагреватель / Вахитов М. Ф., Халимов Р. Х., Вахитов Т. М., Фархуллин Р. Г., Деревянко Р. М.; Заявитель и патентообладатель: Общество с ограниченной ответственностью (ООО) Уфимский научно-исследовательский и проектно-инженерный центр „Нефтегаз-2" (RU). — № 2004106111/03; заявл. 24.02.04 ; опубл. 27.03.05.

Мета. Обґрунтування конструкції, особливостей компонування та розрахунку основних параметрів багаторівневої системи підігріву пластової продукції, що виконана на базі глибинних трубних підігрівачів „ПЕТ", які розміщуються в нафтовидобувній свердловині та поліпшують умови видобування пластового флюїду з високим вмістом асфальто-смоло-парафіністих відкладень (АСПВ) шляхом підігрівання продукції в заданих інтервалах.

Методика. Методичною основою проведених досліджень є комплексний аналіз та узагальнення літературних джерел, а також позитивного промислового досвіду боротьби з асфальто-смоло-парафіністими (АСП) відкладеннями під час видобування вуглеводневої сировини з підвищеним вмістом АСПВ із застосуванням експертного аналізу та оцінки одержаних даних.

Результати. Результатом досліджень є обґрунтування конструкції підігрівача трубного глибинного типу „ПЕТ", а також розроблення на його базі багаторівневої системи підігріву пластової продукції, котра інтегрована до складу підйомника з насосно-компресорних труб (НКТ). Обгрунтована розрахункова модель для визначення параметрів роботи багаторівневої системи підігріву пластової продукції, виконаної на базі трубного електричного підігрівача типу „ПЕТ". Розроблена методика визначення потужності, що необхідна для живлення багаторівневої системи підігріву пластової продукції.

Наукова новизна. Уперше розроблені: модель роботи багаторівневої системи підігріву пластової продукції; методика визначення коефіцієнта теплових втрат підігрівачів трубних глибинних, оснащених різними типами кожухів теплоізоляційних багатошарових.

Практична значимість. Обґрунтована та наведена конструкція підігрівача трубного глибинного типу „ПЕТ", а також запропонований принцип компонування та розрахунку багаторівневої системи підігріву пластової продукції, котра інтегрована до складу підйомника НКТ і дозволяє зменшувати рівень відкладень АСП на робочих поверхнях глибинного обладнання. Запропонована конструкція багатошарового теплоізоляційного кожуха, що застосовується у складі конструкції підігрівача трубного глибинного типу „ПЕТ".

Ключові слова: *асфальто-смоло-парафіністі відкладення (АСПВ), глибинний підігрівач, система підігріву пластової продукції, насосно-компресорні труби*

Цель. Обоснование конструкции, особенностей компоновки и расчета основных параметров многоуровневой системы подогрева пластовой продукции, выполненной на базе глубинных трубных подогревателей „ПЭТ", которые размещаются в нефтедобывающей скважине и улучшают условия добычи пластового флюида с высоким содержанием асфальто-смоло-парафинистых отложений (АСПО) путем подогрева продукции в заданных интервалах.

Методика. Методической основой проведенных исследований является комплексный анализ и обобщение литературных источников, а также положительного промышленного опыта борьбы с асфальто-смоло-парафинистыми (АСП) отложениями при добыче углеводородного сырья с повышенным содержанием АСПО с применением экспертного анализа и оценки полученных данных.

Результаты. Результатом исследований является обоснование конструкции подогревателя трубного глубинного типа „ПЭТ", а также разработка на его базе многоуровневой системы подогрева пластовой продукции, которая интегрирована в состав подъемника из насосно-компрессорных труб (НКТ). Обоснована расчетная модель для определения параметров работы многоуровневой системы подогрева пластовой продукции, выполненной на базе трубного электрического подогревателя типа „ПЭТ". Разработана методика определения мощности, необходимой для питания многоуровневой системы подогрева пластовой продукции.

Научная новизна. Впервые разработаны: модель работы многоуровневой системы подогрева пластовой продукции; методика определения коэффициента тепловых потерь подогревателей трубных глубинных, оснащенных различными типами кожухов теплоизоляционных многослойных.

Практическая значимость. Обоснована и описана конструкция подогревателя трубного глубинного типа „ПЭТ", а также предложен принцип компоновки и расчета многоуровневой системы подогрева пластовой продукции, которая интегрирована в состав подъемника НКТ и позволяет уменьшать уровень отложений АСП на рабочих поверхностях глубинного оборудования. Предложена конструкция многослойного теплоизоляционного кожуха, который применяется в составе конструкции подогревателя трубного глубинного типа „ПЭТ".

Ключевые слова: *асфальто-смоло-парафинистые отложения (АСПО), глубинный подогреватель, система подогрева пластовой продукции, насосно-компрессорные трубы*

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NUMERICAL STUDIES ON THE EFFECT OF IMPELLER OUTLET WIDTH ON CHARACTERISTIC CURVE SLOPE OF THE CENTRIFUGAL IMPELLER

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ЧИСЛОВЕ ДОСЛІДЖЕННЯ ЗАЛЕЖНОСТІ КРУТИЗНИ НАПІРНОЇ ХАРАКТЕРИСТИКИ КОЛЕСА ВІДЦЕНТРОВОГО НАСОСА ВІД ШИРИНИ РОБОЧОГО КОЛЕСА НА ВИХОДІ

Purpose. The present paper focuses on study of the pump performance with six different values of impeller outlet width.

Methodology. In order to determine the dependence of impeller outlet width on the slope of characteristic curve in different operating modes, the numerical simulation was used.

Findings. We have analyzed publications related to research studies on centrifugal pump with changing impeller outlet width. The cause of efficiency reducing in extremely narrow and wide impellers was determined. Relationship between impeller outlet width of double-entry centrifugal pump and slope of characteristic curve was established.

Originality. We have defined that changing of the impeller outlet width within some relative width range results in achieving required characteristic curve slope with inessential efficiency drop.

Practical value. The study results are intended to be used while modernizing pump impellers with specific speed, which operate in groups with different initial characteristic curves. Such modernization is possible with existing pump casing and bearing compounds usage, that reduces expenses on modernization significantly and lowers pumping equipment life-cycle cost.

Keywords: *slope of characteristic curve, impeller outlet width, numerical simulation*