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EFFECT OF MAGNETIC FIELD EQUIPMENT (MAU-1) ON ASPHALT, RESIN AND PARAFFIN DEPOSITS

Analysis of scientific studies on the mechanism of paraffin deposits formation in the wells is performed. An important advantage of MAU-1 (magnetic anti-paraffin unit) is the use of plugs of a nonmagnetic material placed on the outer surface of the radially magnetized magnets is the ability to use compound, taken from individual sectors or from elements of another form of radially magnetized magnets using the most modern magnetic materials with rare-earth metals, that allows to increase more the amplitude and gradient of strength affecting on the fluid of a magnetic field and thereby to improve the efficiency of the device for magnetic field conditioning. Magnetic oil treatment the authors suggest as a separate method of paraffin control deposition at it transporting by pipelines.

***Keywords**: product, magnet, paraffin, well, magnetic anti-paraffin devices.*

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ВПЛИВ МАГНІТНОГО ПОЛЯ УСТАТКУВАННЯ (МАУ-1) НА АСФАЛЬТОСМОЛОПАРАФІНОВІ ВІДКЛАДИ

Наведено аналіз наукових досліджень, присвячених механізму формування парафінових відкладень у свердловинах. З'ясовано, що істотною перевагою МАП-1 (магнітних антипарафінових пристроїв) є застосування втулок з немагнітного матеріалу, розміщених на зовнішній поверхні радіально намагнічених магнітів, можливість використання складених, набраних з окремих секторів або з елементів іншої форми радіально намагнічених магнітів із застосуванням найбільш сучасних магнітотвердих матеріалів з рідкоземельними металами, що дозволяє ще значніше підвищити амплітуду і градієнт напруженості, що впливає на рідини магнітним полем і тим самим поліпшує ефективність пристроїв для магнітної обробки рідини. Магнітну обробку нафти автори розглядають, як окремий метод боротьби з відкладеннями парафіну при її транспортуванні трубопроводами.

***Ключові слова:** матеріал, магніт, парафін, свердловина, магнітний антипарафіновий пристрій (МАП-1), нафта.*

Introduction. Exploitation of oil producing wells on the oil fields in Ukraine is complicated by many factors. Large losses in the oil fields happen because of settling in oil-saturated rocks, production casing, and in the tubing of buttery or solid mass of dark color, known as paraffin – ARPD (asphalt – resin – paraffin deposits). ARPD is a complex hydrocarbons mixture consisting of paraffin (20 – 70 mass. %), ARPD (20 – 40 mass. %) silica gel resin, lubricating oil, water and mechanical impurity. Paraffin – hydrocarbons of methane series from $C_{16}H_{34}$ to $C_{64}H_{130}$. In reservoir conditions they are in dissolved oil.

The concept of the formation and control technology with ARPD at oil output to this day is an actual scientific-technical and practical problem, since this factor directly affects the durability and final well productivity.

Formation of paraffin deposits reduces the production of oil and gas, reduces turnaround interval, increases labor and material costs and increases the cost of produced products. Selection of effective methods of prevention and removal of paraffin deposits ensures long turnaround interval of wells, increases oil-gas production rate and reduces material costs.

Nowadays, there are about twenty different ways of paraffin control (the most often dominated methods: thermal, chemical, mechanical, application of coatings, physical). However, each of the methods of paraffin control requires to use at the well quite complex equipment and all sorts of devices that are needed to be control. The development of technology and equipment to control asphalt, resin and paraffin deposits has a long history. However, the variety of conditions of field development and characteristics of mining oil requires an individual approach.

Mentioned methods are used in wells with various ways of crude-oil production (free-flow, and pumping and their varieties) and also at transporting the oil through pipelines.

Methods that are related to physical, based on the use of electrical, magnetic, electromagnetic fields, mechanical and ultrasonic vibrations. The most promising technique is the effect of a constant magnetic field on the waxy oil. On the basis of laboratory and field studies of action of constant magnetic field on oil by PoltNTU experts (assistant professor, Ph.D. A. I. Nalivaiko, senior lecturer A. N.Mangura) was offered the technique of increasing the magnetic parameters of MAY devices (magnetic anti-paraffin devices) namely amplitude and voltage gradient of magnetic field, wherein structural features were considered which are characteristic for magnet systems of electronics with the combined distribution of magnetized magnets. Relevant is in the proposed design (MAY) further improvment of reverse device with a magnetic field, which is regulated in a wide range [1].

Review of the last sources of research and publications. There are a significant number of scientific studies on the mechanism of formation of paraffin deposits in the wells. A great contribution to the solution of theoretical and practical issues of paraffin deposits had A. A. Abramson, Yu. V. Antipin, G. A. Babalyan, N. F. Bogdanov, R. N. Bahtizin, M. D. Valeev, S. V. Vonsovskyi, M. V. Golubev, M. Yu. Dolomatov, N. G. Ibragimov, N. V. Inyushin, A. Yu. Kivokurtsev, I. N. Sidorov, V. I. Lesin, V. I. Neprimerov and others.

These researchers studied not only the mechanism of formation and paraffin deposition, paraffin deposition patterns on various surfaces, peculiarities and profiles deposition on tubing and pipelines but their works had an impact on practical solution to control paraffin problems.

In formation condition solid hydrocarbons ($C_{17}H_{36}$ – $C_{60}H_{122}$) that are beibg a part of paraffin deposits, as a rule initially dissolved in the oil. By reducing the temperature, pressure and de-gassing the dissolvent ability of oil relatively the paraffin deteriorates. This leads to oversaturation of oil by paraffin and move its part to crystalline state. Paraffin crystallization occurs at the interface (surface) on the walls of equipment and solid particles in the oil stream. The decisive role in the deposits formation play the crystals of paraffin and their clusters arising directly on the walls of the equipment.

In general, the development of technology and equipment to control asphalt, resin and paraffin deposits has a long history. However, we cannot say that so far, all the difficulties associated with the solution of this problem are solved. The variety of conditions of field development and characteristics of crude oil requires an individual approach.

Defining parts of the general problem unsolved before. As the analysis shows, earlier at large pipelines acceptable parameters of the magnetic field were received only by the fact that most part of his section was filled with magnetic system. This led to exploitation of the pipeline section, increasing the flow rate of the oil emulsion and reducing the period of the magnetic fluid conditioning. In addition, such devices have a larger mass of the magnets and due to the high value of the last ones are very valuable. In other designs the effective magnetic field is produced only in a small part of the section of the pipeline and a large part of the emulsion is passed without any magnetic treatment. There are no deficiencies in the proposed design data [2].

ARPD is a very complicated dispersed system in which one of the components is in a molecular dispersed state, the second one – in the form of colloidal particles, the third one – in the form of large, hard, insoluble formations whose surface adsorbed resinous substance and other surface-active reagents, and fourth one is an emulsion of water in oil, steady by various natural emulsifiers (low molecular weight emulsifiers kind of alkaline earth naphthenic acids high-carbon «black emulsifiers» kind of asphaltenes and resins, surface-active solid emulsifiers – fine particles of rocks, monocrystals of paraffin). They preferably contain organic material which is practically insoluble and not re-dispersed in crude oil production, it has a greater density compared to oil, which causes precipitation and substances that have surface activity on the separation principle of oil-rock, oil- metal, oil-water.

In the scientific literature, in the press there are a lot of evidence to prove the high technical and economic efficiency of magnetic devices in oil production. Unfortunately, as a rule, the parameters of such magnetic devices are not given. Rarely the parameters of the magnetic field in the patents of these devices are given, although in many cases it is possible to estimate these parameters on the description of design. Almost there are no recommendations for the choice of optimal exposure parameters of the magnetic field depending on the specific characteristics of the oil field, recommendation of preliminary laboratorial assessment of magnetic devices efficiency.

Therefore, the aim of this work is the further improvement of magnetic anti-paraffin unit (MAU) by obtaining the higher strength and the gradient of the magnetic field with mutually perpendicular directions of annular magnets magnetization that allow to increase turnaround period of producing wells.

Basic material and results. When crude oil is being producing one of the problems that cause complications in the wells, oil production equipment and pipeline communications are ARPD. The accumulation of ARPD in the flow channel of the oil production equipment and on the inner surface of the pipes leads to decreasing of system performance, decreasing TBR (time between repairs) of the wells and the efficiency of the pumping systems.

The presence of paraffin, regardless of its amount in oil, set task for petroleum experts many technological and technical challenges associated with the elimination of ARPD complications. The composition of ARPD is determined by the properties and petroleum composition, as well as part of their crystallization conditions and deposition. The contents of the individual components in paraffin mass is different and depends on the conditions of oil deposits formation and oil characteristics.

Generally accepted as per GOST Standard 912-66 technological classification of oil deltas in content of paraffin into the following types: low paraffin less than 1,5% (by weight); paraffin from 1,5 to 6% (by weight); high paraffin more than 6,0% (by weight).

Paraffin in oil at reservoir conditions are in a dissolved state. Oil of the same area contain so much the less paraffin, the more resinous substances are in it. The content of the paraffin in oil of the same field grows at a depth of burial. The melting point of solid paraffinic hydrocarbons is the higher, the larger is the molecular weight. The density of the solid paraffin varies from 865 to 940 kg / m^3 and in melt condition – from 777 to 790 kg / m^3. The solubility of the paraffin in most organic liquids are high, it gets low with increasing of molar mass and rises with increasing of temperature. Thus, the composition of ARPD depends on the oil composition and thermodynamic conditions of their formation.

In table 1 is given oil characterization on deposits in Ukraine, paraffin content of which is more than 5%, that is why process of field development and operating in these fields are complicated.

The main components are the paraffin deposits, the contents of which vary from 20 to 70% (by weight) and compound asphalt pitch from 20 to 40% (by weight). Gelling temperature of paraffin is at 3 – 10 °C above the gelling temperature of deposits is 66 – 75 °C.

Table 1 – Characteristics of Ukraine's oil fields with paraffin content

Oil fields	Horizon	Paraffin, % mass.	Silica gel resins, % mass	Mechanical impurity, % mass	Temperature of paraffin pressure °C
Glinsko-Rozbishevskoe	B-27 B-30	7,44 6,95	– –	0,5 –	72 72
Monastyrschinskoe	B-30	13,05	8,4	-	70
Katchanovskoe	B-23 B-24 B-27	9,3 11,4 5,68	14 6,1 14,0	0,3 – –	68 70 73
Artyuhovskoe	–	11,0	3,2	–	70
Rybalskoe	–	11,78	4,42	0,5	53,2
V.Bubnovskoe	B-26	6,34	5,65	–	69
Skorohodovskoe	–	11,73	8,61	–	57
Lelyakovskoe	–	5,02	8,25	–	54
Bitkivskoe	–	10,14	7,58	–	52,4
Dovbushanskoe	–	13,07	4,71	–	51,5
Lukvinskoe	–	11,5	3,48	0,3	52,8
Spaskoe	–	10,81	3,81	–	51,4
Spaskoe	–	11,78	4,42	–	53,0

ARPD composition depends on the properties and composition of the initial oil, as well as the location and formation conditions. Depending on the age and origin of oil chemical composition of the ARPD can vary widely on the content of the components. ARPD contain paraffin, pyridines, asphaltenes, resins, oxygen, nitrogen, sulfur, metals and mineral substances taken in the form of solutions of salts of organic acids, complex compounds or colloid-dispersed mineral substances. The ARPD composition includes a small amount of water in which are dissolved salts, usually chlorides and sodium hydro-carbonates, calcium, magnesium, as well as sulfates and carbonates. That is, ARPD chemical composition depends on the composition and properties of the produced oil and water, the composition of the

ARPD is mainly as follows: 40 – 60% of solid paraffin and less than 10% of microcrystalline paraffin, 10 – 56% resins and asphaltenes, water, sand and inorganic salts and only paraffin and asphaltenes-resins content can be respectively 40 – 70% and 10 –55%, then the melting point of the wax and paraffin is generally 70 – 90 °C and 60 – 85 °C.

Paraffin deposits formation mechanism can be submitted under the provisions of the crystallization theory of matter that way.

The first step in the formation of deposits or even ARPD is a nucleation and growth of paraffin crystals. In the second stage occurs precipitation of small crystals on the pipe surface, the third - precipitation on the paraffin surface of large crystals. By reducing the temperature of the bottom-hole formation zone and the wellbore to the start temperature of paraffin crystallization is an intensive formation in oil the paraffin crystals with its transition from the dissolved state to the weighted. These crystals serve as centers for the crystallization and the subsequent intensive deposition of paraffin out of oil and its deposit on a solid surface [3].

The thickness and paraffin content in the tubing increases as one approaches to the wellhead. At wax precipitation an important role plays polarity (the opposite of what) of wall pipe material: it increases and interaction paraffin-pipe surface is weakening. This is confirmed by the results of studies that are presented in Table 2.

Table 2 – The results of studies of ARPD formation conditions

Depth, m	Pressure, MPa	The total temperature gradient, °C/100 m	The temperature gradient caused by the expansion of the gas-oil mixture, °C/100
1400	11,5	1,5	0,14
900	7,5	1,9	0,17
600	5,0	2,1	0,34
200	2,3	1,8	0,55

It follows that the wellbore temperature is mainly determined by the heat transfer conditions, and thus the mass flow rate of the well.

In the scientific literature, in the press the most widely are presented hypotheses on the mechanism of magnetic effects on water and water systems. By the study of such influence started the widespread introduction of such magnetic technologies. Magnetic treatment of water and systems to the present day remains the main field of application of magnetic devices. In most cases the oil production deal with oil-water systems.

The main characteristics of the magnetic field are the magnetic induction, magnetic flow, magnetic permeability and magnetic field strength.

The intensity of the magnetic field, i.e. its ability to do work, is determined by a quantity called magnetic induction. The stronger the magnetic field created by a permanent magnet or an electromagnet is, the more induction it has. Magnetic induction can be characterized by a density of magnetic lines, i.e., number of force lines passing through an area of 1 m^2 or 1 cm^2 perpendicular to the magnetic field.

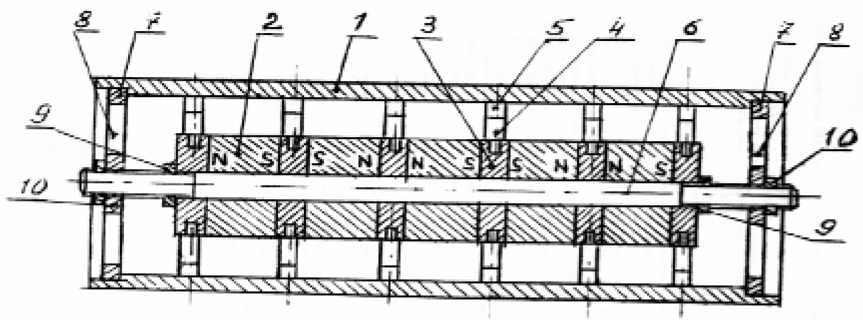
Therefore the choice of preventing method of ARPD formation is closely related to the composition of ARPD and their melting point. The method of paraffin deposit prevention and its application technologies are selected depending on the oil reservoir characteristics: its effective thickness, filtration-reservoir properties of reservoir rock (permeability, porosity), the content and composition of the clay material in the reservoir and the factors that determine its adsorption-desorption properties.

Theoretically, to act on the saturated layer system may use different physical fields - thermal, acoustic, electrostatic, radiation and alternating-electrical.

The mechanism of action of the magnetic field can be briefly explained as follows: when a rigid body is contacted with a liquid between them is unequal exchange of electrical charges. On the surface layers of each phase are concentrated electric charges of equal magnitude but opposite in sign.

The MAU Prototype-1 (magnetic anti-paraffin unit), we used earlier model of the MAU. Magnetic anti-paraffin unit (MAU) consists of a body, the upper pole, a set of permanent magnets, aluminum diamagnetic plug, lower pole and adapter subs under the blow-off line.

During the investigation, it was found that the magnetic field acting on the physical properties of the gas and oil flow and in this connection it changes the wax crystallization process. In particular in the gas-liquid stream after passing through the magnet, the temperature rises dramatic. The pressure on the manifold during the operation of the magnets did not rise. Paraffin clutch of such a structure with the pipe wall is reduced, and therefore it is easily washed off from the pipe wall and is carried up by gas-liquid flow. In this regard, paraffin deposits on the pipes walls after passing through the magnetic device becomes softer and loose, its pores are filled with oil.



Picture 1 – Block diagram anti-paraffin magnetic unit (MAU):
1 – trunk-pipeline; 2 – permanent magnets; 3 – pole pieces;
4 – constituents of rods made of only a soft magnetic material;
5 – rods of components made of non-ferromagnetic material;
6 – rod thread; 7 – profiled discs; 8 – hole discs;
9, 10 – sections for the flow of liquid and nuts

This device for magnetizing fluid consists of a trunk-pipeline (1) of magnetically soft material and fixed magnetic system at its axis, which is a set permanent magnets alongside the trunk-pipeline (2) turn-magnetization directions. This permanent magnets have a circular shape and radial magnetization and placed on the total magnetic circuit. On the outer surfaces of permanent magnets pole pieces are fixed (3) and gaskets are placed between the magnets with nonmagnetic material. The outer surface of the magnetic system with nonmagnetic gaskets between the magnets and placed on the permanent magnets by pole pieces is shaped like a cylinder and a working channel for the treated liquid is the annular gap crossing between the magnet system and the trunk-pipeline. Parts (4) of compound rods made of magnetically soft material, the parts (5) are made of non-ferromagnetic material. Fixing the system can be made via located along the axis of the magnetic rod system (6) threaded in parts of its length, the profiled disc (7) with openings (8) in sections for the flow of liquid and nuts (9,10). This performance provides getting necessary parameters of affecting magnetic field at the smaller size of magnetic system intersection, a smaller number of expensive permanent magnets and a larger working channel intersection. This improves the efficiency of the device, especially for usage with large pipelines crossing. The usage of MAD can be effective at oil-well flowing and at the operation of bore-hole centered pumps and diaphragm pumps and pipelines [4].

In this regard, the group of authors suggested the usage of new improved materials, we have developed a new design of improved magnetic anti-paraffin units (MAU-1).

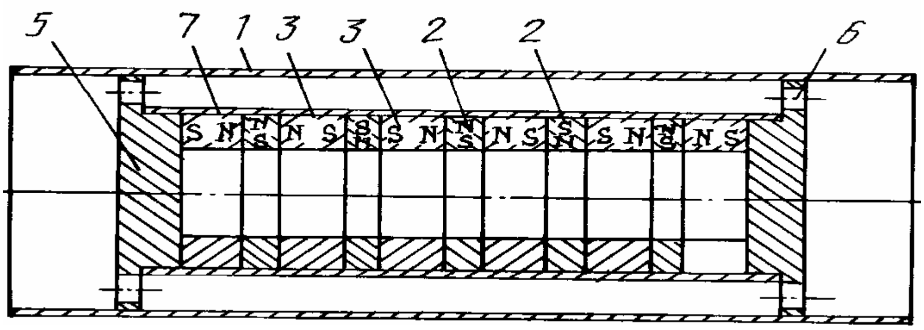
To improve the MAU-1, we performed the calculation of the magnetic induction (*B*) an axially magnetized cylindrical magnets with a radius (*r*) and length (*l*), at a point located at the distance (*d*) from the surface, along the axis of the formula

$$B = \frac{B_r}{2}\left[\sqrt{\frac{d+l}{(d+l)^2+r^2}} - \sqrt{\frac{d}{d^2+r^2}}\right]. \tag{1}$$

By using the principle of combining an improved MAU-1, we were analyzed magnets and more complex geometric forms.

However, due to the fact that the cylindrical magnets can be calculated more difficult, they are recommended for computer calculation methods [4, 5].

Long cylindrical chain of permanent magnet 1 is fixed in the pipe 2, has a reversal axial magnetization produced in such a way that the outer poles have the same polarity and the opposite polarity is formed in the middle of its length. The working channel for fluid is the annular gap between the intersection of the outer surface of the pipe 2 and the outer geometric trunk 3. In order for the liquid to be delivered to the channel and out of it after the completion of processing in the walls of the pipe 2, near the ends of the magnet are made holes 4.



Picture 2 – Schematic diagram of a magnetic anti-paraffin unit (MAU-1) with mutually perpendicular directions of magnetization of the magnet ring: 1 – pipeline; 2 – axial magnetized magnets; 3 – radially magnetized magnets; 4 – rod; 5 – non-magnetic spacers; 6 – openings for treated liquid; 7– nonmagnetic pipe

In it, through the use of complex magnetic cores, magnetic pipe system occupies only a small part of the section of the pipeline. As the material for the magnet is used much stronger magnet alloy than the other magnetic alloys. Number of magnets is not big, effective magnetic treatment of total volume of fluid is provided which flows through the device in the same conditions of high-gradient field at sufficient processing time.

Taking into account the above mentioned factors, we proposed improved magnetic anti-paraffin unit (MAU-1), in which complex cores are used (MAU prototype). In the new design concept MAU-1 suggested the redistribution of magnetized ferromagnets and increasing of their number by one step (7 magnets), which allowed, in our laboratory data, to intensify the process of paraffin decrysjtallization bigger by half. Although the number of magnets is small, but it ensures the effectiveness of magnetic treatment of the whole volume of the liquid passed through the device under the same conditions of high-gradient field at a sufficient processing time. The device differs from the other magnetic devices for fluid treatment, that it operates on permanent magnets, while ensuring the necessary magnetic field strength and magnetic induction. MAU-1 has a small mass of the magnets, resulting in lower cost compared to other similar devices. Therefore such devices have to be used in wells with high content of asphaltene particles (especially in winter).

MAU-1 devices provide a very high intensity and the field intensity gradient. So, getting the field with intensity of 150 – 200 sq / m (magnetic induction 0,2 – 0,25 T) in the vicinity of the surface of the magnetic system can be achieved even when the use of cheap magnets with hard ferrite. With magnets made of materials with rare earth metals are obtained field intensity up to 600–700 sq / m (magnetic induction in 0,75–0,9 T) [6, 7].

Conclusions. Magnetic anti paraffin unit (MAU-1), compared with the analog and the prototype, it allows to obtain a significant increase in the density of the magnetic field lines on its surface near areas with the facing surfaces of the magnets with axial and radial magnetization and rapid reduction in the density of magnetic field lines as the distance between these areas, thereby increasing the amplitude and the gradient of magnetic field on the surface of the magnetic system and increases the efficiency of the device for magnetic treatment of liquids.

A significant advantage of (MAU-1), especially with plugs of non-magnetic material disposed on the outer surface of the radially magnetized magnets is the ability to use compound taken from individual sectors or elements of the other form of radially magnetized magnets using the most modern magnetic materials with rare-earth metals, which allows even greater to increase the amplitude and gradient of tension acting magnetic field on the fluid and thereby to improve the efficiency of the device for magnetic treatment of liquids.

Due to the fact that laboratory tests of MAU-1 resulted in a positive, we recommend to install MAU-1 in the elevator of tubing in oil field wells.

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