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Improving Paraffin Deposits Detection Methodology for Better Ecological Safety during Hydrocarbon Transportation

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Abstract

Development of the transportation system together with oil production (partly resulting from inventing methods for high-viscosity oils production) and expanding consumer network result in more strict requirements to be met by processes and transportation. These days, accidents resulting from paraffin deposits, and the consequences related thereto, are a hot issue. The work outlines basic factors affecting the mechanism of paraffin deposits formation, and the methodology for detecting and measuring those deposits during oil transportation via pipelines. The measuring system is based on using radioisotope radiation, which allows measuring the thickness of such deposits on the inner surface of the pipeline wall, without breaking in. The work additionally discloses the basic algorithm for measuring, and calculation equations.

Keywords: ecological safety, paraffin deposits, radioisotope, intelligent system, consumption, oil, pipeline, transportation, density.

INTRODUCTION

Oil transportation via pipelines is the mainstream in the Russian Federation and in many foreign lands, too, compared to other types of transport. Multiple advantages of pipelines each makes its own contribution, for example, oil field geography has a sophisticated pattern, therefore, pipelines are a way more efficient, capable of going just anywhere, with installation automated to far greater extent than whatever else, feeding consumers continuously rather than discreetly, capable of being controlled automatically – all those elements, each being rather promising alone, together compose significant profit. Oil transportation by pipelines is the most convenient and popular type of transportation [1, 2].

However, this method has a number of disadvantages, which cause complications in the distribution pipeline operation, and as a consequence, leads to a reduction in overall system performance by increasing energy consumption. The main disadvantages are the following: difficulties in the process of transporting of highly viscous and high pour point oil, turbulence in the flow and the formation of asphalt-resin-paraffin deposits on the pipeline inner surface, which results in emergency situations and ecological damages in places of raw material spills [3].

RESEARCH TECHNIQUE

A detailed analysis of oil extraction process as well as oil pumping and transportation revealed some factors that influence the mechanism of asphalt-resin-paraffin deposits formation. During transportation of oil through the pipeline the following processes take place: oil enters the pipeline and contact with chilled metal surface and this produces a temperature gradient, which is directed perpendicular to the cooled surface, towards the flow center. For paraffin deposits formation on the surface, the following conditions must be met: presence of high-molecular hydrocarbons in oil, primarily those of methane range; reducing the temperature of the flow to the values, when solid phase takes place; reduction of pressure to saturation pressure level; the presence of the substrate, with reduced temperature, when hydrocarbons are crystallized; watering; pipe wall roughness and the presence of solid impurities, within the system, to facilitate the paraffin extraction; flow velocity value (resulting from the oil flow velocity increase, the intensity of the deposits increases at first, due to increasing of flow turbulence, and at the certain speed begins to decrease). Also, laboratory studies have shown that gas bubbling and behavior of gas bubbles, within the mixed flow, affects the mechanism of paraffin deposits formation [4, 5]. It is known that gas bubbles have the ability to float the suspended paraffin particles. When a bubble is in contact with the pipe surface, paraffin particles are in contact with the wall and are deposited thereon.

Transport network, connecting providers and consumers, mostly passes through the areas, located in zones of different temperature gradients, and also in harsh natural climatic conditions. Taking the influence of the above-mentioned factors into account, the depositing of asphalt-resin-paraffin deposits can occur on the inner surface of the pipeline, making the pipeline a potential source of accidents [6]. According to analytical studies by “Lukoil-Komi” for 2015, within the territory of the Russian Federation, asphalt-resin-paraffin deposits cause almost every fifth accident (19% of total accidents).

Figures 1 and 2 shows that the annual temperatures across Russia are changeable. In Siberia, for example, the temperature ranges from about -40 to +20 degrees. In wintertime, in case of emergencies, repair work is complicated by the weather conditions and transit blockade due to road quality, which is a severe test for any equipment.

Summer months are also a dangerous time of year when there is a high frequency of fires in places, where broad main lines of hydrocarbons transmission are located (especially in Rostov region, Volgograd region, the Republic of Tatarstan and other southern regions), which causes irreversible environmental damage.

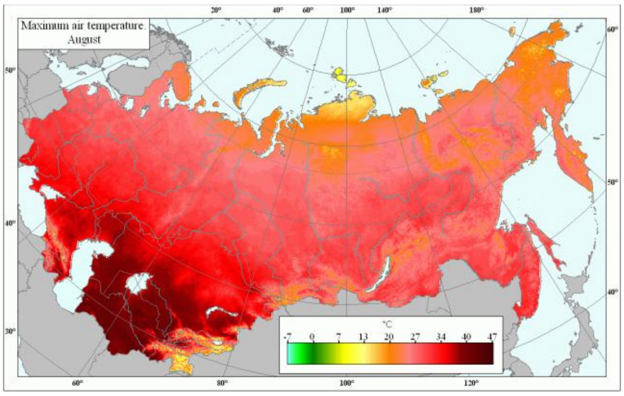

Figure 1. Maximum air temperature in Russia (August)

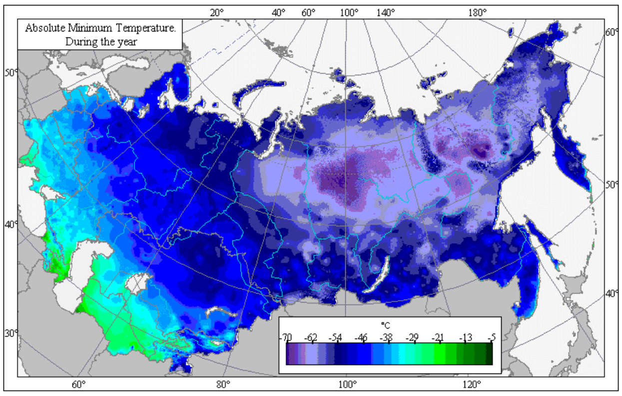

Figure 2. Absolute minimum temperature in Russia (during the year)

Together with the development of the transport system, an increase in oil production (among other reasons this is due to invention and improvement of methods for the extraction of high-viscosity oils), extension of the network of consumers, and increasing demands to processes and quality of transportation [7, 8]. These days, accidents resulting from hydrocarbon distillation by pipelines, and the consequences related thereto, are a hot issue. Usually, in order to provide an accident damage control, all transportation process should be stopped, which results in additional material investments by companies, the need to stop production, late delivery of raw materials, and is a source of intractable ecological problems [6, 9].

Currently, methods for dealing with asphalt-resin-paraffin deposits are implemented in two ways: prevention of formation and removal of deposits already formed. These methods include physical (vibration, ultrasound, effects of electric and magnetic fields), chemical (wetting, modifiers, depressants, dispersants, solvents and removers), mechanical (scrapers, scrapers-centralizers) thermal methods (washing with hot oil or water as a coolant, hot steam, electric ovens, induction heaters, reagents) [10-14]. Selection of appropriate ways to deal with asphalt-resin-paraffin deposits and the efficiency of various methods depends on many factors, particularly, on the method of oil extraction, thermobaric mode of flow, composition and properties of products extracted, which often require individual approach and even the development of new technologies. It is worth noting that the efficiency of the abovementioned methods is dramatically reduced by missing instruments and methods of early detection and quantity measurement of asphalt-resin-paraffin deposits (for example, the most common ultrasonic methods are not applicable for this task, because impurities, within the oil flow, create additional inaccuracy of measurements), the measurement of intervals of possible paraffin formation and intensity of depositing on the pipeline walls. Thus, there is a need to control the pipeline condition in the most important section points along the entire path and under different conditions.

MEASUREMENT METHODOLOGY

Saint-Petersburg Mining University and LLC “Complex-Resource” have developed a fundamentally new measuring system, which has no analogues in Russia and abroad, based on wave radiation that allows, with high precision, detecting and measuring the thickness of deposits without entering into the flow, without breaking the transportation process and the pipeline integrity [15, 16].

The developed measuring system, based on the photoelectron absorption, consists of two components: a primary converter, which interacts with the test medium and identifies an informative parameter; secondary instrument, in which the processing is carried out, grading, presentation and transmission of the obtained value. The process is performed as follows: section of the pipeline 1, comprising the oil flow 2 and paraffin deposit layer 3, is placed into a radioisotope measuring system consisting of a block of gamma radiation 4, represented in the form of a collimating apparatus for forming a narrow-beam radiation of radionuclide ^{137}Cs in the energy area of 0.2 - 1.0 MeV, and the detection unit (DB) 5, based on the use of scintillation crystal NaJ(Tl), a photomultiplier, a pulse generator and secondary instrument 6 (Fig. 3).

Two types of radiation, direct and diffused, occur during interaction of gamma radiation with the flow. Relatively even distribution of paraffin deposits on the pipeline walls [17, 18], it is sufficient to control the substance via a narrow beam of direct radiation, wherein the secondary radiation, due to Compton scattering, is not applicable. Direct gamma radiation 7, when passing through the controlled substance, undergoes a photoelectron absorption, and the mechanism of determining its intensity is a simple task compared with the scattered radiation [19].

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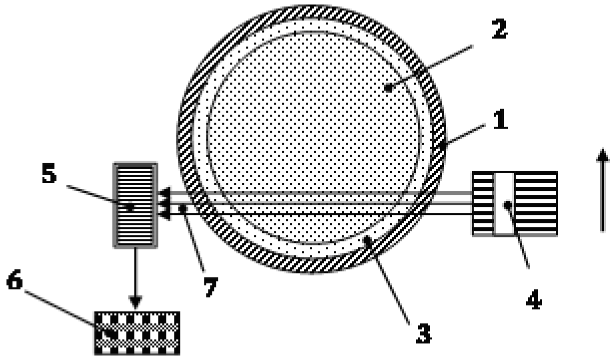

Figure 3. Radioisotope measuring unit

Direct gamma radiation intensity depends on the substance density (ρ) with the radiation attenuation coefficient (μ) and its thickness (δ), and is generally described by Beer-Lambert law [20]:

$$I = I_0 \cdot \exp(-\mu\rho\delta) \qquad (1)$$

In our case, the monitored medium may be split into three sites: pipeline wall (site 1), pipeline wall with paraffin settled onto (site 2), and pipeline wall with paraffin settled onto with oil flow transported (site 3). Then the gamma-radiation intensity for the site 1 would be:

$$I_1 = I_0 \cdot \exp(-\mu_{st}\rho_{st}\delta_{1st}) \qquad (2)$$

For the site 2 would be:

$$I_2 = I_0 \cdot \exp[(-\mu_{st}\rho_{st}\delta_{2st} + \mu_p\rho_p\delta_{2p})] \qquad (3)$$

For the site 3 would be:

$$I_3 = I_0 \cdot \exp[(-\mu_{st}\rho_{st}\delta_{3st} + \mu_p\rho_p\delta_{3p} + \mu_o\rho_o\delta_{3o})] \qquad (4)$$

$$\delta_{3p} = \delta_{2p} - D\sin(\arccos 2\frac{R-\Delta}{D})$$

$$\delta_{2st} = \delta_{1st} - 2R\sin(\arccos\frac{R-\Delta}{r})$$

$$\delta_{2p} = 2r\sin(\arccos\frac{r-\Delta}{r})$$

$$\delta_{3st} = \delta_{2st}$$

where I1, I2, I3 - are intensities of the primary radiation as registered by the sensor within the given volume in presence of adsorbing material for, correspondingly, the 1st, the 2nd and the 3rd sites of the pipeline cross-section; ρ_{st}, ρ_p, ρ_o - would be densities of the pipeline steel wall, paraffin and oil correspondingly; δ_{st}, δ_p, δ_o - would be equivalent thickness of the pipeline steel wall, paraffin and oil phase, correspondingly, μ_{st}, μ_p, μ_o - would be mass attenuation coefficient for the primary radiation by the pipeline steel wall, paraffin and oil flow, correspondingly; with Δ - is the distance between the pipeline edge and the point of scanning at the moment by direction of motion for the entire measuring system; R, r - are outer and inner radii of the pipeline in the section given; D - is the pipeline diameter [15].

Figure 4 represents the obtained relation between the radiation intensity and the depth of gammas penetration into the flow monitored, wherein figure 4(a) is the curve break during transfer from paraffin to oil, figure 4(b) is the curve break during transfer from steel wall to paraffin.

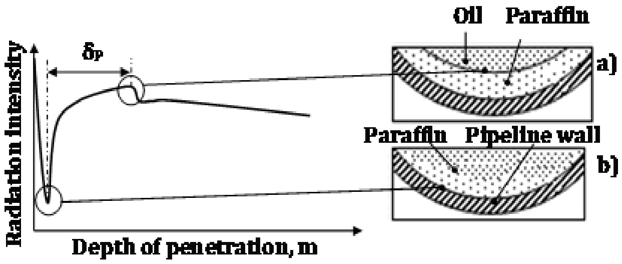

Figure 4. Relation between radiation intensity and gamma penetration depth

Method for measuring the thickness of paraffin deposit in the process of oil transportation via the pipeline includes irradiation of the crude flow with a narrow beam of ionizing radiation, registration the radiation, which passed through the controlled environment in different section points of the pipeline and forming the corresponding information signals in a form of discrete counting. Further comes detection of thickness of paraffin deposit via processing the results of the passed radiation measurement, which shall differ by its intensity for different media, the pipeline material, paraffin deposit, moving oil.

The detection unit principle of operation is based on the registration of gamma flow via scintillation detector with a photomultiplier, the formation of the spectrometric signals, with amplitude proportional to the energy of registered quanta, extracting two component from the general flow of the registered quanta, corresponding to energies of quanta, from two non-crossing energy ranges, data processing by the microcontroller according to the established algorithm. Powered on, the detection unit shall be ready to operate within one hour, i.e. after thermal balance is obtained in the housing.

Gamma radiation from the source, having passed through the medium controlled, is converted into electric signal via the scintillator to be presented by positive rectangular impulses with varying amplitude and duration. The scintillator output signal enters the microcontroller to be further processed in accordance with a dedicated algorithm to be further passed via the RS-485 interface. The detection unit then gives out the average values of calculations into the data collection system, in proportion to the registered gamma quanta amount.

CONCLUSION

The developed measuring system allows efficient detection of the deposits with absolute error ±5mm, thus becoming a sufficient tool to provide reliable and efficient pipeline operation and preventing far more accidents, which would otherwise have brought irreversible environmental damage. The developed measuring system allows efficient detection of the deposits with absolute error ±5mm, thus becoming a sufficient tool to provide reliable and efficient pipeline operation and preventing far more accidents, which would otherwise have brought irreversible environmental damage.

REFERENCES

[1] Voytyuk, I. and Kopteva, A., 2015, "Noncontact measurement method for assessing oil quality and quantity in main pipeline". Int. Conf. on Mech. Engineering, Automation and Control Syst. MEACS-2015.

[2] Lishchuk, A, 2003, "Consideration of hydrocarbons: a new look at familiar things". Oil Industry, №3, pp. 1–3.

[3] Targulyan, O, 2002, "Dark black gold page. Environmental aspects of the oil industry in Russia". Greenpeace Russia.

[4] Bulatov, A, 2011, "Asphalt-resin-paraffin deposits hydrate and warning and disposal". Krasnodar, South.

[5] Chernikin, V, 1998, "Pumping viscous oils and solidifying". Gosoptehizdat. 1998.

[6] Prusenko, B and Martyniuk, V, 2003, "Analysis of accidents on the pipeline transport". Hazard Analysis.

[7] Badiru, A and Osisanya, S, 2013, "Project Management for the Oil and Gas Industry". A World System Approach. NY.

[8] Barak, A, 2015, "The dependence of oil prices on the introduction of new technologies". Oil and Gas. 2, pp. 29–32.

[9] Stadnikova, M and Glebova, 2009, "Analysis accidents and their consequences on the main oil pipelines". Ecology and Industry of Russia.

[10] Ivaniec, V, 1997, "A method for determining the thickness of sediments in the pipeline". Patent 2099632, Russian Federation MPK6 F 17 D 3/00.

[11] Akhmedov, G, 2009, "The process for determining the thickness of deposits on the inner surface of pipelines". Patent 2009149649 Russian Federation, MPK6 F 17 D 1/16, G 01 B 17/02.

[12] Jennings, D, 2009, "Reduces hydrocarbon deposits; mixture of fluid and crystal growth inhibitors prepared by mixing polymer having characteristic of inhibiting paraffin crystalline growth in formation fluid from oil and gas wells with weak to moderate wax solvent and strong wax solvent; synergistic". Patent US 7541315 B2.

[13] Kopteva, A and Starshaya, V, 2015, "Analysis of sediment control systems for operation of pipeline transport in Russia", Vol. 4, 2015, pp. 58-63.

[14] Kopilov, A. 2013, "Composition for removing asphalt-resin-paraffin deposits". Patent 2490296 Russian Federation.

[15] Koptev, V, 2016, "Automated monitoring system for asphaltene-resin-paraffin deposits in main oil pipelines". Int. J. of Applied Engineering Research, 22(4), pp. 2191-2198.

[16] Kopteva, V, 2014, "Ways of improving wave systems for measuring multiphase oil flow". Modern scientific research and innovation. Vol. 5-1 (37), pp. 56-62.

[17] Siljuberg, M, 2012, "Modelling of Paraffin Wax in Oil Pipelines. Norwegian". Earth Sciences and Petroleum Engineering.

[18] Mozhayskaya, M, 2008, "Hydrocarbon Composition and Structural-Group Analysis of HighMolecular Components from West Siberian Oils". The Third International Conference on Chemical Investgation and Utilization of Natural Resources, Vol. 1, pp. 198-201.

[19] Bujdosó, E, 1996, "Analysis by absorption and scattering of radation". J. of Radioanalytical and Nuclear Chemistry, Vol. 12, pp. 557-577.

[20] Bieberle, A and Härting, H, 2013, "Gamma-ray computed tomography for imaging of multiphase flows". Chemie Ingenieur Technik, Vol. 7, pp. 1002–1011.