Recovery Throughput of Technological Pipelines and Useful Volume of Tanks for a Long Time Operated Pump Stations

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Abstract. The paper discusses the problems of cleaning technological pipelines and tanks to restore the capacity and useful volume capacity of oil pumping stations. The world experience of using chemical reagents for cleaning oil pipelines from asphalt-resinous paraffin deposits is considered, the disadvantages and advantages of the method are determined taking into account the restrictions that exist at the facilities of the main oil pipeline transport. The analysis of the results of experimental laboratory studies and pilot tests of the chemical washing technology at the existing facilities of Transneft PJSC is presented. Recommendations are given on improving the technology to reduce the consumption of chemicals and time costs. Particular attention is paid to the shortcomings and features of the use of hydrocarbon solvents for cleaning technological lines from pipes of small diameter and large tanks. The expediency of an additional physical effect is substantiated to increase the efficiency and rate of destruction and removal of hard-to-remove deposits, for which the use of ultrasonic resonators providing flow homogenization and dispersion is proposed.

1. Introduction

During the operation of oil pipelines on the inner surface of pipelines and tanks, the formation and deposition of wax deposits (mix of asphaltenes, resins, paraffin and inorganic participations) occur, which affect the decrease in the effective diameter of pipes and useful volumes of tanks, increase in direct (electricity consumed by the pumps) and indirect pumping costs (increase the quantity of pigging required), loss in the quality of commodity oil and in-line inspection data. In the case of the transfer of the oil pipeline to the pumping of light petroleum products, its cleaning from wax is also a paramount task, which allows to reduce the capital investments for the reconstruction of the facility. When liquidation and preserving objects, cleaning the internal cavity of oil residues and its wax solid contaminants is also of great importance.

If cleaning sections of the linear part of oil pipelines has a great background and experience, both Soviet and modern, and with the correct calculation of technological parameters - the scheme, solvent plug length, speed and type of solvent (chemical reagent, heated distillate or fuel used), to achieve the required quality of the surface being cleaned - the problem has already been solved at the presence, while the cleaning of oil pumping stations, tanks and process pipelines without opening, there is still uncertainty, since there is still no proven sufficient theoretical and feasibility studies confirmed by both laboratory and pilot industrial investigations.
Thus, in spite of the existing experience in cleaning oil pumping stations, including at Transneft JSC objects, there are still a number of uncertainties, such as the choice of the type of chemical reagent, the required volumes, speed and duration of washing, the technological scheme of connection, as well as needed solvent volume and sequence of cleaning operation, seasonality and temperature. Important issues are also the disposal of spent reagent, especially when cleaning oil tanks, as well as the need for complete removal of inorganic paraffin compounds not insoluble in hydrocarbon solvents. The issues of controlling the degree of purification, the subsequent preservation of the commercial quality of the pumped products, as well as the possible impact of chemicals on the construction materials used are brought to the forefront during feasibility study for projects planned. The possibility of intensifying corrosion processes and the need to restore anti-corrosion protective properties when deciding to extend the life of long-operated facilities of oil pumping stations are brought to the forefront, dictating strict requirements for the cleaning technologies used [1-3].

All of these issues and problems that have not been unambiguously resolved today, as well as a number of other important factors - the lack of start-up and intake chambers for scrapers, the high cost of chemical reagents, their high consumption and the need for disposal, hamper the expansion of the practice of applying chemical technologies to reduce material -time costs during the reconstruction of oil pumping stations of long-running trunk oil pipelines, including cases of transferring of old oil pipeline to light petroleum products.

2. Review
The main goal of this work is to analyze and generalize the existing experience in flushing pipelines using chemicals and distillates to improve the technical and economic indicators of existing cleaning technologies and expand the practice of their application, which will determine the most promising areas for further research, the disadvantages and advantages of various methods. Moreover, the widespread use of chemical reagents, most of which are by-products of the synthesis of domestic petrochemical enterprises and the oil and gas refining industry, fits well with the framework of state import substitution, environmental friendliness and energy efficiency programs of the Russian fuel and energy complex.

Meanwhile, the use of chemical reagents for cleaning the cavity of oil pipelines from asphalt-resinous paraffin deposits (hereinafter referred to as wax) originates practically from the first years of their operation. Thus, systematic observations since 1924 during the pumping of the Grozny-Makhachkala oil pipeline, and then the opening of individual pipe sections, showed that the inner surface of the wall was covered with a dense layer of deposits, which could explain a significant decrease in the flow capacity. The analysis of the wax layer probed showed that the deposits resemble ozokerite with a high content of paraffins and ceresins.

In this regard, already in 1920-1923 along with the passage of mechanical cleaning pigs, light oil products, mainly kerosene and gasoline distillates, were used to flush the pipeline. Thus, pumping gasoline in 1927 for 10 days in the forward and reverse directions contributed to the complete removal of the loose layer of deposits from the walls of the pipeline. In the summer of 1932, the technology of transferring it to pumping light oil products was already successfully tested at the existing Grozny-Kalaus pipeline, as a result of which the pipeline wall after washing with gasoline and kerosene distillates presented a clean smooth surface.

The largest and most significant during the Soviet period was the flushing of the Ufa-Omsk oil pipeline, an attempt to clean which in 1956 by pigging was unsuccessful. As a result, it was decided to flush the pipeline by pumping preheated pyrolysis raw materials. With the length of the section 165 km, a solvent plug of 36 km long was created. The pumping of heated oil and pyrolysis raw materials was carried out under normal conditions at a speed of 1-1.2 m/s. The acceptance of the spent solvent was carried out in the intermediate tank of the oil pumping station, where, in the process of settling and cooling, about 1000 tons of solved sediments were released. Further, the settled pyrolysis feedstock was pumped already through the next section of the pipeline to the final destination. As a
result of such cleaning, the design flow capacity was fully restored, and the subsequent opening of control sections showed a high degree of cleaning of the inner surface of the pipeline.

Subsequent studies conducted in the country’s research institutes confirmed the advisability of periodic washing with detergents and solvents in cases where wax deposits in the pipes are insignificant and there are restrictions or the absence of the possibility of skipping mechanical means. An example is the task of cleaning the technological pipelines of oil pumping stations, where inserting temporary chambers for the start-up and reception of scrapers will increase the cost, labor and metal consumption of the work, which can be quite comparable with the cost of building new pipelines and is not always technically feasible. Due to the fact that technological pipelines cannot always be cleaned from the bulk of paraffin deposits by physic-mechanical methods (warming with hot oil, passing foam rubber pistons and polyurethane balls, steaming with hot steam), satisfactory cleaning results can only be achieved through the joint usage of surfactants or organic hydrocarbon solvents with high properties of solubility and saturation.

If in order to solve the problems of restoring the design capacity (pressure and flow rate), in addition to mechanical means of cleaning or instead of them, a thorough technical and economic calculation is required, the results of which make a decision on the advisability of using hydrocarbon solvents and other chemicals, then in cases of transferring oil pipelines to pumping light petroleum products chemical flushing is mandatory condition, since only with its help can a high degree of purification be achieved, enough to provide qualities of petroleum products to be pumped in accordance with technical regulation standards.

From the first foreign experiments on preparing an oil pipeline for pumping light oil products, solvent washing of three oil pipelines with a diameter of 300 mm and a length of 112 km each in Southern Iran in 1969 can be distinguished. For this, a multi-stage purification scheme was chosen, including sequential pumping of solvents, low-concentrated acids, alkalis and salt aqueous solutions. To ensure sufficient contact of detergents with the surface of the walls of the pipeline and reduce their dosage, the pumping speed was reduced to 0.4-0.5 m/s, which fully ensured the turbulent flow required for better washing. One pipeline required 720 m³ of light oil product as hydrocarbon wax solvent, 150 m³ and 320 m³ of solutions of hydrochloric and citric acids, respectively, 160 m³ of soda ash solution, not counting aqueous solutions of sodium nitrate and caustic soda to prevent wall corrosion. Complete cleaning of all pipelines took about 7 days. A check on after opening certain sections showed that as a result of such cleaning not only the main wall layer was completely removed, but also deposits in the technological gaps between the pipes and backing rings.

In 1971, Continental Pipe Line Co proposed its own multistage technology, which consistently removes oily substances, wax and inorganic compounds (rust, scale and metal sulphides in the pores) from the walls of the pipelines. In total, 179.7 m³ of diesel fuel was required to remove 45 tons of wax. Laboratory studies have shown that a 15% hydrochloric acid solution completely removes rust, scale and iron sulfides from the walls of the pipeline coils cut. To reduce the destructive effect of an acid on a metal, it was necessary to add corrosion inhibitors to the acid. Pigging tools played the role of not only cleaning devices, but also mechanical plugs between different batches of chemicals (alkalis and acids), for which their parts were specially made for use under the influence of acids. To neutralize the acid, 5 tons of limestone were poured into a pit dug to dump chemical reagents. The pumping capacity was specially chosen to ensure the contact time of each reagent, the hydrodynamic effect of the flow and the required speed of the pigging.

At the same time, the American companies Gulf Refining Co, Golf Oil Cor and Dowell Incorporated proposed a similar technology for transferring a pipeline with a diameter of 200 and 250 mm and a length of 71.2 km for pumping light petroleum products. Mechanical pigs, also playing the role of batching plugs, were introduced every 15.9 m³ of injected reagents and at the interface of each chemicals batch. A distinctive feature of this technology is the use of chemical surfactants instead of hydrocarbon solvents, which is definitely a significant drawback. In totally, 159 m³ of an alkaline solution containing a detergent and 79.5 m³ of an inhibited hydrochloric acid solution with the addition of a wetting agent were used directly to clean the pipes. All chemical reagents, unlike the
hydrocarbon solvents used in the previous two cases, were to be discharged into a specially dug foundation pit for further disposal. The cleaning time in this case was 27 days [3].

In 2015-2016, Transneft Upper Volga as part of the project “Increasing the throughput capacity of the "Vtorovo-Primorsk" trunk product pipeline, including the transfer of the "Gorky-Yaroslavl" oil pipeline to the transfer of diesel fuel, reconstructed the "Zalesye-1" and "Stepanovo" oil pumping stations, providing for the chemical flushing of old technological lines - main pumping collectors by hydrocarbon solvents. Earlier in 2014, chemical flushing was already tested at the facilities of Transneft Siberia ("Tyumen - Yurgamysh" oil pipeline) and Transneft Baltic as part of the project "Development of a trunk pipeline system to increase the supply of oil products to the port of Primorsk". Later, similar cleaning works were made on the main oil pipelines of Transneft Urals and other subsidiaries of Transneft, JSC [1-7].

If cleaning the linear part of the main oil pipeline is no longer difficult, although it still raises a number of questions regarding determining the required length and speed of movement of the solvent plug, the chemical cleaning of technological pipelines of pumping stations is a fairly new experience for both the Company and the industry in the whole, and despite the great background in the use of chemical cleaning methods and means at domestic enterprises and abroad, the work done is a great scientific practical interest, while the results gotten clearly indicate the need to improve the used methods to get the best technical and economic indicators, better than pipeline relaying [8-14].

3. Discussion

Graphs on Fig. 1-2 shows the results of lab static tests of the solvent used in the chemical cleaning technology considered above. As can be seen from the graphs, the dissolution rate is too low, the required contact time of the solvent with deposits from 6 to 15 hours depending on the temperature of the solvent and the quality of the metal surface (base or weld pipe metal).

![Graph 1](image1.png)

**Figure 1.** The results of static tests of a hydrocarbon wax solvent at a temperature of +22°C.

![Graph 2](image2.png)

**Figure 2.** The results of static tests of a hydrocarbon wax solvent at a temperature of +6°C.

As can be seen from the graphs, a rise in temperature helps accelerate natural diffusion processes and wash deposits. Heating of the solvent in the conditions of pumping stations is quite feasible and economically justified, however, due to the high volatility and toxicity of solvent vapors, safe heating is advisable only in the cold season. Higher temperatures can be allowed only for pressured flushing when flow pressure is higher than saturated vapor pressure; however in oil tanks such heating is dangerous and could lead to evaporation loss of solvent.
Due to the fact that, in practice, the washing mostly is carried out in a dynamic mode, preferably by pressured turbulent flow, the results of lab tests of the solvent with vigorous stirring of the vessel by lab blender were also analyzed. The necessary contact time for full dissolution of similar samples ranged from 1 to 1.5 hours (fig. 3).

Figure 3. The results of dynamic tests of a hydrocarbon wax solvent at a temperature of +22 °C.

The obtained dynamic test data is still insufficient for the efficient use of solvents on the linear part of the main oil pipelines - the required volumes of plugs will be large, and low speeds to ensure the required contact time will lead to spreading of the plug and unpressured contact with surfaces to be cleaned. As for the cleaning of technological pipelines and tanks of oil pumping stations, the results obtained are more than satisfactory, so in the conditions of the station, by looping the lines it is possible to provide the required capacity and duration of chemical flushing.

However, there is one more technological peculiarity, limiting of using hydrocarbon wax solvents, namely, when flushing large trunk pipes, the specific solvent volume enclosed in the unit length of the tube is many times higher than the volume required for its dissolving ability, and in fact most of it is used as a pressing ballast. This fact is also true for technological pipelines of small diameter with a large number of deposits, in which the volume of solvent enclosed in the pipe to be washed is almost always insufficient to completely dissolve the oil deposits. Moreover, a hydrocarbon solvent cannot dissolve inorganic impurities in itself - particles of water, sand, corrosion and erosion products, but only contributes to their dispersion for subsequent removal by a turbulent flow. The situation is similar for oil tanks with a large number of bottom sediments, the complete dissolution of which with hydrocarbon solvents is not economically feasible because of great volume of chemicals required. In such cases, the use of buffer tanks will be required, the length of the loop line for strapping the washing circuit will also give a slight effect.

Subsequent studies of the total washing ability of solvents (Tab.4) showed that a significant part of the deposits does not dissolve, but simply disperses into small unbound particles that can be easily removed by pressure flow. Moreover, depending on the type and age of deposits, the amount of inorganic particles insoluble in hydrocarbons may increase, and therefore dispersion will be more preferable to dissolving deposits, since it requires a significantly lower concentration of hydrocarbon diluent components and instead of which surfactants can be used more effectively.

Table 1. The lab testing results of total washing ability of hydrocarbon solvents for wax deposits.

| Controlled testing indicator | sample №1 | sample №2 | sample №3 | sample №4 |
|-----------------------------|-----------|-----------|-----------|-----------|
| Insoluble part, %           | 20 °C     | 0 °C      | 20 °C     | 0 °C      | 20 °C     | 0 °C      | 20 °C     | 0 °C      |
|                             | 17.73     | 29.94     | 19.27     | 41.33     | 9.78      | 30.81     | 3.79      | 20.95     |
| Dissolved part, %           | 52.71     | 39.65     | 55.9      | 42.76     | 56.45     | 46.86     | 55.66     | 48.68     |
|                             | 29.55     | 30.41     | 24.83     | 15.92     | 33.77     | 22.33     | 40.55     | 30.37     |
| Dispersed part, %           | 82.26     | 70.06     | 80.73     | 58.68     | 90.22     | 69.19     | 96.21     | 79.05     |
| Total washing ability, %    |           |           |           |           |           |           |           |           |
4. Conclusion
The last results of lab studies of real efficiency of chemicals indicate the possibility of reducing the dosage of solvents due to mechanical dispersion, which can well be achieved using additional ultrasonic processing of the flushing flow and cleaned surfaces. Modern ultrasonic small-sized resonators are capable of dispersing a large volume of liquid with deposits in a short period of time with lower energy costs compared to heating and pressing by creating in flow the cavitation fields. The effect is simultaneously achieved both by instantly mixing the active substances of reagents with deposits (multiphase flow homogenization), and by tribalization and cavitation (numerous high-energy bubble explosions destroy even strong structures of wax deposition and inorganic compounds).

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