SAFETY OF TECHNOLOGICAL PROCESSES AND PRODUCTION

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ESTIMATION OF THE VOLUME OF ASPHALT-RESIN-PARAFFIN DEPOSITS IN PROCESS PIPELINES

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Abstract. Analysis of the mechanism of precipitation of asphalt-resin-paraffin deposits made it possible to identify the conditions for their accumulation in process pipelines during the movement of petroleum products. Connections between the intensity of heat and plastic transfer and the increase in the thickness of asphalt-resin-paraffin deposits in process pipelines have been identified. An expression was compiled to determine the total hydraulic losses caused by asphalt-resin-paraffin deposits in process pipelines. Proposed procedure for measuring the thickness of asphalt-resin-paraffin deposits on the inner surfaces of pipelines.

Key words: petroleum products, asphalt-resin-paraffin deposits, gas hydrates, pressure losses, bypass line, hydrodynamic characteristics, effective diameter, liquid flow rate

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Introduction

The fire safety level in the process of downhole extraction of asphalt-resin-paraffin (ARP) grades of oil with its subsequent in-field transportation during oil extraction by gas and oil producing enterprises is largely determined by the volume and thickness of various deposits on the inner surfaces of such pipelines.

As oil fields are exploited, deposits containing mechanical impurities, inorganic salts, and water precipitating from heavy components of ARP oil accumulate on certain sections of pipelines, which increases the risks and possibility of accidents. This is due to a probable narrowing of the cross-sectional area of technological pipelines, which leads to a decrease in the consumption of the pumped product, which requires constant monitoring of their internal surfaces condition for the presence of asphalt-resin-paraffin (ARP) deposits to support the process of efficient operation [1].

Main part

A sufficiently homogeneous solution of oil and solid components is formed, which can lead to further formation of ARPD [2].

As the oil rises to the surface, pressure and temperature decrease, and the possibility of ARPD dissolution in the oil lowers, while the oil is saturated with ARP components with possible crystallization of some of these components. However, for such process, it is necessary to have crystallization centers, which can be solid suspensions in the oil stream, as well as elements of local resistances on the inner surface of the pipeline [3].

The formation of an ARPD solid plug should be qualified as a dangerous emergency situation, in most cases due to serious deviations from the technological regulations for the operation of pipelines or errors in the course of making design decisions, as well as possible violations in construction.

Monitoring of the technical condition of main and distribution pipelines at oil or gas field enterprises includes procedures for detecting hydrate deposits that look like continuous hydrate plugs, as well as measuring their thickness and location on the pipeline. It is also very important to fix the beginning of the ARPD formation process on the crystallization centers of the inner surfaces of pipelines [4].

Monitoring of the formation of gas hydrate deposits is necessary to improve the efficiency of the gas transfer systems and predicting the occurrence of possible emergencies. This increases the possible period of trouble-free operation and decreases the likelihood of a breach in the pipeline.

For timely prevention of the ARPD formation process and neutralization of such negative phenomena, it is necessary to receive objective information in a timely manner.

In [5], a method is proposed for determining the volume of deposits in gas pipelines, which involves connecting a bypass line with a gas volume flow meter to the problem section of the pipeline and obtaining measurement results using a differential pressure gauge.

The first indicator can be obtained from the analysis of design documentation, and the second is determined when liquid is injected into the pipeline section under study with a density greater than the density of the pumped product, it is necessary to prepare for the separation of liquids.

The disadvantage of this method is the lack of information on the exact location of APDR along the length of the examined pipeline segment. The solution to this problem is creating a procedure for finding the volume of the ARPD adhesive component.

A possible method for measuring the volume of ARPD in a pipeline involves the movement of liquid media of different densities, which has the ability to pass through narrowing areas in the pipeline.

Maintaining a constant flow rate of the liquid injected into the pipeline with a separator at the initial section of the pipeline allows you to measure the pressure values at the inlet and outlet of the examined pipeline section using differential pressure gauges located there.

Thus, the value of the pressure drop allows us to form a picture of the ARPD distribution:

$$V_{dep} = \frac{\pi \cdot D^2 \cdot l}{4} - Q \cdot (t_2 - t_1) \quad , \qquad (1)$$

where V_{dep} – volume of ARPD, located on the inner surface of the pipeline; l – the distance between two differential pressure gauges at the inlet and outlet of the examined pipeline section; D – the inner diameter of the unpolluted section of the pipeline; Q – The volumetric flow rate of the liquid in the pipeline maintained at a constant value during the deposit volume assessment procedure; t_1 – the moment of the first pressure surge in the area of the differential pressure gauge located on the initial section of the pipeline during the passage of the liquid separator; t_2 – the moment of pressure surge in the area of the differential pressure gauge located on the end section of the pipeline during the passage of the liquid separator.

It follows from the basic principles of hydraulics [6] and gas dynamics [7] that the value of local pressure losses h_{ms} or pressure drop P_{ms} of a liquid moving through a pipeline is determined, among other things, by local internal surface resistances, which can be calculated using the formula:

$$P_{мс} = \xi \cdot \frac{w^2}{2 \cdot g} \cdot \rho \quad \text{or} \quad h_{мс} = \xi \cdot \frac{w^2}{2 \cdot g}, \qquad (2)$$

where w – the average flow velocity over the flow section; ρ – the density of the liquid, which can be considered constant during the measuring; ξ – the coefficient of local resistance, numerical values depending on the condition of the inner surface of the pipeline walls are given in [8].

In [9], it is proposed to use a magnetohelium compound for liquid separation, which is loaded onto the examined pipeline section as it poses no problem of its further extraction upon completion of the measuring procedure. Otherwise, it is necessary to remove such a separator using a special receiving device [9].

The diagram of the pipeline section with the equipment allowing to implement the described method is shown in fig. 1.

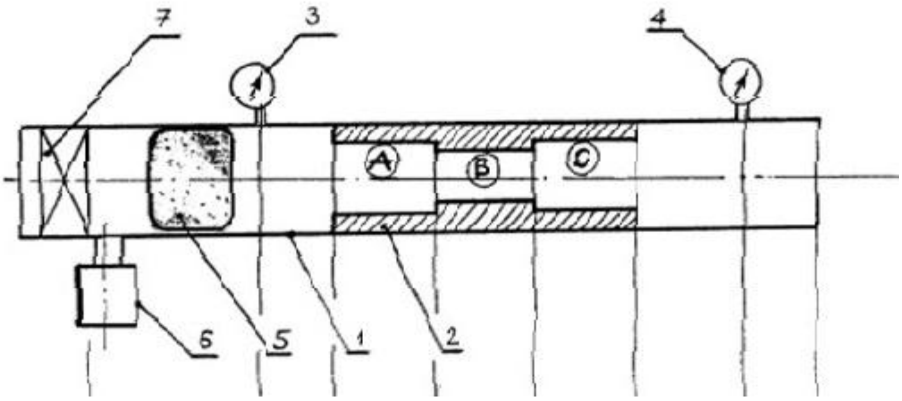

Fig. 1. **Scheme for measuring the thickness of ARPD in a pipeline: 1 – examined pipeline section; 2 – pipeline section with an ARPD and a narrowing of its passage section; 3 – differential pressure gauge at the initial section of the pipeline; 4 – differential pressure gauge at the end of the pipeline; 5 – liquid separator that emulates local resistance; 6 – mobile pump used for pumping liquid; 7 – valve in the closed position**

When using the presented scheme, the pressure in the measuring area of the differential pressure gauge (fig. 1) can be represented as the sum of three types of pressure:

$$P_1 = P_2 + P_{pipe} + P_{sep}, \qquad (3)$$

где P_1 – the pressure measured by the first pressure gauge on the beginning of the pipeline; P_2 – the pressure measured by the second pressure gauge on the end section of the pipeline; P_{pipe} – pressure loss due to local friction in the area between two differential pressure gauges in the absence of a liquid separator in the pipeline, which is determined using the Darcy-Weisbach equation [10]; P_{sep} – total additional pressure loss due to local resistance of the liquid separator.

Using formula (3), it is possible to plot pressure changes P_1 and P_2 over time (fig. 2), analyzing the stages of movement of the liquid separator from the beginning of the pipeline to its end.

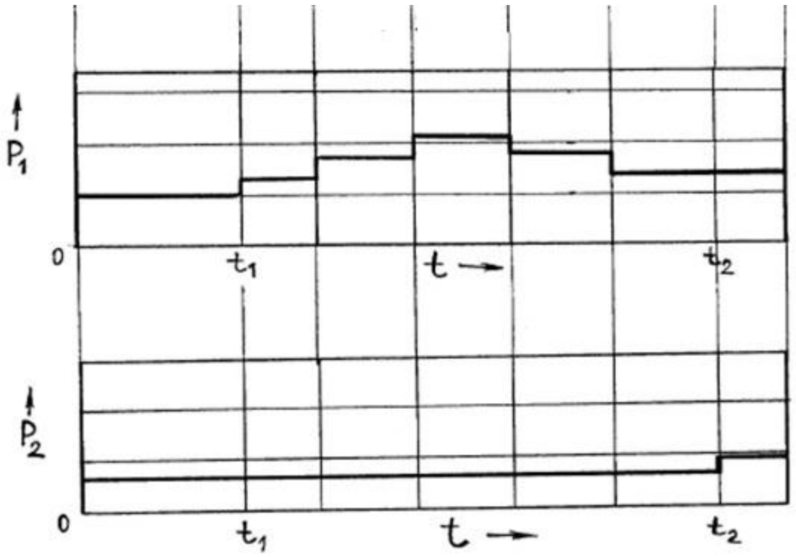

Fig. 2. **Graphs of pressure changes at the beginning of the pipeline P_1 and at the end of the pipeline P_2 over time**

Until the separator 5 moves into the area of the differential pressure gauge 4 (fig. 1), the value of the pressure P_2 measured by it can be expressed based on equation (3):

$$P_2 = P_1 - P_{pipe} - P_{sep}. \quad (4)$$

The components of equation (4): the pressure at the inlet of the pipeline P_1 and the additional loss of pressure due to friction in the area of movement of the liquid separator P_{sep} synchronously increase or decrease by the same value, therefore, the pressure at the outlet of the pipeline P_2 remains constant until the liquid separator 5 (fig. 1) is moved to the end of the examined pipeline section.

Thus, based on the readings of two differential pressure gauges, it is possible to determine the duration of movement of the liquid separator $\Delta t = t2 - t1$ along the examined pipeline section, which allows using equation (1) to estimate the volume of ARPD in adhesive form on the inner surface of the examined pipeline section.

Conclusion

In conclusion, it can be noted that during the use of oil fields, deposits accumulate on certain sections of pipelines. They form out of heavy components of ARP oil, and can lead to a possible narrowing of the cross-sectional area of technological pipelines. They can also increase the chances of risks and possible accidents. Periodic monitoring of the condition of the pipelines' internal surfaces for the presence of ARPD benefits the efficiency of oil fields use. The downhole extraction of ARP oils' fire safety with the safety of its subsequent transportation is largely determined by the volume and thickness of various deposits on the inner surfaces of pipelines.

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