On the efficiency of wastewater treatment from solid suspended particles at Tuimazaneft Oil and Gas Production Division (NGDU "Tuimazaneft")

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Abstract. The article shows that the implementation of filters at the intake of submersible pumps along with the flushing deposits from filter elements by a reverse flow of liquid without lifting the pumping equipment is an effective means of cleaning products being extracted from the reservoir from suspended solids. The work notes a considerable experience of NGDU "Tuimazaneft" in the use of mesh filters in pressure maintenance systems. The results present the optimal parameters of the structures and sizes of filter elements, and a high technical and economic effect from their use.

1. Introduction
One of the significant problems in the production, collection, treatment of oil and water is the control of the removal and separation of total suspended solids (TSS) in the well production. Their presence in the liquid causes wear of equipment, corrosion of pipeline metal, clogging of technological systems and complicates the preparation of oil and water. The presence of TSS in the injected water of the reservoir pressure maintenance system leads to clogging of the bottomhole zone of injection wells, deterioration of waterflooding performance and a decrease in the rate of oil production [1], which ultimately leads to a decrease in oil recovery [2–10].

The main source of the TSS in the discharged water is mechanical impurities carried out from the reservoir together with oil.

The use of filters at the intake of pumps of production wells is a rather effective means of preventing further penetration of TSS into waste water and the bottomhole zone of injection wells. However, clogging of the filter causes the well to be stopped and the equipment removed to clean the filter element.

2. Materials and methods
The figure shows the schematic diagrams of the filter [11] providing its cleaning without lifting the pumping equipment.
A sucker rod pump 2 is lowered into well 1, to the reception of which a liner pipe 3 is fixed, passing through the packer 4. In the liner pipe 3, an inner pipe 5 is located, forming a concentric annular space, which has radial channels 6 and 7 above and below the packer 4, communicating the cavity of the pipe 5 with the borehole space above and below the packer. Horizontal partitions 8 and 9 with through-holes are located under the lower radial channels 7, and windows 13 are made between the partitions in the pipe 5, communicating the cavity of the pipe 5 with a concentric annular space. Inside the pipe 5, hollow spherical valves 10 and 11 are not hermetically located, rigidly connected to each other by a rod 12. Outside the tail pipe 3, a cylindrical filter 14 is installed, which is muffled from below. Spherical valves 10 and 11 with stem 12 have positive buoyancy in liquid.

The filter works as follows.

Pump 2, assembled with liner pipe 3 and packer 4, is lowered into well 1. The leaky design of valves 10 and 11 in pipe 5 allows hydraulic communication between the productive formation and the above-packer (annular) space of the well through the filter and radial channels 6 and 7.

When pump 2 is put into operation (see figure), the spherical valves 10 and 11, due to their buoyancy and the gap between them and the pipe 5, will float into the liquid and take the extreme upper position, in which the opening of the partition 8 will be open, and the partitions 9 are closed by the valve 11. The formation fluid will enter pump 2 through filter 14, being cleaned of solids, channels 7, opening in the partition 8, windows 13, concentric space, bypassing the outer sides of radial channels 6.

If the filter 14 is clogged, as evidenced by measurements of the well flow rate on the surface, without stopping the operation of pump 2, flushing fluid is pumped into the annulus of the well, which can be used as heated or low-viscosity oil to simultaneously wash the filter from tar and paraffinic substances.

The flushing fluid from the annulus (see Figure b) enters through the channels 6 into the pipe 5 and...
pushes the spherical valve 10, the stem 12 and the valve 11 down. In this case, the spherical valve 10 will block the passage opening of the partition 8 and open the access of the pumped liquid from the pipes 5 to the channels 7 and further to the filter from its inner side. The pressure of the liquid will wash away the particles of mechanical impurities and resin-paraffin deposits adhered to the outside. At the same time, when the valves 10 and 11 are pushed down, the through hole of the partition 9 will open. The flushing liquid, having sharply changed its direction through the hole in the partition 9, will enter the windows 13 and then through the annular space will go to the pump intake and will be pumped out to the surface.

A sharp change in the direction of movement of the flushing fluid after the filter 14 allows it to get rid of suspended particles due to centripetal forces. These particles will be freely released downward and collected in the sump of the well. After long-term operation, the bottom of the well can be flushed out with the removal of accumulated mechanical impurities.

Continuous operation of pump 2 when flushing the filter avoids liquid squeezing into the reservoir and clogging of the pore space with particles of mechanical impurities.

After flushing the filter, the pumping of the flushing liquid is stopped and the pumping unit returns to normal operation.

3. Results and Discussion

The developed design with minor changes was tested at the wells of the Tuimazinskoye oil field, which are characterized by an increased influence of mechanical impurities on the Time Between Overhauls (TBO). For 6 months of operation of these wells, the flow rate of the SPR decreased on average by 22%.

TSS in the produced products, according to studies by the Central Scientific Research Institute of Oil and Gas Production "Tuimazaneft" for these wells, was 215 and 360 mg/l, respectively.

In one of the wells, the mesh size of the filter mesh element was 15 μm, and in the other, 25 μm. The filtration area in both cases was 0.05 m².

Tests have shown that with a mesh size of 15 μm, the filter becomes clogged after 25–30 days of operation. With a cell size of 25 μm, it occurs in 60–80 days.

The tests showed a decrease in the TSS at the wellhead by an average of 64%. In this case, the average size of particles remaining in the liquid in both cases was about 7 μm.

The products of the groups of producing wells are then fed to the apparatuses or installations of preliminary water discharge. Practice has shown that the separation of TSS in them is impractical and filters should be installed at the pump intake of a modular horizontal pumping station (MHPS) [12, 13]. On the one hand, a decrease in TSS in wastewater increases the service life of centrifugal units, comb blocks and wellheads, on the other hand, it reduces clogging of the near-wellbore zone of the formation.

At the Tuimazinskoye field, a fine filter was used, which is a vertically installed cylinder with a total height of 1405 mm and a diameter of 426 mm with connecting flange connections for a pipeline with a diameter of 159 mm. The filter element is a metal mesh. The size of the cell for capturing particles of mechanical impurities is selected based on the requirements for the quality of water for injection, and is 5–10 microns. The filter frame is a cylindrical drum with holes wrapped in a metal mesh.

TVO-29 facility was chosen as the object for pilot testing of this filter.

According to the cascade technology, additional quality requirements are imposed on the water injected into injection wells with low reservoir properties. Water for this category of wells must undergo additional treatment from mechanical impurities and oil products at the wellhead.

As a filter for wellhead equipment at NGDU "Tuimazaneft", a construction is used, which is a horizontal cylinder with a grid installed in front of the central valve. The main material used as a filter element in filters is a metal mesh used in the "vibrating sieve" of the flushing system when drilling wells. As an alternative to the used mesh elements, a combined filter element was proposed for testing, consisting of a metal mesh P48-12*18N9T GOST 3187-70 in two layers in combination with a sorbing material "Sormat" art. C-53 manufactured by LLC Tuimazinskaya Textile Factory. The sorbing material has a high hydrophobic effect and traps oil products well.

Laboratory tests were carried out with the sorbent material "Sormat" to determine the pressure loss
per unit area of the material and the maximum volume of the passing liquid required for the complete saturation of the filter element with particles of mechanical impurities and oil products.

The results of the analysis of waste water at TVO-29 when testing the filter are shown in Table 1.

Table 1. Results of testing filters with "Sormat" sorbing material

| Testing date     | Before filter | After filter | Efficacy |
|------------------|--------------|--------------|----------|
|                  | oil prod. [mg/l] | TSS, [mg/l] | oil prod. [mg/l] | TSS, [mg/l] | oil prod. [mg/l] | TSS, [mg/l] |
| 01.12.2004       | 16            | 22           | 15        | 8         | 7            | 47           |
| 10.12.2004       | 13            | 42           | 11        | 20        | 15.5         | 53           |
| 20.12.2004       | 19            | 43           | 18        | 27        | 6            | 37           |
| 29.12.2004       | 17            | 41           | 15        | 29        | 12           | 30           |
| 14.01.2005       | 15            | 26           | 13        | 20        | 13           | 13           |
| 26.01.2005       | 14            | 29           | 11        | 27        | 11           | 6.9          |

Change of filtering element

|                  | Before filter | After filter | Efficacy |
|------------------|--------------|--------------|----------|
| 08.02.2005       | 14            | 48           | 12        | 27        | 14           | 43.7         |
| 25.02.2005       | 14            | 54           | 12        | 32        | 14           | 40.7         |
| 09.03.2005       | 12            | 60           | 10        | 39        | 17           | 35           |
| 17.03.2005       | 15            | 34           | 13        | 28        | 13           | 18           |
| 24.03.2005       | 17            | 48           | 14        | 36        | 18           | 7            |

Change of filtering element

|                  | Before filter | After filter | Efficacy |
|------------------|--------------|--------------|----------|
| 31.03.2005       | 14            | 57           | 11        | 33        | 11           | 42.1         |
| 08.04.2005       | 13            | 50           | 11        | 31        | 15           | 38           |
| 29.04.2005       | 15            | 53           | 13        | 37        | 13           | 30.2         |

Obviously from Table 1, the test results showed a high efficiency of the filter when using a filter element in the form of a metal mesh with a cell of up to 5 microns, which makes it possible to reduce the content of mechanical impurities to 53% and oil products to 18%.

After the first pilot tests, a program was developed for the implementation of these filters at the facilities of the Tuimazinskoye field of various sizes in terms of diameter, area of the filter element and connecting pipes, based on the diameter of the intake pipeline, the place of its installation and the object of the pumped liquid.

According to this program, FS 300-16 filters with a metal mesh filtering element with a cell up to 5 microns were installed on the receiving pipelines:

- in 2006, two boreholes TVO-29 and 28 "C", BKNS-28 "D";
- in 2007, borehole wells of the "Ardatovka" OPS, BKNS-22;
- in 2008, wells at BKNS-20 "D" and BKNS-20 "S".

The results of the filters for wastewater treatment are shown in Table 2.
Table 2. Test results of FS 300-16 filters

| Installation facility | Before filter TSS, [mg/l] | After filter TSS, [mg/l] | Efficacy TSS, [mg/l] | Efficacy oil prod. [mg/l] |
|-----------------------|---------------------------|--------------------------|---------------------|---------------------------|
| BKNS-28 "D"           | 67                        | 45                       | 39                  | 40                        |
| Pits-28 "C"           | 63                        | 43                       | 40                  | 35                        |
| Pits of UPS "Ardatovka" | 71                      | 49                       | 45                  | 43                        |
| BKNS-22               | 57                        | 30                       | 37                  | 25                        |
| BKNS-20 "S"           | 47                        | 32                       | 45                  | 27                        |
| BKNS-20 "D"           | 53                        | 33                       | 28                  | 27                        |
| Pits TVO-29           | 64                        | 47                       | 41                  | 39                        |

Evidently from Table 2, on average, the content of mechanical impurities in the injected waste water after the introduction of filters reduced in the range from 35 to 47% and oil products from 11 to 19% for different injection objects, which made it possible to bring the values of the content of mechanical impurities and oil products to the required RD 16-015-2004 conditions. The achieved values for the removal of mechanical impurities up to 50 mg/l testify to the effectiveness of the implementation of these filters. During their implementation, not a single premature failure due to clogging with mechanical impurities of the ESP installations, launched into the boreholes of objects 28 "C", OPS "Ardatovka", TVO-29, was recorded, while before the introduction of filters there were up to four premature failures per year due to clogging of the working bodies and receiving grids of the ESP with mechanical impurities.

During pilot tests, the subsequent implementation and operation of filters at injection facilities, a certain experience has been gained in assessing the duration of the effect of cleaning the injected wastewater before the next change of the filter element. With an increase in the pressure drop between the inlet and outlet nozzles of the installed filter by more than 0.04 MPa, its efficiency sharply decreases. The drop in the cleaning effect is up to 7% for mechanical impurities, after which, accordingly, the replacement of the filter element is required. According to operating experience, the operating time of the filter element before its replacement is from 1 to 1.5 months. Due to the fact that a spare element is supplied with the filter, the process of its replacement in time is from 1.5 to 2 hours. The filter element is reusable: the mesh is cleaned of filtration products for further use.

4. Conclusion

The use of filters at the intake of submersible pumps with flushing from deposits on the filter elements by reverse flow of liquid without lifting the pumping equipment is an effective means of cleaning products from the formation from solid suspended particles.

NGDU "Tuimazaneft" has accumulated considerable experience in the use of mesh filters in pressure maintenance systems; the optimal parameters of the structures and sizes of filter elements have been determined, and a high technical and economic effect has been obtained.

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