Design changes of injection and supply wellhead fittings operating in winter conditions

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Abstract. The article deals with design changes in the existing injection well fittings. Disadvantages of the existing fittings are stagnant zones, considerable height and dimensions which cause problems of thermal insulation leading to rapid freezing of wellhead equipment in winter. At low temperatures, supply lines freeze and fail. The design of small-sized fittings of injection wells was developed. Elastic rubber cords, which absorb pressure caused by ice expansion due to water freezing and prevent rupture of the supply lines, are recommended to use.

1. Introduction

Despite the fact that development of most oil fields with hard-to-recover reserves is characterized by low oil recovery coefficients [1-4], there are methods for increasing final oil recovery values and improve overall efficiency of these facilities. Among these methods is unsteady flooding [5]. However, its widespread use is hampered in winter due to wellhead fitting freezing.

One of the methods preventing wellhead fittings from freezing is design changes in the existing injection wellhead fittings.

Currently, the oil industry uses ANK 1-65x210 wellhead fittings [6] and small-sized ANK 65x210K1M (TU 3660-003-49652808-2001) fittings. Their disadvantages are low reliability due to the large number of compounds working under pressure, maintenance and thermal insulation problems at low external temperatures due to high metal consumption and dimensions, including height. The presence of stagnant zones and significant height and dimensions cause thermal insulation problems and contribute to rapid freezing of wellhead equipment at low temperatures.

2. Results and discussion

It is possible to increase reliability and reduce operating costs by reducing the number of units and assemblies operating under pressure by combining a tee, a sub and a tubing head in one single body whose central hole with a thread and a bypass channel forms a sub with a tee, while the side hole with a bypass auxiliary channel forms a tubing head [7, 8].

The unit operates as follows:

The unit assembly (Figure 1) is mounted on flange 15 connected to the wellhead. The pressure pipe is connected with bypass channel 12 through the check valve, end valve 6. When pumping, the liquid...
flows through the discharge pipe, non-return valve, end valve 6 (end valves 4 and 5 are closed), outlet channel 12 in the tubing string suspended on thread 11 of single part 9. A lubricator can be installed on end valve 5 to lower-lift devices through central hole 10 of part 9 into the tubing string. To carry out technological operations, research and repair works in the casing tubing annulus, auxiliary channel 14 with lateral hole 13 can be used.

Figure 1. Wellhead fittings for injection wells: 1 - tubing head; 2 - sub for suspension tubing; 3 - tee; 4, 5, 6 - end valves; 7, 8 - control devices and pressure outlet; 9 - single case; 10 - central hole in the single body; 11 - central hole thread; 12 - branch channel; 13 - side hole of the auxiliary channel; 14 - side auxiliary channel; 15 - flange.

We described the design features of the wellhead fittings to emphasize improved reliability of operation by reducing the number of pressure connections. Simplification of the design and reduction of metal consumption and dimensions reduces production, maintenance and repair costs.

The design of thermal insulation is also simplified and involves development of a unified design which will be suitable for the entire wellhead fittings of injection wells [9]. But this design does not prevent wellhead fittings freezing from freezing.

To improve reliability of the wellhead fittings in winter, it is possible to reduce the number of stagnant zones (without water movement) in the process channels and wellhead fittings, as well as to facilitate installation and removal of fittings (without disassembling them). An improved design of wellhead fittings (Figure 2) was developed. It includes a tubing head, a sub and a tee in one body with technological channels. The pressure line is connected to the central channel through a mechanically adjustable fitting, and dead zones of the nozzles are fitted with plugs on the flanges to remove water and replace it with antifreeze. The flange of the central channel is equipped with a coupling connected to the lifting nozzle.

Before starting water injection, the valve assembly is installed on column flange 10 using a lifting nozzle connected to coupling 12. Pressure line 7 is connected to central channel 2. End valve 5 on the discharge line is closed, water from nozzle 8 is removed and antifreeze (oil) is supplied through the plug on flange 9. Injected water enters the well (indicated by arrows) through pressure line 7, mechanically adjustable fitting 6 to central process channel 2 with end valve 3 and then into the tubing string in single body 1. When operating, end valve 3 is open, end valve 5 is closed, mechanically adjustable fitting 6 is open and adjusted to the required flow rate of injected water. Mechanically adjustable nozzle 6 regulates the flow of injected water and contains less metal than the existing gate valves.
Figure 2. Wellhead fittings for injection wells: 1 - single body (tubing head, sub for tubing string suspension); 2 - central channel; 3 - end valve; 4 - discharge channel; 5 - end valve discharge channel; 6 - mechanically adjustable pressure line fitting; 7 - pressure line; 8 - pipe with a flange; 9 - plug for draining water and antifreeze inlet; 10 - column flange; 11 - flange of the central channel; 12 - coupling flange of the center channel.

Thus, this design prevents fittings from freezing due to reduced idle technological channels and stagnant zones in the housing and nozzles and reduces metal consumption and size which decreases manufacturing, maintenance and repair costs and increases reliability due to the reduced number of assemblies working under pressure. The design of thermal insulation is also simplified and involves development of the unified design that will be suitable for all wellhead fittings of injection wells. In addition, the coupling with a lifting pipe which is mounted on the flange of the central channel helps remove and install the valve assembly without disassembling it. The mechanically adjustable nozzle controls the flow rate of injected water.

In the winter period, the possibility of freezing of the supply pipeline and its rupture and failure increases. This is due to the fact that when water freezes, the ice volume formed is 9% more than the initial volume of water, therefore the internal pressure in the closed space of the pipeline increases, significantly exceeding the tensile strength of steel, and is 203 MPa at 20 °C below zero. Physically, this is due to the fact that in the process of complete water freezing, ice becomes denser at pressures exceeding 203 MPa which decreases pressure. In addition, an increase in the pressure of freezing liquid decreases the crystallization temperature. As a result, freezing liquid inside the closed space is a mixture of water and ice even at high values of negative temperatures [10, 11].

Table 1. Calculations of the diameter of the rubber cord

| Pipeline size | Pipeline section area, cm² | Increase in the volume of ice, cm³ | Rubber cord section area, cm² | Diameter, cm |
|---------------|----------------------------|----------------------------------|-----------------------------|--------------|
| 4 inches      | 128                        | 11.39                            | 17.09                       | 4.67         |
| 5 inches      | 138                        | 12.28                            | 18.42                       | 4.84         |
| 6 inches      | 190                        | 16.91                            | 25.37                       | 5.68         |
| 8 inches      | 330                        | 29.37                            | 44.06                       | 7.49         |

To prevent rupture of the pipeline of an idle well with internal pressure, it is possible to transfer excess fluid by installing a perforated tube to form a channel with a compensating continuous elastic
element (a rubber cord). The ends of the perforated tube are welded. To produce rubber cord, an elastic material is used (e.g., rubber with a Young's modulus of 0.2-2 kg/mm²). In this case, the elastic cord resembles a gas that, like soft rubber, is capable of making large reversible shape changes. With uniform compression, an elastic rubber cord takes up the entire load of increasing pressure, thereby unloading the pipeline. Therefore, in the closed space of the pipeline, initial pressure does not change after complete freezing of water. Calculations of the diameter of the rubber cord are presented in Table 1.

In contrast to the known methods and devices allowing for the movement of the changed volume of water and ice along the pipe, the pipeline of the idle well lacks this possibility, since the pipeline is usually filled with water. There is no place to move for excess water when ice is formed. Thus, when using this method, excess ice compresses the elastic rubber cord. As a result, the internal pressure does not rupture the pipeline [11-13].

3. Conclusions
The developed design of the wellhead valve prevents fittings from freezing due to the reduction of idle technological channels. This reduces metal consumption which improves reliability of the fittings, reduces manufacturing and maintenance costs. The design of thermal insulation is simplified and universal. It is suitable for all injection wells.

In the pipeline of an idle well, an elastic cord, perceiving pressure of an excess amount of ice formed during water freezing, is used. As a result, the internal pressure does not break the pipeline.

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