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OPERATION OF WELLS ON THE MEDVEZHIE GAS FIELD ON THE BASIS OF PLUNGER LIFT AT A FINAL STAGE OF THE FIELD DEVELOPMENT

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ABSTRACT

The world largest Medvezhie field, which already produced over 1500 bcm of gas, is at the final stage of development. From the very beginning of operation (from 1972) the main part of gas is produced from wells equipped with $6^5/_8$″ production tubing. In a number of wells due to decreased gas flow rate in production tubings the formation water and condensation water are accumulated which sharply decreases the well's production rate; the wells operation is also complicated due to water accumulation in the borehole at gas velocities in the production tubing insufficient for lifting water to the wellhead, which results in the rock wetting and destruction of the producing formation, bottomhole sand production with a possible formation of a lengthy sand plug at the well's bottomhole.

To improve operation of wells with 6 $^5/_8$" production tubing on the Medvezhie gas field plunger lift is testing. One unit of plunger is made of special rubber resistant to impact load and wear. After 8000 cycles of operation plunger failures were not observed. The plunger is in continuous up and down trip. On wells plunger lift will be applied with another function namely, for preventing drainage of water condensed from gas.

Till now plunger lift in gas wells equipped with small-diameter production tubing has not been used.

TABLE OF CONTENTS

Abstract

1. Preamble
2. General information on Medvezhie gas field
3. Technology of fluid removal from gas wells with plunger lift
4. Special conditions of wells operation on Medvezhie field
5. Special conditions of application of plunger lift on Medvezhie field wells
6. The object for 168 mm plunger lift test: gas well No. 623 of Medvezhie field
7. Test of plunger lift equipment on experimental stand
8. Conclusion
9. References
10. List of figures

1. **PREAMBLE**

First test of plunger lift set for the wells furnished with OD=168 mm (ID=154 mm) tubing will be carried out in January 2006 on the well No. 623 of Medvezhie field in Russia (Figure 1).

Figure 1 - Wellhead of the well No. 623 of Medvezhie field. The year of 2006.

Before the use of plunger lift, the water accumulated periodically in the well No. 623, while the gas flow from the well to gas pipeline discontinued. To maintain the operation, the well was periodically disconnected from gathering pipeline and water was removed using technological blowdowns carried out by well service operators.

The technology and equipment of plunger lift intended for efficient operation of wells with the tubing of 168 mm ($6^5/_8$") diameter are tested on Medvezhie field and on special test stand. This paper presents the results of the study of water influence on the operation mode of Senoman gas deposit wells and of the tests of plunger lift designed for the well equipped with the tubing of large diameters.

2. **GENERAL INFORMATION ON MEDVEZHIE GAS FIELD**

Medvezhie field, one of the largest in the world, has produced 1,700 bcm of gas already and is on the final stage of development [1, 2]. Medvezhie field is situated in the north of Tyumen Region of Russia. The dimensions of the deposit are: 116 km length, 26 km width, area of gas presence is 1993.3 sq km. Gas composition is 97.37% ÷ 99,68% of methane. Gas relative density is about 0.56 (re air). The temperature of gas in production formation is not evenly distributed and is within the range of 30-35°C. At present about 80% of initial gas resources have already been recovered.

Since the beginning of industrial operation (1972) the formation pressure has decreased to 2.5 ÷ 3.5 MPa. The pressure difference between the formation and well bottom (depression) does not exceed 0.3 ÷ 0.4 MPa. Through all these years the main volume of gas has been produced with the wells equipped with tubing pipes of large diameter, OD=168 mm ($6^5/_8$"). Since the beginning of declining gas production the gas output rates have decreased. In the number of wells, because of decreasing the gas flow in the tubing below critical one, the conditions arise of water accumulation in the bottom hole and the operation of the wells becomes impossible without removal of water.

To the wells of Senoman deposits, together with gas, the reservoir and condensation waters arrive. The mineralization of reservoir pressure water is 16.6 to 21.2 g/l and its chemical composition changes insignificantly in the field area. The reservoir temperature of water is 30 ÷ 37°C in various zones of the field.

Condensation water is the result of the condensation of water vapor dissolved in natural gas coming from the reservoir. The mineralization of condensation water is 0.05 to 1.0 g/l.

For practical evaluation of reservoirs water volumes the method is used based on the separation of reservoir water share in the sample, calculation of condensation water volume using the difference of water content in the system 'production reservoir-wellhead' and the volume of the gas produced by the well [3].

At the final stage of the field development the operation of the wells is complicated because of: water accumulated in the borehole at gas flows through the tubing not sufficient for water lifting to the wellhead; wetting of reservoir rock, disintegration of production reservoir; sand appearance in the bottom hole, formation of lengthy sand plug in the bottom hole.

The stable operation of the majority of Medvezhie filed wells (about 80%), including those equipped with OD=168 mm tubing, is maintained by means of keeping the pressure difference in the reservoir and gas-gathering pipeline such that the gas flow through the tubing is sufficient to effectively recover the water without using the special technologies. The number of wells where water can be removed in such a way is decreasing every year by 2-3% of total wells of the field.

In about 20% of the wells the water is removed by means of technological blowdowns (short-term increase of gas flow in the tubing for a time of water lifting from bottom hole to wellhead) with the use of foaming surfactants. During the periods between water recovery cycles, the wells of this group work with decreased gas production rates. The blowdowns of wells are carried out by operators servicing the wells. The reduction of period between blowdowns leads to increase of technological gas loss and increase of working time of operators. The number of wells which have to be blown, increases by 2-3% of total field wells every year.

To reduce the period of well operation with gas production rate decreased because of water accumulation, the plunger lift is proposed to use, which allows to effectively recover the water and can work in automated mode for long-term periods.

3. **TECHNOLOGY OF FLUID REMOVAL FROM GAS WELLS WITH PLUNGER LIFT**

Plunger lift is the conventional process of fluid lifting through tubing pipe with the help of gas and plunger.

The main arrangement of the set of plunger lift for gas wells is the plunger of "flying valve" type. Flying valve (plunger) consists of two independent, not joined mechanically, parts – tubular cylinder body and detachable element of, for instance, spherical form (ball) (Figure 2).

Figure 2 – Flying valve, LK168/140/120 model.

To recover the fluid the “flying” valve is placed into tubing pipe between bottom and top limiters of plunger moving, and then the well is put into operation. While the well is stopped, the ball (detachable element) and tubular body, separately, one by one, descend (due to own weight) to the bottom limiter which is to be earlier placed below the level of accumulating water in the well. On the bottom limiter, below the level of the fluid, body and ball join. Upon the putting of the well into operation the gas inflowing into the tubing, lifts the “flying” valve (body and ball) to the wellhead. For the operation of “flying” valve the volume of gas coming into the tubing should exceed the volume of gas passing through the annular gap around “flying” valve during its whole lifting cycle. The “flying” valve with the fluid ascends to the wellhead. At the end of its rise the “flying” valve reaches the top limiter of plunger movement. The ball thrusts into top limiter rod, stops for a moment and starts moving downward. The cylinder body, already without ball, keeps moving up under inertia until touching the well bumper, stops and then starts going down. Having thus separated on two elements not fastened together mechanically, the body and ball, under own weight, move down in upward gas flow. The cycles of running down and up repeat many times. The “flying” valve moves in the well in the mode of self-regulation of its velocity up and down depending on actual gas pressure and flow.

The plunger lift for water removal from the wells was introduced in the mid-1950s in the USA and is in operation up to now. The set of plunger lift contains the equipment mostly developed and intended for oil wells. Up to now the plunger lift has been used only for recovery of the fluid having entered the well in drop condition from the production reservoir and filling the physical volume of the borehole rather limited in height.

The designs of the plunger consisting of two independent parts not fastened together mechanically – tubular (cylinder) body and detachable element (ball) are given in the descriptions of inventions: US Patent No. 2001012 (1931) and USSR Inventors Certificate No. 63148 (1941). The described designs of plungers with the ball were proposed for using in oil wells. This approach for developing the plunger lift was considered as perspective one, and in 1963, in the USSR, the design of the plunger with the ball as well as the special equipment for gas wells (USSR Invention No. 171351) equipped with the tubing pipes of OD≤89 mm and less were developed. At present the designs are already developed of plungers able not to fail because of thrusts during the operation in gas wells including those equipped with tubings of large diameters [4].

4. **SPECIAL CONDITIONS OF WELLS OPERATION ON MEDVEZHIE FIELD**

The operation of the wells of Medvezhie field is accompanied with natural conditions essentially influencing on the technological mode of well operation at the final stage of field development:

- reverse filtration of water from the well to the reservoir,
- dynamical drying of gas by means of pressure reduction on the way from reservoir to the well (at gas pressures in reservoir conditions: P_r<5.0 MPa).

In the process of reverse filtration the arrival of water from reservoir to bottom hole and its outflow - reverse filtration to reservoir, take place simultaneously. Reverse filtration of the fluid to reservoir is typical for gas fields with well-permeable gas-bearing reservoirs having the thickness exceeding few tens of meters, for instance Senoman deposits in the area of Urengoy, Yamburg and Medvezhie fields.

The process mechanisms of reverse filtration are explained by the specialties of gas inflow to the well. The accumulation of water in physical volume of the pipes at levels exceeding 5-10 m leads to the increase of pressure in the bottom hole and causes the reverse filtration of the fluid from the well to the reservoir. The quantity of fluid overflowing to the reservoir depends on the height of water located in perforation interval of borehole. During well shutdowns the filtration of water from the well to reservoir increases. In certain conditions, when gas recovery out of well is stopped, the water can entirely escape to reservoir.

The effect of dynamical drying of gas is stipulated by natural properties of gas at pressures less than 5.0 MPa:

1) absorbing more water vapor at less pressures than at big overpressures;
2) gas cooling during its filtration, movement through the reservoir and through perforation holes in reservoir near-bottomhole zone;
3) heat transfer from the rock of production reservoir to the gas.

In near- bottomhole zone of production reservoir the pressure of gas decreases but the temperature is kept up by heat transfer from surrounding rocks, the gas is not saturated with water vapor i.e. becomes dry. The natural process takes place called dynamical drying of gas. It is found that after the decrease of pressure in the reservoir to 5.0 MPa, and further on to less than 5.0 MPa until the end of field development, the dry gas, unsaturated with water vapor, comes from the reservoir to Senoman wells. The results of calculation of gas relative humidity change (in the well bottomhole) at various reservoir pressures and operational depressions to reservoir are given on the graph (Figure 3).

The results of calculation are in good compliance with temperature measurements in the well No. 623 (Figure 4) during the operation with production rate of 150 mcm/day and in 6 hours after temperature stabilization. Water vapor contained in gas, condensates to drop moisture because of gas temperature decrease in the tubing when gas flows up from the top of reservoir to the wellhead.

Thermal-gasodynamical computations and the analysis of group chemical composition of the waters produced from the well showed that the water comes to the majority of wells (about 70%) of Medvezhie field from the production reservoir (together with gas) and is in vapor state of condensation type. The flow of gas and water vapor in the well cools down from 32°C (bottom hole) to 10-15°C (wellhead), the vapor condensates in the form of drops on inner surface of tubing, water drops trickle down along tubing inner surface to bottom hole. The less is the distance along the tubing to the wellhead, the more intensive is the cooling of gas-water vapor flow and the more water escapes from this flow. Maximal volume of water condensing in the wells from every 1000 m3 of gas on Medvezhie field does not exceed 1.5-2.0 liters, and total water volume to be recovered to ensure continuous well operation will not be more than 300 liters per day, accordingly the expected number of plunger cycles per day will be 100 ÷ 120.

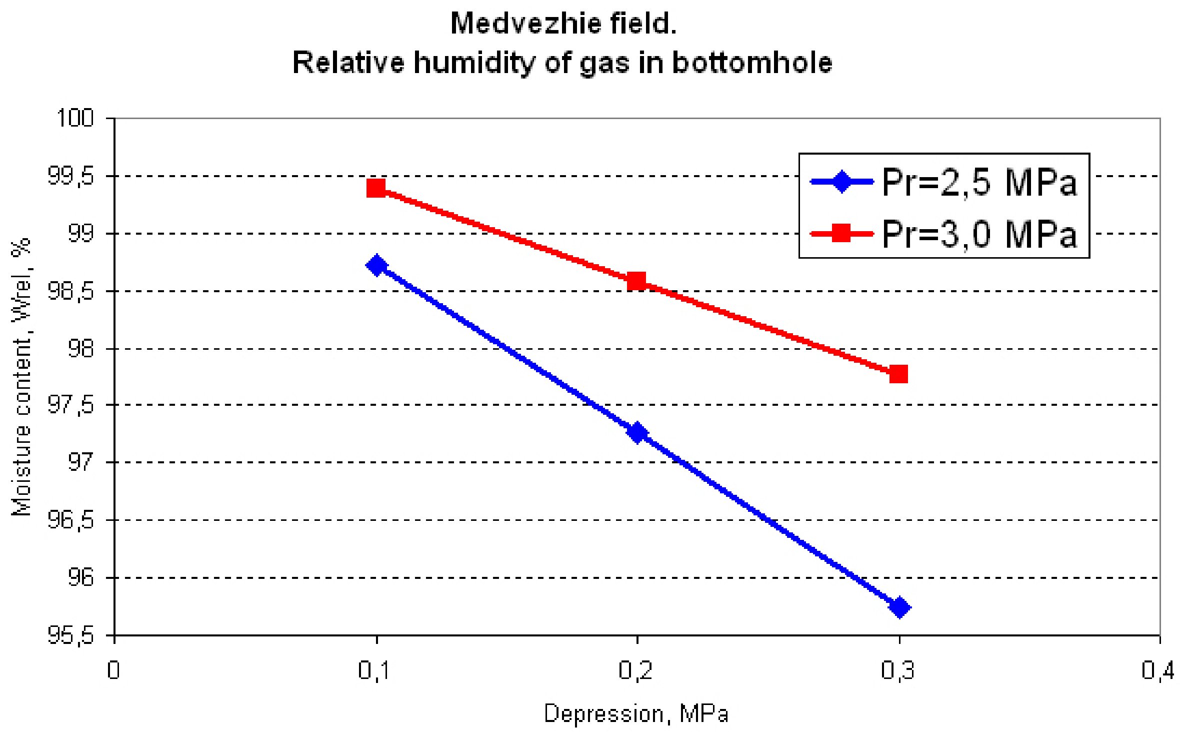

Figure 3 – Results of calculation of relative moisture content in bottomhole

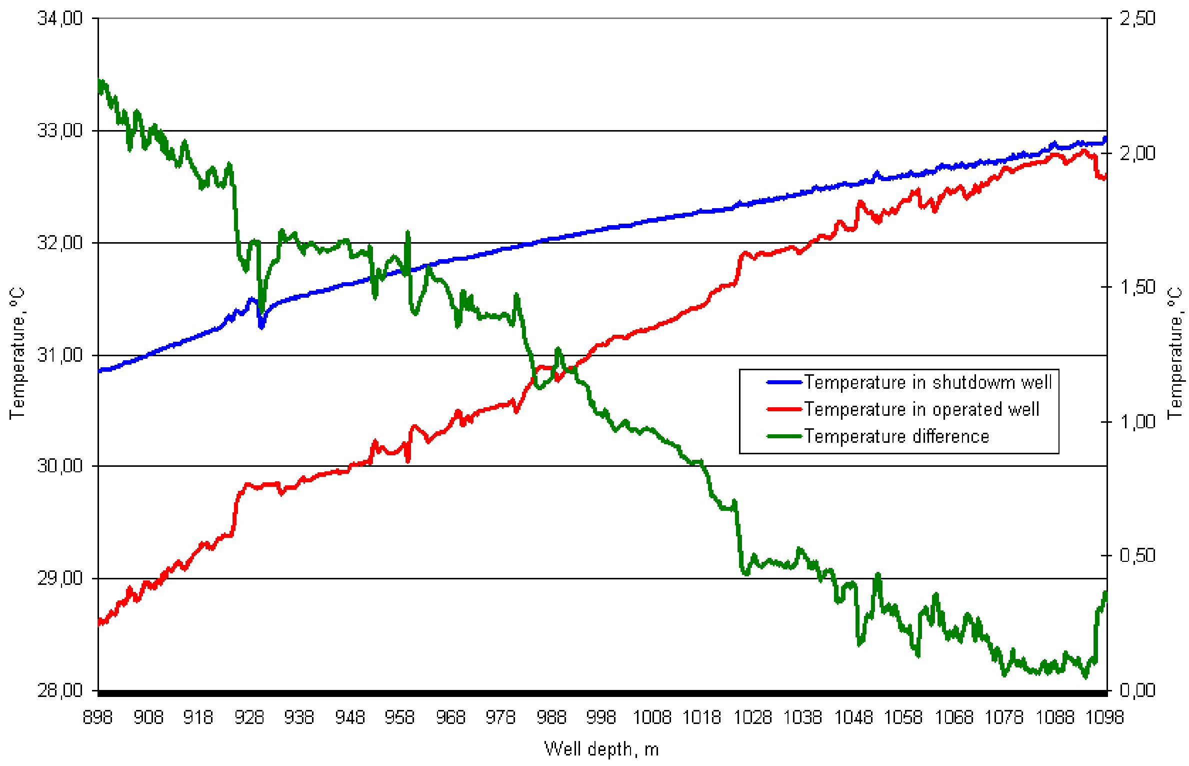

Figure 4 – Results of gas temperature measurement in the well No. 623

It is expected that when using plunger lift, the water will be removed from tubing pipes, will not reach the bottom hole nor permeate to the reservoir, and will not lessen the strength of rock of production reservoir. The well will be in operation with dry bottom hole. In the result the sand production from the reservoir to bottom hole will decrease. Finally, it is supposed that the influence of sand appearance on production capabilities of Senoman wells will be partially abated.

5. SPECIAL CONDITIONS OF APPLICATION OF PLUNGER LIFT ON MEDVEZHIE FIELD WELLS

For the first time in world practice of gas field development the plunger lift is supposed for operation in the wells with large diameter tubing (Medvezhie field) for:

1) elimination of conditions favoring to water accumulation in the form of fluid column causing additional hydraulic resistance to gas movement and limiting gas production of the well - by means of creating, with the help of plunger, the conditions of changing the downward direction of water film movement to upward one in the interval of tubing pipe where the condensation is most intensive;

2) increase of service life of the wells with tubing pipes of OD=168 mm ($6^5/_8$") without carrying out the blowdowns and/or replacing the tubing (with less OD), for 5 to 8 years.

In the wells of Medvezhie field the plunger lift will be used with the new purpose - **for the prevention of trickling water condensed because of temperature decrease of gas on its moving from production reservoir to wellhead.**

6. THE OBJECT FOR 168 MM PLUNGER LIFT TEST: GAS WELL NO. 623 OF MEDVEZHIE FIELD

Well No. 623 was put in operation in 1976. The production reservoir in the well is perforated in the interval of 1082-1104 m. The diameter of tubing is OD=168 mm. Tubing running depth is -1084.8 m. Packer is installed at 927-932 m. Borehole vertical deviation does not exceed 1°30'.

Up to now 4,515,985 mcm of gas has been recovered from this well. At the beginning of operation gas production rates were 1,000 mcm/day to 1,850 mcm/day. With production rate over 150 mcm/day the well was in operation until 2003. To intensify gas inflow the surfactants were injected to the well in 1988, 1991, 1996, 1997, 1998, 1999, 2000, 2001, 2002. Since 2003 the water started accumulating in the well periodically and had to be removed. In 2003 the well had blowdowns every 15 days, since 2004 the blowdowns are carried out every 7 days. Upon the removal of water the production rate increases to 150 mcm/day, then during 3-5 days it decreases to 100 mcm/day, and already after 8 days the well stops spontaneously. Gas temperature at well head increases to 12°C whereas before blowdown it decreases to 6°C. It is expected that with using the plunger lift the well No. 623 will be working stably with gas rate of about 150 mcm/day and gas temperature at the wellhead of about 10-12°C.

The technical condition of the well No. 623 meets the main requirement: the dimensions of X-tree (ID=150 mm) and tubing equipment (OD=168 mm) do not bring any limitations to the application of plunger of flying valve type (D=168 mm) in this well. Additional works for dismantling the equipment and shutting the well were not needed.

As additional equipment the bottom limiter of plunger movement was lowered into the well whereas top limiter of plunger movement was installed at wellhead (Figure 1).

To specify the information, the thermo-gas-dynamical studies were carried out on the well using geophysical technologies: the temperature was measured in borehole and production reservoir zone in working and stopped well, and also using SKM micro-caliper the inner diameter of the pass was measured along the whole length of the tubing and X-tree.

Micro-caliper measurements showed some narrow spots in pipes and assemblies located above the packer. Results of measurement are given on the graph (Figure 5).

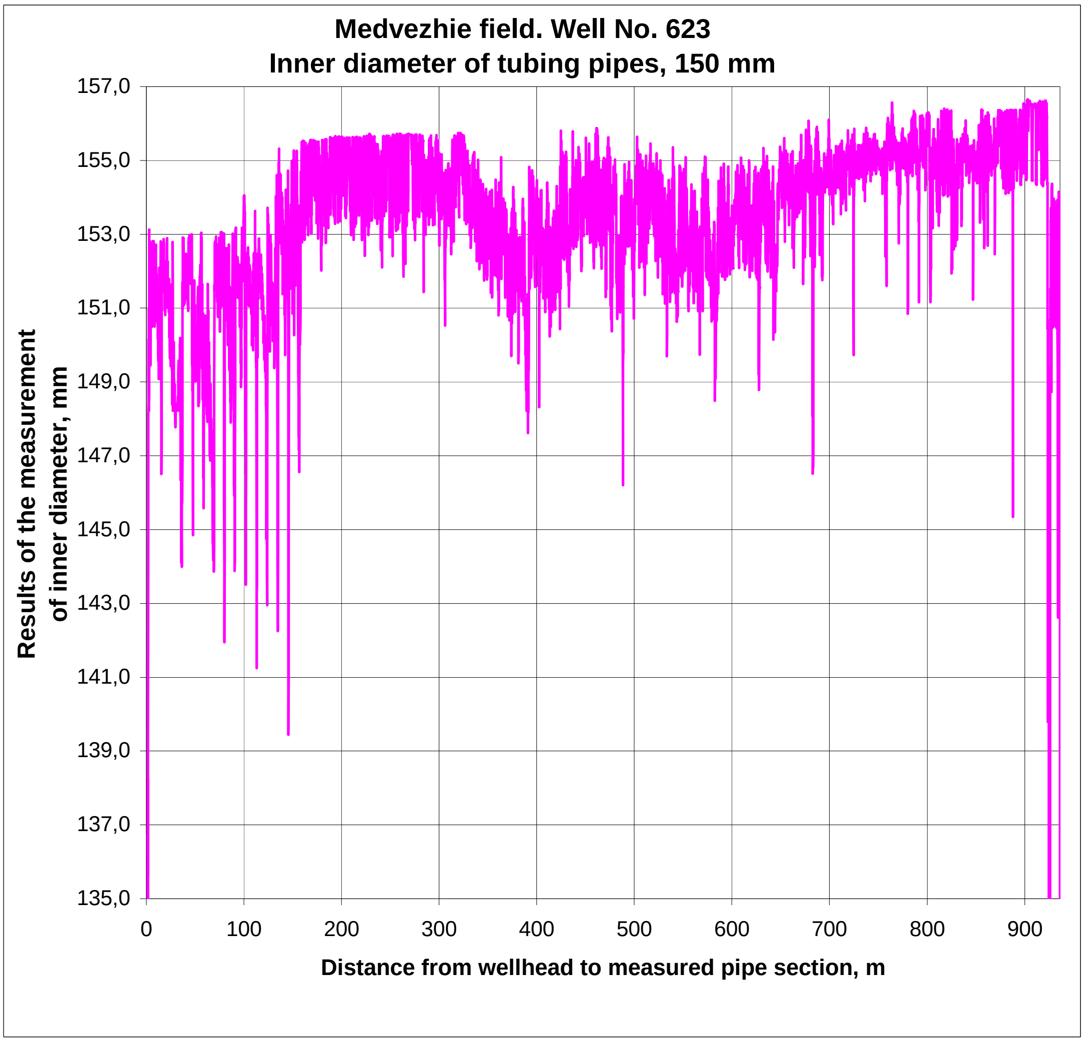

Figure 5 - The results of the measurement of tubing inner diameter with micro-caliper in the well No. 623

In the interval of 923.0-924.0 m, in the zone of circulation valve body placement, the diameter of narrowing was 133.5 mm, and on the depth of 925.1 m the narrow spots of 54.78 mm were measured.

To specify the results obtained with micro-caliper, the gage of cylinder form was run into the well; gage had the outer diameter of 147±0.2 mm, length of 300 mm, weight of 30 kg. Gage descending was made with the velocity of 0.1÷0.15 m/s. During descending from wellhead to the depth 160 m the gage stopped every 10-12 m and had to be pulled up by 5-7 meters and then, being sent down with increased velocity of 1÷2 m/s, the gage could pass the narrow spot in the tubing. In the interval of 160-923 m i.e. until the body of circulation valve the gage went down without apparent delays. The gage stopped after reaching the circulation valve body at the depth of 923 m. A boss inside the tubing made by circulation valve body at the depth of 923 m was used as the support for bottom limiter of plunger movement.

The study of conditions of gage passing through the narrow spots of tubing pipe marked by with micro-caliper allows to suppose that the decrease of tubing pipe diameter is not caused by the deformation of pipe metal but by the accumulation of mechanical impurities of non-metal origin, for instance: excessive grease of pipe thread connections, clay, cement, sand and solid components of surfactant solutions injected to the well to foam the water before its removal from the well.

The double-part plunger of "flying valve" type is used in the set of equipment tested in the well No. 623, and one or both parts of the plunger are made of elastic material - the rubber resistant to thrust loads from rigid limiters of movement and not decreasing the external dimensions in the process of contacting the inner surface of pipes. The results of testing the plungers designed for well tubing of OD=168 mm ($6^5/_8$") are successful. After few thousand cycles any failures in plunger operation because of downhole equipment destruction were not noted.

7. **TEST OF PLUNGER LIFT EQUIPMENT ON EXPERIMENTAL STAND**

Traditionally the known plunger lift for water removal is used, up to now, in the gas wells with the tubing of diameters less than ID=89 mm ($3^1/_2$"), mostly in the tubing of $2^3/_8$", $2^7/_8$" diameter. It is explained by the lack of equipment able to stand without damage the plunger knocks on top and bottom limiters for a long time.

Mechanical damage of well equipment by the plunger is the main obstacle preventing wide use of plunger lift in gas wells. Therefore the main requirement to the plungers for the tubing pipes of large diameters (OD≥114 mm) is the mechanical fastness to frequent thrusts of the plunger. Plunger lift equipment of 168 mm diameter intended for the application in the wells was tested in special unit in the conditions equal to well conditions, and the number of thrusts that the plunger and limiters have stood during testing exceeded 150,000 cycles.

To test the equipment of plunger lift set a special unit was built using the parts of X-tree (ID=150 mm): cross tees, gates, elbow branches. For experimental tubing the pipe was used of D=168 mm ($6^5/_8$") with inner diameter of 154 mm (6") and length of 3 m. The plunger movement limiters were installed in cross tees in the ends of tubing pipe. Total height of this stand is 5 m. Gas (methane) is supplied to experimental tubing at pressure of 2.0-2.7 MPa during operation. Flow rate and pressure of gas required for tests are regulated by flow nipples at the input and output of the stand. Gas flow measurement is made by orifice flowmeters installed in gas input and output pipes. For measuring the pressure in experimental tubing and the parameters of plunger operation (velocity of flying valve lifting and velocity of tubular body and ball falling) the highly sensitive pressure transducer of MTU-04 type (producer: NPP Grant, City of Ufa) and the digital dictaphone (Cenix VR-P2340) were used. In real time mode, once in 0.01 sec, were recorded the pressure and acoustic noises of flying valve thrusts to the top limiter of plunger movement and of ball and tubular body to bottom limiter of plunger movement. The sample of measurement results of flying valve parameters during its operation in test stand are given in the graph (Figure 6).

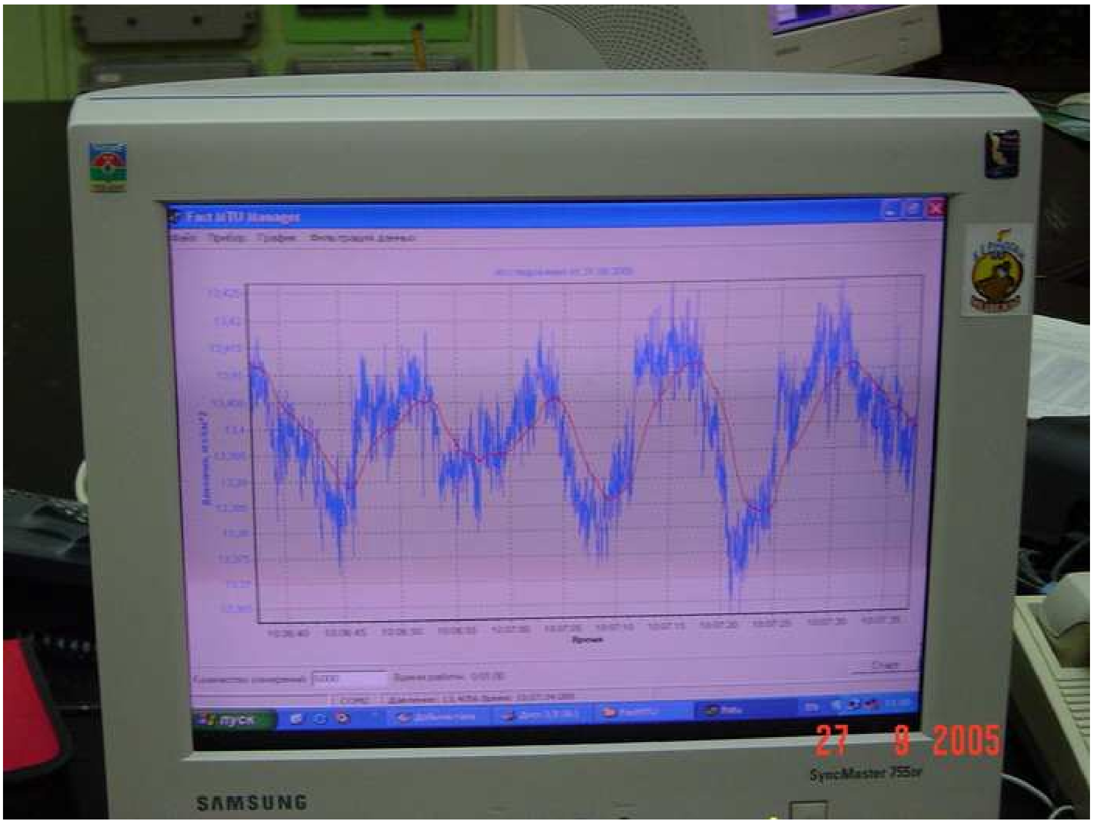

Figure 6 - Measured parameters of LK168/145/120 flying valve operation
in the test stand during 60 sec

Basing on the results of measuring the pressure and flow of the gas, time intervals between thrusts of flying valve and its parts to movement limiters, the main hydrodynamic characteristics of plunger are calculated as well as gas leaks occurring:

during plunger movement upward - through annular gaps between tubing pipe and tubular body and between tubular body and the ball;

during plunger parts movement downward - through annular gap between tubing pipe and the ball, totally through inner channel of tubular body and through annular gap between tubing pipe and tubular body.

The following were tested in the experimental stand:

- X-tree solution of wellhead, top and bottom limiters of plunger movement;
- flying valves with outer diameter of 140÷150 mm of tubular body and balls of 100mm and 120 mm diameters having various weights in the range of 1.35 to 3.6 kg;
- upper and lower bounds of plunger lift stable operation were defined.

8. CONCLUSION

After finishing the tests on Medvezhie field the plunger lift will be used for the removal of very small volumes of fluid (about 5-10 liters per cycle of lifting) from the wells equipped with the tubing of OD=168 mm ($6^5/_8$"). The technology and equipment of plunger lift will find the application in the wells equipped with the tubing pipes of large diameter on the various fields producing the main volume of natural gas in Russia.

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10. **LIST OF FIGURES**

Figure 1 - Wellhead of the well No. 623 of Medvezhie field. The year of 2006

Figure 2 - Flying valve, LK168/140/120 model

Figure 3 - Results of calculation of relative moisture content in bottomhole

Figure 4 - Results of temperature measurement in the well No. 623

Figure 5 - The results of the measurement of tubing inner diameter with micro-caliper in the well No. 623

Figure 6 - Measured parameters of LK168/145/120 flying valve operation in the test stand during 60 sec