NEW MATERIALS AND METHODS OF INSULATION REPAIR WORKS IN GAS WELLS ON URENGOY FIELD

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Keywords: 1. wells, 2. water influx, 3. insulation repair works

One of the main sources of natural gas production in Russia in the short-term and long-term stay Cenomanian and Neokomian deposits of Urengoy oil, gas, condensate field (UNGKK).

The relevance of development of new materials and methods of repair and insulation works for the gas wells on the fields of public joint stock company (OAO) Gazprom is due to the fact that «... the current base fields are largely depleted - they reached gas recovery factor of 60-80%».

Thus development of Cenomanian formations of Big Urengoy (MBU), which are under long-term development (from 20 to 30 years) (Urengoy and Yen-Yakha fields, West dome of Severo-Urengoy field) is accompanied by a currently active occurrence of water drive, and the work of wells is complicated by flooding wells with condensing and reservoir water, by destruction of the bottom-hole formation zone (PZP).

Heterogeneity of permeability and porosity (FES) of productive horizons, a significant decline in the initial formation pressure (up to 4 times), the rise of gas-water contact (GVK), flooding and destruction of PZP with the building of fluidized and sand plugs in lifts are the main determinants of the decline and stop the flow of wells.

To ensure reliable and sustained recovery of the required design quality and the introduction of modern methods of repair and insulation work (RIR) to eliminate and restrict water inflow into the well.

«The last three decades of gas production in Russia was maintained thanks to the base fields - Medvezhye, Urengoy and Yamburg, which are largely depleted and entered into the stage of production decline. The annual decrease of gas on them is 20 ÷ 25 mlrd.m3.

Relevant to these fields is the problem of further development optimization in order to save reservoir energy for the extension of «life» of the deposits and to increase the rate of gas extraction».

The problem of improving the efficiency of repair and insulation work is relevant to many natural gas, gas condensate and oil fields in Russia, because they are at the final stage of development, characterized by the decline of reservoir pressure and strong water influx in productive strata.

Cenomanian gas deposit of Big Urengoy was commissioned on 22 April 1978.

At present the following objects are in operation: Urengoy field with Tab-Yakha area, Yen-Yakha and Pestsovaya deposits of Urengoy field and Severo-Urengoy field.

The productive horizons are confined to the upper part of the Upper Cretaceous deposits of Pokurskoe suite at depths of 1030÷1260 with thickness of up to 230 m.

The deposit is a roof, submassive and bottom water-drive reservoir.

Technological solutions are designed with the high primary production characteristics of wells in view (flow rate up to 2 million m3/day) with large diameter tubing strings (168 mm).

From the beginning of MBU development estimate 01.01.2009 approximately 6.0 trln m^3 gas was produced. At that the current gas recovery factor (KIG) for objects varies in a wide range because of their input into the development at different time periods: from 12.1% to Pestsovoy area to 78.3% of Urengoy and reservoir pressure - from 23.1 to 110.5 atm.

Average formation pressure decline and GVK rise values from the beginning of the MBU development to the present time are:

- for Urengoy field – formation pressure decline to 9,4 MPa, GVK rise to 31 m;
- for Yen_Yakha area – 8,2 MPa and 14 m;
- for Severo-Urengoy field – 8,5 MPa and 28 m respectively.

As the top layer of GVK rises in stratum it comes to the lower holes perforation interval.

Formation water enters the well, leading to its unstable work and fluid accumulates in the bottomhole and in tubing.

Under the influence of the water column the productive perforation interval decreases and changing PZP stress condition, resulting in the destruction of rock collectors with the formation of fluidized sand and jams at the forehead and the reduction of FES in this zone, that in the end leads to a reduction of productive performance of wells.

As a result of lower initial reservoir pressure occurs a significant increase in the pressure gradient between the gas and parts of the aquifer, resulting at present intense water influx in the gas reservoir of the Cenomanian deposits. This process is at the stage of production decline occurs more intensively.

Total volume of water from wells at all Cenomanian complex gas treatment plants (UKPG), is currently 150-170 thousand m^3 per year. At that, the specific volume of water supplied to UKPG, increased by an order of magnitude since the early development of the deposit.

Watering gas wells leads to the following complications:

• First, the destruction of PZP stratum, causing water and sand influx and complicating the work of the producing wells.

• Secondly, the flow of water in gas wells causes self-squeezing (flooding) of wells, and it ceases to produce gas.

• Finally, because of the wells watering, (taking into account the first two reasons) reserves on the operation objects are drained uneven-numbered.

In practice, the above-listed processes occur together and at the same time.

Uneven reserves drainage caused by the wells watering on operation objects leads to a ‘jam’ of about 30% of recoverable gas reserves. This raises the problem of low-pressure gas production.

At the early stage of flooding such technologies of waterproofing were applied as creation of hydrophobic emulsion screens in a productive part of the reservoir, artificial calmatation of water-saturated pore space, installation of cement bridges, pre-injection of various waterproofing materials with the installation of cement bridges, etc.

These technologies have been adapted to the geological and technical conditions for the initial development phase of the field.

With the decline of reservoir pressure and enhanced intrusion of reservoir water in the gas bearing part of the formation the efficiency of these technologies has declined.

In 1993÷2008 the average wells debit reduced in 3,8 times, while the initial formation pressure declined 2,4 fold, i.e. wells debit reduction as a result of water influx is faster than the initial formation pressure decline rate.

This is due to wells watering and a decrease in the effective thickness of the perforation interval as a result of its partial overlapping by the fluid column.

Reduced operating wells stock as a result of water and sand influx leads to breach of deposits development and equity of gas reserves on operation objects, i.e. to reduction of the ultimate gas recovery factor.

The increase in the total number of wells with water and sand influx until 2000 reflects the period of production rise while maintaining the energy potential of hydrocarbon deposits (HC) at a high level at which a significant speed in tubing (NKT) allows for carrying over the sand and water.

Since 2000, the decline in the number of wells with water and sand influx was due to effective geological and technical measures (GTM) carried out, which included limiting the flow rate of wells, optimization of operation modes, repair and insulation works.

Analysis of the repairs results of the gas wells on Cenomanian deposit of MBU indicates that, despite the objective factors of the geological and technical conditions deterioration, as a result of improved technology overhaul wells (KRS), more reasonable selection of candidate wells for specific technologies and improving of repair work production organization, their effectiveness has a positive tendency of growth in the whole period revised.

Wells watering is caused natural reasons related to the decline of reservoir pressure and the GVK rise, both for technical reasons - because of the annulus cement stone leakage.

Analysis of the causes watering gas wells has shown that one of the defining reasons is the quality of casing cementing.

The combination of these reasons led to a decline in 1996 of gas output at more than 5.0 billion m^3 of Urengoy area and more than 1.0 billion m^3 of Yen-Yakha area of Urengoy field.

The poor quality of cementing leads to cross flows and premature wells watering.

Industrial research found that during operation cement stone is saturated with the formation water and hydration of silicate phases occurs (lime in cement slurry). This leads over time to enhanced microporosity of cementing and increases its permeability, which is its natural ‘aging’.

Because of a significant decline of reservoir pressure, GVK rise, poor quality of cementing of combined casing columns and reduction of net gas thickness, the number of idle wells stock is growing, which makes the reaching of projected and planed gas production targets difficult.

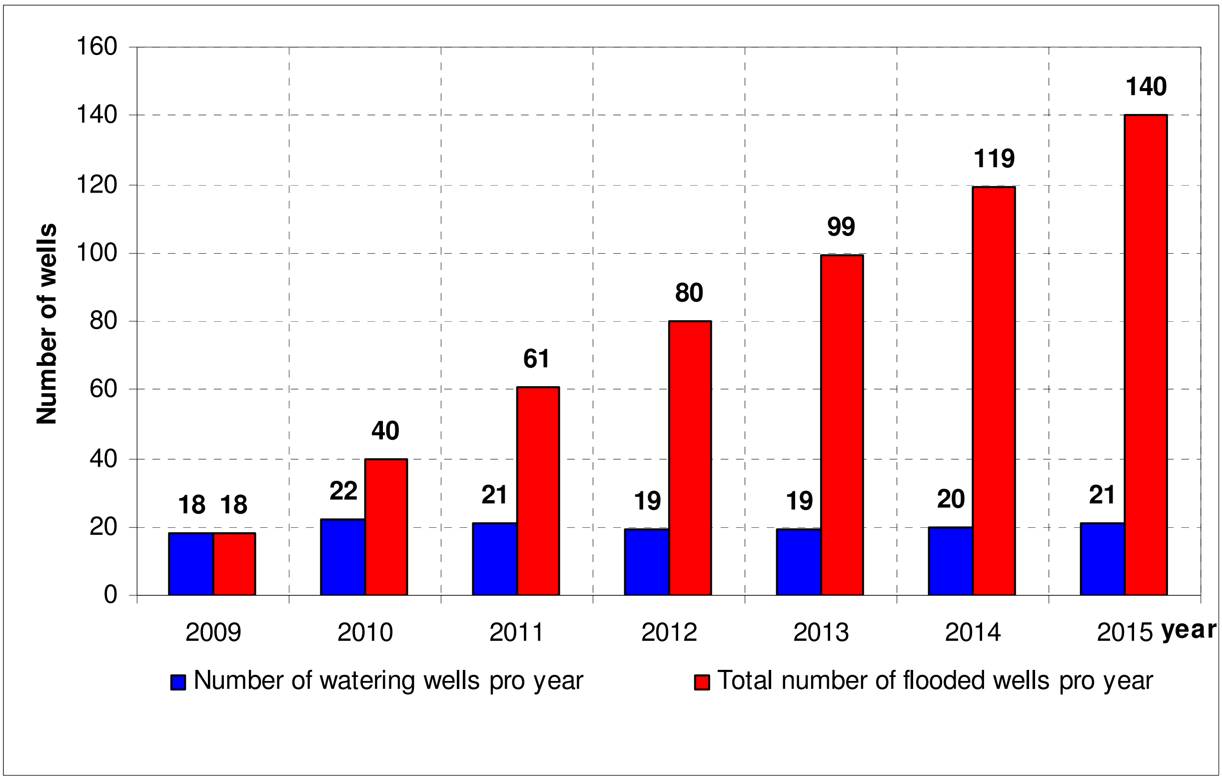

Рис. 1 – Forecast of watering holes resulting from GVK rise and its overall quantity in 2009÷2015

Fig. 1 presents the results of predictive calculations of wells watering for Cenomanian deposits of MBU in the light of the overall GVK rise (calculations on the three-dimensional models of deposits), the technical condition of wells (results of the geophysical monitoring of holes watering, depending on the tightness of annulus cement stone) and the history of their operation (the dynamics of production characteristics, technological regimes, repairs).

Projected estimates indicate that the annual watering is expected as a result of GVK rise in about 20 wells, with the total for the period 2009 ÷ 2015 without conducting of RIR may reach 140 units.

New RIR technologies and materials were developed for the period of production decline, with a view of geological and technical condition of wells, causes and nature of reservoir water influx.

Main geological and technical processes at the current stage of development of the Cenomanian deposits, leading to watering of operating gas wells stock in UNGKK are shown in Fig. 2-4.

Fig. 2 – annulus reservoir water influx from the deeper lying water-bearing horizons

Water influx through annulus into well (Fig. 2). The poor quality of cement stone after cementing of production casing is over and its leakages during operation of wells with a decrease of formation pressure leads to the building of channels through which the water flows into wells.

Coning (Fig. 3) occurs in wells where the speed of GVK rise - as a result of intensive gas production – is faster than the rise in the whole reservoir.

GVK rise (Fig. 4) in the process of development of deposits of the type of waterfowl, with a significant decline in reservoir pressure leads to the influx of reservoir water in the perforation interval.

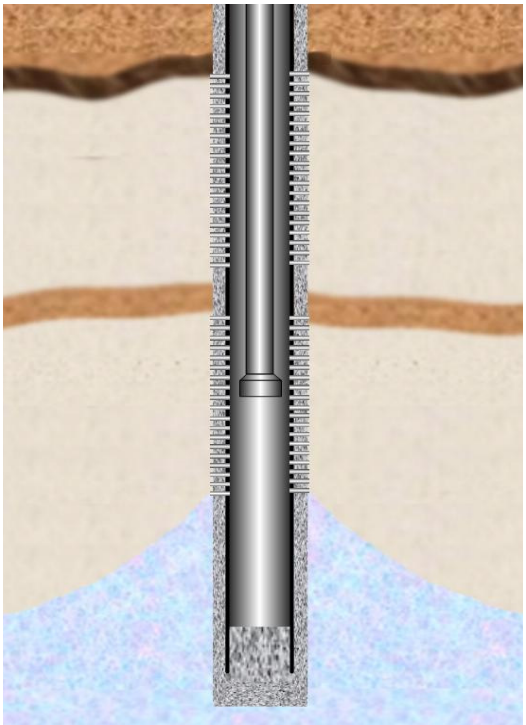

Fig. 3 – Depression socket build-up in the process of operation (intense coning)

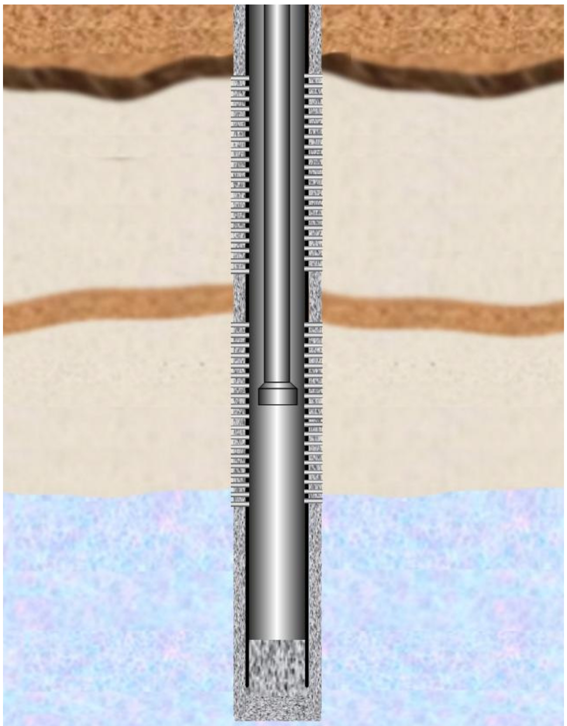

Fig. 4 – Gas-water contact level rise

Analysis of previous works to eliminate water inflow into gas wells of MBU showed that, depending on the nature and extent of water inflow in the following RIR technologies were applied:

• to limit the water influx in the initial stages of water inflow - a way to isolate the water inflow, which is based in the light of changes in the reservoir phase permeability for water and gas, creation of hydrophobic emulsion screen. Water-proofing technology carried on thus injection of gas wells with a design speed of first surface-active substances (PAV) - modifiers, followed by liquid hydrocarbons with the addition of PAV emulsifiers. To ensure the delivery of chemical reagents, rate of delivery of fluids to determine the treatment downloaded settings in which the pressure in the wellbore zatrubnom space remained the same hydrostatic;

• to limit water inflow into the well, due to the rise of local cone GVK and delivery of water to out-of-tubing space due to defects in cementing - methods interpore sedimentation. The methods include the alternating injection into a well of water solutions of mineral salts in the lower interval to create a watertight screens;

• installation of cement bridges in the interval of water influx to exclude the part of the productive reservoir.

Fig. 5 schematically depicts the process of limiting water inflow into a well with cement bridge in place.

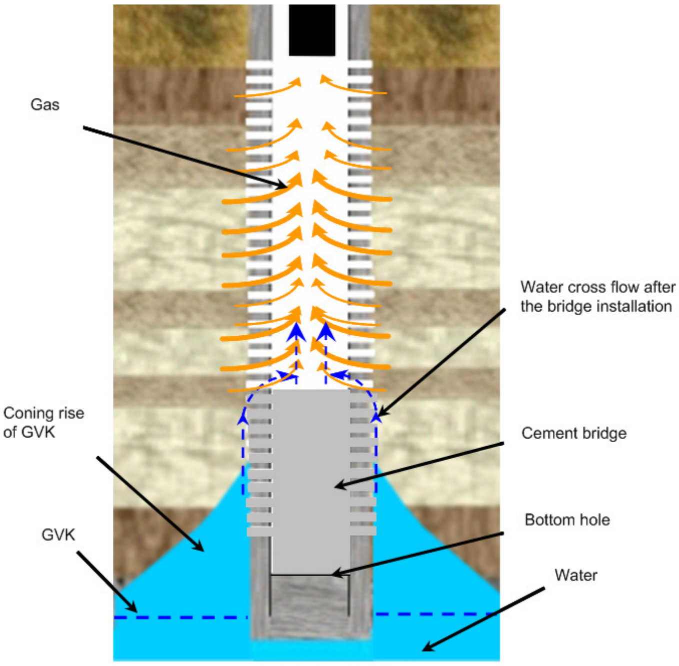

Fig. 5 - RIR works in the well removing water influx caused by a cone rise of GVK while creating a cement bridge

After water-proofing of a well with a cement bridge, with time water influx re-appeared because annulus flow because of the loose contact of cement with a rock. This is due to filtration of a fluid part tempering in the cement in the permeable intervals during the cement hardening waiting period (OSZ) during the installation of bridges and subsequent shrink of the formed cement stone.

To limit the influx of reservoir water in the well, combined usage of a cement bridge installation technology started in 1995 with the technology of waterproof screens creation while injecting various waterproof materials.

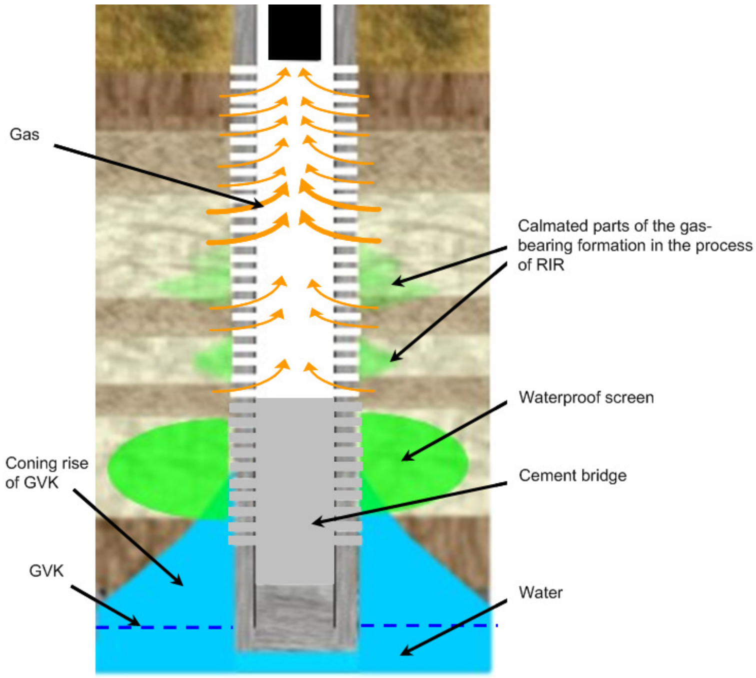

Fig.6. – RIR works in the well, removing water influx created by the GVK rise by a cement bridge installation with preliminary creation of water tight screen

Such reagents as AKORA A-Plast, liquid sodium glass, etc. were used as materials, which was injected into the portion of the reservoir flooded before the installation of cement bridge. With this technology water tight materials also entered into gas-saturated portion of the reservoir and blocked the pore space (Fig. 6).

Works to reduce water inflow into the gas wells on Urengoy fields until 2003 were carried out by the above-mentioned technologies. These technologies did not provide selective isolation of flooded intervals, reduced the thickness of productive layers, which reduced the production wells flow rate, and as a result led to a decrease in gas production on the fields.

Complicated geological and technical conditions (a significant decline in reservoir pressure, GVK rise) demanded new materials and new technologies, allowing selectively create waterproof screens directly in the formation part with water influx while retaining properm properties of the gas bearing deposit.

For low-pressure formations and different stages of wells watering of Cenomanian deposit of UNGKK, based on the experimental field and laboratory studies conducted for in Gazprom dobycha Urengoy, new materials and RIR methods have been developed and tested.

Analysis of development and operation of oil, gas and gas condensate fields in Russia (and former USSR) has shown that the basic materials used for repair and insulation works are divided into the following 3 groups:

- injection of polymeric organic chemicals (polyacrylamide, hydrolyzed polyacrylonitrile, etc.) into the formation;
- injection of inorganic water tight materials (inorganic salts, their solutions, magnesium, liquid glass, etc.) into the formation;
- methods based on injection of organoelement compounds (silicon-organic compounds, etc.).

On the basis of the analysis, as the main product for the repair and insulation of gas wells sodium naphthenate ('mylonaft') was selected.

Sodium naphthenate - technical product - a dark-colored paste material, which is hydrolytic resistant, it is obtained as the result of interaction of naphthenic acids with aqueous solution of NaOH.

Naphthenate soap with the dissolved in the reservoir water electrolyte builds practically non-permeable to water screen.

This property of naphthenate soap is used to prevent and isolate water influx in the wellbore.

Sodium naphthenate may be stored in a dehydrated state and connect with chemicals before injection into the formation. A solution of sodium naphthenate in a mixture with other chemical reagents is called NMN-400, is certified in System of certification of fuel and energy complex, corresponds TU, has a toxicology passport GSEN. According to GOST 12.1.007-76 belongs to IV danger class - «low-hazard agent».

Aqueous solutions of NMN-400 have surface-active properties, detergent action and good emulsifying ability, when in contact with the electrolyte (calcium chloride, magnesium chloride) form a large, durable, waterproof sediment.

For selection of new materials based on the NMN-400 and the choice of selective RIR methods, a set of laboratory studies was conducted.

As a result of these studies was found that:

- The optimum concentration at which the apparent maximum insulating properties of the material is generated by the interaction of fluids NMN-400 with 20% of chloride salt in volume ratio 3:2
- The maximum reduction in permeability models for reservoir water (98%) with creation of water tight screen is achieved with a cyclic injection solutions (NMN-400 and chloride salt)
- Water tight screen is mobile with an increase in differential pressure

In order to eliminate the displacement generated by the water-tight material from pore environment of Cenomanian reservoir the screen must be strengthened by a cement bridge.

Based on the results of laboratory studies technological schemes of carrying out RIR in field conditions were developed.

Fig. 7 shows the volume and the successful rate of new materials and developed water-tightening methods introduction in 2003 ÷ 2008.

152-well operations were carried out by this technology in the idle gas wells on UNGKM.

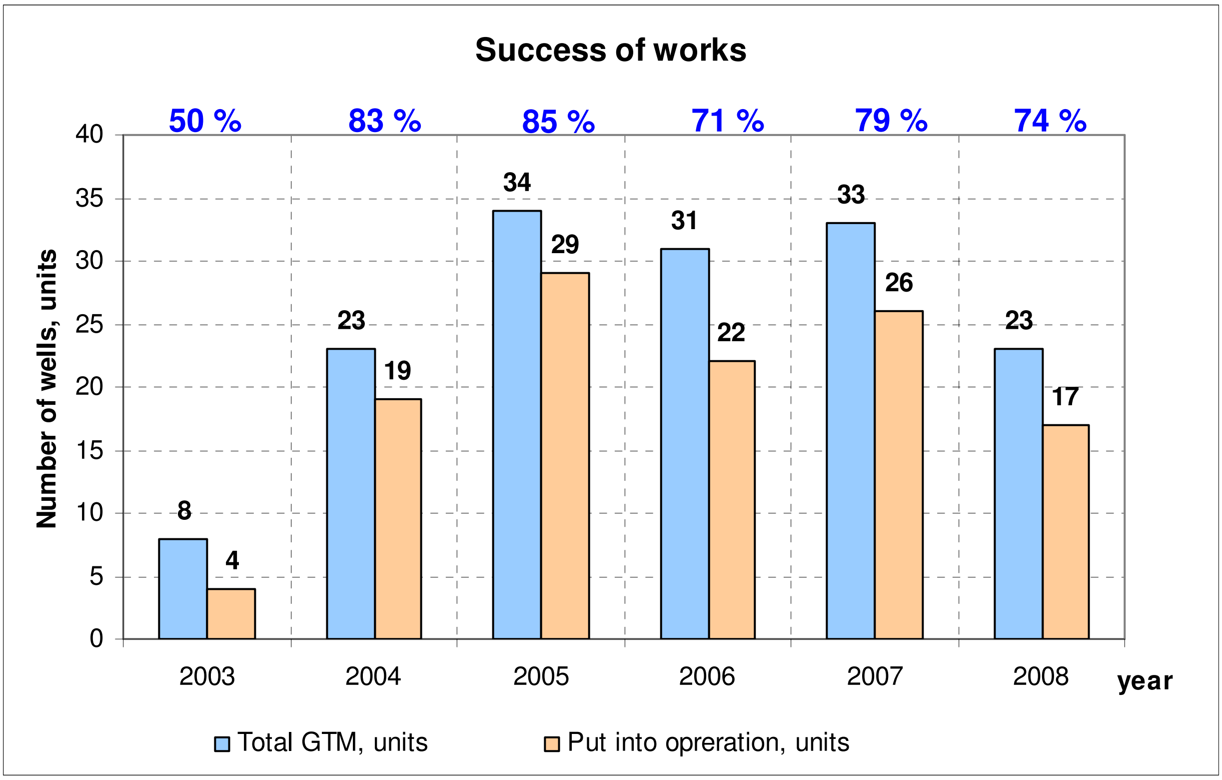

Fig. 7 - The scale and effectiveness of the new materials and developed RIR technology introduction 2003 ÷ 2008.

Duration of the effect after RIR made up more than three years.

New materials and RIR methods implementation scale in Cenomanian gas wells is shown in Fig. 8.

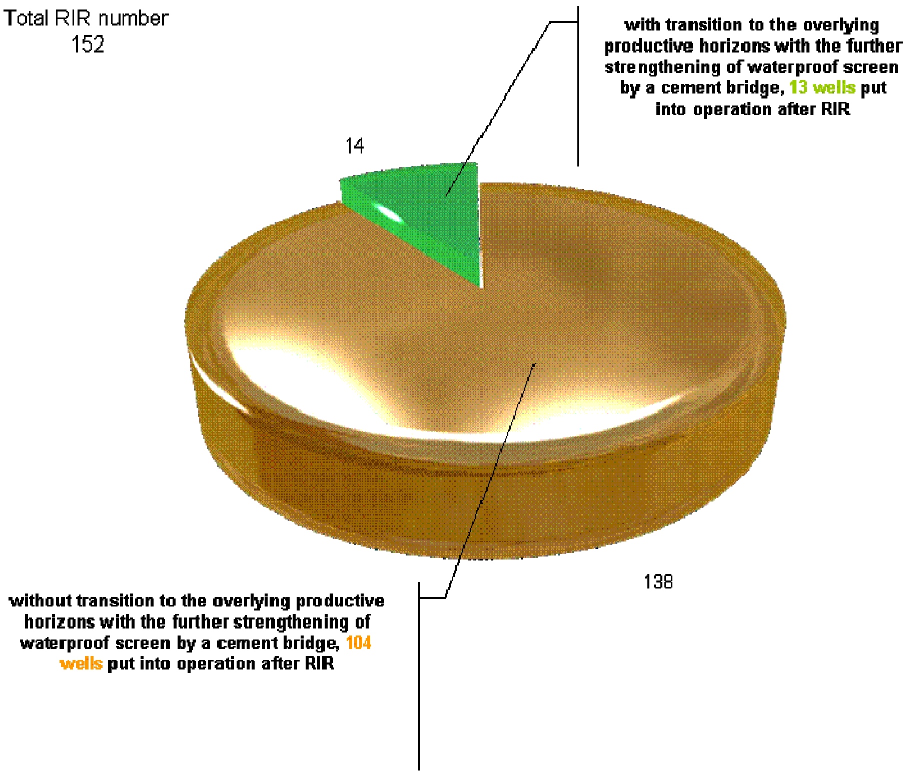

Fig. 8 – New RIR method implementation scale in gas wells in 2003-2008

In summary, it can be noted that the Gazprom dobycha Urengoy LLC has developed new watertight materials and selective RIR methods for the elimination of water reservoir influx in gas wells at the current stage of development of the Cenomanian deposits of Urengoy oil, gas and condensate field.

Protocols of meetings of scientific and technical councils (NTS) recommend the new developed materials and methods of repair and insulation for use in the repair of wells in gas fields of OAO Gazprom.

The results of the work performed allows the following conclusions.

1. Developed and introduced new materials and methods of repair and insulation work allow for putting into operation Cenomanian inactive gas wells and to ensure the planned levels of gas production of Gazprom dobycha Urengoy LLC

2. The work was carried out under the Programs for capital repair of wells on fields of OAO Gazprom for 2001÷2005 and 2006÷2010, Further development project of Cenomanian layer of Big Urengoy (Urengoy, Yen-Yakha, Pestsovaya areas of Urengoy field and Severo-Urengoy field)

3. Authors developed new materials and methods of repair and insulation works, which are introduced in 152 operating gas wells on Big Urengoy fields

After the RIR applied 117 idle wells were returned to the operation mode with the success rate about 80%.

The main advantage of the RIR technology over the previously applied is that you can selectively create a watertight screens directly in the formation part with water influx while retaining properm properties of the gas bearing deposit.

In addition, technologies to reduce water inflow into the well developed by Gazprom dobycha Urengoy LLC, have a relatively low cost, increase the environmental safety of works and are based on the use of domestic materials, reagents and equipment. All the technical solutions developed and materials are patented.

The economic effect for 6 years of the new RIR technologies application was more than 30,0 million U.S. dollars.

New materials and methods of repair and insulation works can be applied not only on the fields of Gazprom dobycha Urengoy LLC, but also on the other gas fields in the late stage of development.