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## Original article

### Monitoring and elimination of inter casing pressure

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#### ABSTRACT

**Background:** The appearance of inter casing pressure in many cases is associated with inadequate quality of primary cementing. Despite the fact that many studies are aimed at preventing problems of primary cementing, at improving the quality of well completion, it should be noted that the problem of inter casing pressure at existing gas and gas condensate wells is increasing.

**Aim:** The purpose of this work is to study and eliminate wells with inter casing pressure at the Amangeldy gas condensate field.

**Materials and methods:** This paper presents the procedure for preparing the well and carrying out the elimination of inter casing pressure, as well as the chemical components of cementing slurry.

**Results:** The conducted studies and measures on wells No.121; No.105; No.103 and No.101 showed a positive result and the effectiveness of the composition of cementing slurry.

**Conclusion:** The presented technology for the elimination of inter casing pressure and the composition of the cementing slurry can be widely used in many fields of Kazakhstan.

**Key words:** *cementing, cementing slurry, bottomhole zone, cement stone, inter casing pressure.*

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## Оригинальное исследование

### Мониторинг и ликвидация межколонных давлений

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#### АННОТАЦИЯ

**Обоснование.** Появление межколонных давлений во многих случаях связано с несоответствующим качеством первичного цементирования. Несмотря на то, что много исследований направлены на предотвращение проблем первичного цементирования и повышение качества заканчивания скважин, проблема появления межколонных давлений и борьба с ними на действующих газовых и газоконденсатных скважинах не становится менее актуальной.

**Цель.** Целью данной работы является исследование и ликвидация скважин с межколонным давлением на газоконденсатном месторождении Амангельды.

**Материалы и методы.** В данной работе представлены процедуры подготовки скважины, проведения исследований и ликвидации межколонных давлений, а также химические компоненты тампонирующих растворов.

**Результаты.** Проведенные исследования и мероприятия по скважинам №121, 105, 103 и 101 показали положительный результат и эффективность рецептур тампонирующих растворов.

**Заключение.** Представленная технология ликвидации межколонного давления и рецептура тампонирующих раствора может широко применяться на многих месторождениях Казахстана.

**Ключевые слова:** цементирование, тампонажный раствор, призабойная зона, тампонажный камень, межколонное давление.

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## Түпнұсқа зерттеу

### Бағанаралық қысымды бақылау және жою

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#### АННОТАЦИЯ

**Негіздеу.** Бағанаралық қысымның пайда болуы көптеген жағдайларда бастапқы цементтеу сапасының сәйкес келмеуімен байланысты. Көптеген зерттеулер бастапқы цементтеу проблемаларын болдырмауға және ұңғымалардың аяқталу сапасын жақсартуға бағытталған болса да, қазірдің өзінде жұмыс істеп тұрған газ және газ конденсатты ұңғымалардағы бағанаралық қысым проблемасы артып келе жатқанын атап өткен жөн.

**Мақсаты.** Бұл жұмыстың мақсаты Амангелді газ конденсаты кен орнындағы бағанаралық қысымды ұңғымаларды зерттеу және жою болып табылады.

**Материалдар мен әдістер.** Бұл жұмыста ұңғыманы дайындау және бағанаралық қысымды жою процедурасы, сондай-ақ тампонаж ерітінділерінің химиялық компоненттері көрсетілген.

**Нәтижелері.** №121, 105, 103 және 101 ұңғымалар бойынша жүргізілген зерттеулер мен іс-шаралар тампонаждық ерітінділер рецептураларының оң нәтижесі мен тиімділігін көрсетті.

**Қорытынды.** Бағанаралық қысымды жоюдың ұсынылған технологиясы және тампонаждық ерітіндінің рецептурасы Қазақстанның көптеген кен орындарында кеңінен қолданылуы мүмкін.

**Негізгі сөздер:** цементтеу, тампонаждық ерітіндісі, кенжар аймағы, тампонаж тасы, бағанаралық қысым.

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## Introduction

The quality improvement of well cementing and casing leak tightness with the development of new technologies and with the increase of well depth gets more urgent.

Intercasing pressure (hereinafter referred to as ICP) take place at most of the fields, which is especially typical for gas and gas-condensate fields. Both technogenic factors (quality of well construction, materials and equipment used) and natural factors, independent of human activity, influence the occurrence of ICP [1].

The authors of the work [2] assume that the main causes of the appearance of intercasing pressures are:

- leaky casing threaded joints;
- leakiness of wellhead gaskets of casing strings;
- gas migration during the waits on cements (here in after WOC).

During the WOC, a contraction occurs, which can lead to serious violations of the integrity of the cementing slurry. This phenomenon appears mainly in the WOC in the conditions of fluid-resistant layers, which contain dense and low-permeable rocks. The results of this phenomenon may be shrinkage deformations [3].

It is necessary to pay special attention to the ways of formation fluid migration to the surface regardless of the cause of ICP, the main of which are:

- cement ring channels formed during cement stone formation due to low sedimentation stability of cementing slurry;
- micro-gaps in the contact between the cement and the casing, due to insufficient adhesive capacity of the cement, as well as those formed during operations inside the cemented casing, such as drilling out the cement plug and further deepening of the well. The formation of micro gaps is also promoted by casing pressure tests to check for leaks, determination of well injectivity, and stimulation activities;
- casing leakage in the body or threaded joints;
- leakage of casing head in places where sealing elements are installed and fluid flow from annular space to intercasing annulus (hereinafter referred to as ICA) or from one ICA to another;
- impact of temperature factor during startup and shutdown of wells.

There is also a necessity to be taken into account that casing is pressurized with liquid, and in this case, the casing and intercasing annulus are hermetically sealed.

According to theory, there should be no ICP in such situation, but since gas permeability is much higher than liquid permeability, so gas penetrates where liquid does not filter.

Furthermore, there are a number of important but poorly understood factors which undoubtedly

affect the occurrence and magnitude of ICDs, which include: electric fields that change over time due to changes in:

- metal intensity of the deposit, changes in the subsurface and in the environment;
- physical and chemical processes taking place in ICA;
- osmotic phenomena in the cement stone.

The reasons mentioned above confirm that cementing quality of wells will directly influence the occurrence of ICP. As the problem of improving the quality of well cementing was discussed in papers [4–7], and at present there are many wells in Kazakhstan, which have problems with cementing in gas and gas-condensate wells, the purpose of this work is to study and eliminate wells with ICP.

The problem of intercasing pressures occurs in many wells of our republic. For example, at the North Buzachi oil field, which is located in Mangistau region, out of 97 wells drilled since the discovery and up to 2000 years, 72 wells were abandoned due to poor quality of well cementing. At 15 wells drilled from 2003 to 2004 there were problems with the formation of griffins and the presence of intercasing pressures [1].

At the Amangeldy field, operation of wells with intercasing pressure is carried out in accordance with the "Program of well management with intercasing pressure at the Amangeldy field", developed by NIPIneftegaz JSC in 2008.

In order to minimize risks when operating wells with ICP and to ensure the safety of personnel servicing the wells, as well as the negative impact on the environment, AmangeldyGas LLP conducted monitoring of wells with ICP, provided for by the Program [8, 9].

Under the calculation of maximum permissible pressures (MPP), conducted in accordance with the "Methodology for determining the categories of emergency wells with intercasing pressure at the Amangeldy field" and the category of danger of wells with ICD was determined.

The maximum average pressure recorded between the production and intermediate casing for the period from 2003 to 2012 was 6.8 MPa (well 117), and between the intermediate casing and surface casing – 2.7 MPa (well 103). The maximum MAP percentage was 31% (well 117) in 2006. At all other wells the percentage of MAP was much lower, so practically all wells were classified as category 4 ICP, since the recorded MCPs were less than 25% of the MAP.

In 3 wells (106, 111, 16-G), ICPs were practically absent during the analyzed period. In 7 wells (105, 111, 117, 120, 121, 2-G, 6-G) pressure was observed mainly only between the production and intermediate strings. Pressures in both spaces during the whole period of analysis were registered in 7 wells (101, 103, 108, 112, 113, 114, 122).

Therefore, as of 01.05.2012 all wells of the field belonged to the 4th category of danger ICP. Therefore, with the purpose of control over well operation, creation of safe working conditions for personnel and environmental protection when working at wells with ICP, and considering that 21 wells of the 4th category were identified in the field the following recommendations were developed [10]:

- it is recommended to carry out weekly monitoring of pressures in inter casing annulus;
- wells that do not have ICPs should be monitored on a weekly basis;
- in case of new wells with high pressure in the interwell space or growth of interwell pressures of more than 25% of MPP, to transfer to another category, assess the technical condition of the well, carry out work to reduce or eliminate high pressure in the interwell space and continue observation with weekly monitoring.

In 2016, Yu. A. Daribayev and employees of "Clinal" LLP conducted monitoring of wells in the field, or rather work on the research and diagnosis of the causes of inter casing pressure in several wells of Amangeldy field.

On well No.121 of Amangeldy field were conducted work on research and diagnosis of the causes of the occurrence of inter casing pressure.

The work is carried out by the autonomous laboratory IDL-1[8,11].

1 stage of research – complete study of geological and tectonic characteristics of the well, data of materials during well drilling, logging, conclusion of GIS, LLS, CBL, materials of work performed on the well, gas compositions coming out of the inter casing annulus (hereinafter – ICA).

The second stage of the research is determining the causes of ICP by wellhead injection of the technological solution.

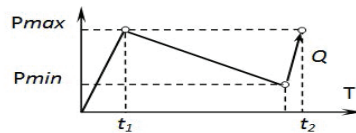
The injectivity of the wellbore was usually determined in two ways:

- by the volume of injected solution providing constant pressure in the ICP;
- by initial pressure recovery.

The first method is to pump such volumes of process fluid that ensure constant pressure in the wellbore packer. In this case, its inflow rate, i.e. injectivity, will be equal to the rate of fluid outflow from the ICP through micro channels to the source of interwell pressure. This method allows pumping at maximum pressure and fluid supply to the ICP. The disadvantage of this method is difficulty to keep constant pressure in ICP because of spontaneous change of injectivity, on which the value of pressure at the wellhead depends.

The second method can be implemented at any pressures in ICP (below the maximum allo-

wable values). It is relatively simple in realization and allows to determine injectivity of the well more accurately. For this purpose, it is necessary to start dosing pump and pump solution up to pressure in MCP equal to the preset one ( $P_{max}$ ). Then the pumping is stopped ( $t_1$ ) and the pressure drop to a certain value or stabilization ( $P_{min}$ ) is recorded. After that the dosing pump is started and the solution (liquid) is pumped until the initial pressure  $P_{max}$  is restored. At the same time fix the volume ( $Q$ ), pumped liquid and time ( $t_2$ ) from the pump stop till the moment of pressure restoration ( $t_1-t_2$ ). If we assume, that the volume of pumped liquid was spent for replacement of hollow space in ICP, the injectivity is defined as quotient of division of pumped liquid volume by total time of pressure drop and recovery. Meanwhile, the average injection pressure is defined as half the sum of maximum and minimum pressures, which were obtained during the work (Fig. 1).



**Figure 1. Example of determination of injectivity and average pumping pressure**

$t_1$  – time from stopping of pump operation;  $t_2$  – time of pressure restoring;  $Q$  – volume of pumped liquid at pressure recovery

Determination of injectivity (1):

$$q_{ing} = \frac{Q}{t_2 - t_1} \tag{1}$$

Average value of intake pressure (2):

$$P_{avg} = \frac{P_{min} + P_{max}}{2} \tag{2}$$

The intake capacity of the ICP was determined by the volume of the injected solution until the pressure was restored.

We presented calculations of the depth of penetration (immersion) of the solution injected into the ICP of the well, and the growth of back pressure at the source of ICP, taking into account the injection volume and shrinkage of the cement stone.

1. Cement ring area:

$$S_{cs} = 0,8 \cdot (d_{1in}^2 - d_2^2) = 0,8 \times (d_{1in} + d_{2in}) \cdot (d_{1in} - d_2) \tag{3}$$

where  $d_{in}$  and  $d_2$  are the inner and outer diameters of the technical and production casing, in cm:

$$d_{in} = d_1 - 2\beta \tag{4}$$

where  $d_1$  – outer diameter of the intermediate casing, in cm;  $\beta$  – wall thickness of the intermediate casing, in cm.

2. Total area of vertical microchannels formed as a result of cement stone shrinkage (5):

$$\Delta S y = S_{cs} \cdot \eta \tag{5}$$

where  $\eta$  – maximum shrinkage ( $\eta = 0,3\%$ ).

3. Depth of solution immersion ( $Lx$ ) taking into account injection volume ( $Qp$ ) (6):

$$Qp = \Delta S y \cdot Lx \tag{6}$$

from here:

$$Lx = \frac{Qp}{\Delta S y} = \frac{Qp}{S_{cs} \cdot \eta} \tag{7}$$

4. Calculation of the back pressure value at the source (8):

$$P = Lx \cdot \Delta \gamma = \frac{Qp}{S_{cs} \cdot \eta} \cdot (\gamma_p - \gamma_\phi) \cdot 10^{-3} \tag{8}$$

where  $\gamma_p$  and  $\gamma_\phi$  – density of solution and filtrate from ICP, in  $g/cm^3$ .

**Calculation for the conditions of well No.121**

- $d_{in} = 32.4 - 2 \cdot 0.95 = 30.5$  cm;
- $d_2 = 24.4$  cm;
- $\eta = 0.3\%$ ;
- $Qp = 1l = 1000$   $cm^3$ ;
- $\gamma_p = 1.00$   $g/cm^3$ ;
- $\gamma_\phi = 0.001$   $g/cm^3$ ;
- $S_{cs} = 0.8 \cdot 54.9 \cdot 6.1 = 268$   $cm^2$ ;
- $\Delta S y = 268 \cdot 3 \cdot 10^{-3} \approx 0,80$   $cm^2$ ;
- $Lx = 1000 / 0.8 = 1250$   $cm = 12.5$  m;
- $\Delta P = 1250 \cdot 1 = 1250$   $g/cm^2$  or 1.25 atm.

Calculation of the maximum allowable pressure of the solution injection in the ICP.

**Table 1. Data on well No.121 of Amangeldy field**

Casing	Outer diameter, mm	Descent depth, m
Conductor pipe	426	30
Surface casing	324	450.15
Intermediate casing	244.5	1300
Operational	168,3 Liner 114	0–1707 1707–2273

We take the following values of MPP for calculations, taking into account 50% safety margin. Taking into account production casing

wear on work and tear, the maximum allowable pressure is equal to:

$$P = \frac{P_{collapse} \cdot K}{2} \tag{9}$$

$$P = \frac{P_{in.lim.y.s} \cdot K}{2} \tag{10}$$

where  $K$  – coefficient of casing string wear is taken into account depending on well operation life (value – 0.8 is assumed), assuming that corrosion rate is 0.1 mm/year and well operation life is insignificant; 2 – coefficient of 50% safety factor.

**Table 2. Parameters of triangular threaded casing strings, strength grade D**

Casing Structure	Diameter, mm	Descent depth, m	Wall thickness	Pressure, MPa	
				collapse pressure	Internal limit yield strength
Conductor pipe	426	30	9.5	3.5	15
Surface casing	324	450.15	9.5	10.9	26.9
Intermediate casing	244.5	1300	10	20.9	37.9
Production casing	168.3 114	0–1707 1707–2273	10.59 7.39	55	58.1

For the 24 mm diameter surface casing, the yield strength  $P_{ys} = 26.9$  MPa. For the 244.5 mm diameter intermediate casing, the collapse pressure  $P_{cp} = 20.9$  MPa.

The maximum allowable pressure in inter casing annulus between surface casing and intermediate casing with allowance for casing strength and aging will be equal to:

$$P = 26.9 \cdot 0.8 / 2 = 10.8 \text{ MPa} \tag{5}$$

The maximum allowable pressure of pumping of technological solution in ICP in the well No.121 of Amangeldy deposit should not exceed 10.8 MPa.

To determine injectivity, at the first stages of work, we proposed to use service water. Technical water is collected in a container (100-liter barrel). In order to eliminate the inter casing pressure and to fill microcracks in the cement stone behind the column we used a chemical component of a complex composition (sodium liquid glass  $Na_2SiO_3$  + gelling material blast furnace slag and acid), which is widely used in recent years for liquidation of ICD.

**Preparation for work on the well**

1. Acceptance of the well for work with indication of pressures in tubing, annulus and inter casing annulus.

2. IDL-1 was installed on the windward side at a distance of 30-50 meters from the wellhead.



3. Warning signs were erected at the site of the work.
4. Measured wellhead pressures.
5. The IDL-1 laboratory through the high pressure hose and the distribution coupling has been connected to the branch of the wellhead No.1.
6. The pressure gauges were installed in the tubing and annular outlet of the wellhead.
7. Pressure sensors are connected to control panel IDL-1 by electric cable.
8. The tank for collecting and disposing of the solution, silicone hose, connects to the distribution sleeve.
9. Starting the pump, filling the discharge line with solution.
10. Pressurize discharge line to pressure of pressure reducing valve.

**Carrying out the work**

1. Start the dosing pump and increase the pressure in the ICP to 30 bar above the initial pressure.
2. Stopping the dosing pump and observing the change of pressures in all the spaces of the well during the calculated time.
3. After the set time, start the dosing pump and additionally increase the pressure in the ICP by 10–50 atm. At the same time constant monitoring of pressures in tubing and annular space, as well as possible leaks in different units of injection line and wellhead equipment.
4. Pressure build-up up to 150 atm according to work program.
5. After every stop of dosing pump to determine the angle of pressure drop and to calculate the value of intake of ICP.
6. At the end of pumping calculation of pumped technological solution volume.

**Results and discussions**

Brief information about the well No.121.

**Table 3. Well design and equipments**

Equipment title	Parameters
Conductor pipe	426mm x 30m(TOC to wellhead)
Surface casing	324 mm x 450.15 m (TOC to wellhead).
Intermediate casing	244.5 mm x 1300 m(TOC to wellhead)
Production casing	168.3 mm x (0–1707 m) (TOC -324 m to wellhead)
	114 mm x (1707–2273 m)
Artificial Pit	2273 m
Column head	Wellhead 2-35-324x245x168
Christmastree	CPT6 – 65 x 35 Chl
Tubing suspension	Ø73 mm – 2171.6 m
Hp	4 m

After the work were obtained ACBL conclusions: on the intermediate casings: 10.9% of the site has partial cement bonding

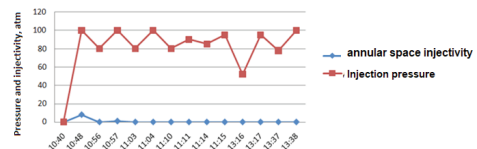
to the column, 56.8% – solid, 31.6% – bad, 0.7% no cement; on production casing: 11.8% of the site has partial adhesion of cement to the column, 38.7% – solid, 48.2% – bad, 0.8% – no cement; gas from the intercasing annulus is not flammable.

**Carried out work on the well for the study and elimination of ICP**

*First day.* Study of well case materials: well drilling materials, conclusions of LLS and ACBL, gas characteristics, well construction materials, work done on the well. Manometer readings were as follows  $P_{icp1} = 10$  atm,  $P_{icp2} = 5$  atm. We bled the pressures between the technical and production BOP-1, surface casing and the intermediate casing BOP-2 to 0 atm. When bleeding annular space hereinafter AS-1 at the outlet combustible gas, AS-2 (between the surface casing and the intermediate casing) at the outlet incombustible gas. Further on AS-1/2 was pumped an inhibited solution (process water + BrinePac inhibitor) for flushing and filling of microcracks in the cement stone behind the columns, as well as for improvement of setting quality of chemical components. Capacity AS-1 – 10 liters, AS-2 – 11 liters. We monitored the pressure set.

*Second day.* Reading of pressure gauge at the well  $P_{icp1} = 12$  atm,  $P_{icp2} = 17$  atm. We bled pressure between the technical and production casing of AS-1, surface casing and intermediate casing of AS-2 to 0 atm. We pumped 4 liters of chemical agent into AS-1. We closed AS-1 under pressure of 100 atm. For reacting and setting of chemical components. We pumped into AS-2 a chemical component (liquid glass + bottom ash) in the amount of 6 liters. We closed AS-2 under pressure of 95 atm for reaction and setting of chemical components. We watched the pressure setting.

*Third day.* Lowered the pressure in the MCC-1/2 to 0 atm. After restoration of pressure the readings of manometers  $P_{icp1} = 0$  atm,  $P_{icp2} = 20$  atm. Bled pressures in AS-2 to 0 atm. We re-injected 6 liters of chemical component into AS-2. We re-injected AS-2 under pressure of 95 atm. For reacting and setting of chemical components.



**Figure 2. Dependence of AS injectivity on solution injection pressure in the well No.121**  
Other wells of Amangeldy field were investigated in the same way

The gas composition in the annulus and inter casing annulus are identical. This indicates that the gas in the inter casing annulus is identical to the gas from the Permian Serpukhov horizons. Due to the decrease in injectivity and for further work on liquidation of AS, injection of those solutions was stopped.

### Conducted work on the well No.103 on the study and elimination of ICP

*First day.* Study of materials of the well case: materials of well drilling, conclusions of LLS and ACBL, characteristics of gases, materials of well construction, work done on the well. Manometer readings were as follows  $P_{icp1} = 37$  atm,  $P_{icp2} = 25$  atm. We bled pressure between the technical and production casing of AS-1, between the surface casing and the intermediate casing of AS-2 to 0 atm. While bleeding AS-1 output was incombustible gas, AS-2 output was incombustible gas.

We pumped an inhibited solution (process water + BrinePac corrosion inhibitor) into AS-1/2 to flush and fill microcracks in the cement stone behind the columns, as well as to improve the quality of setting of chemical components. Pressure setting of AS-1, 7 liters, AS-2, 22 liters.

*Second day.* Pressure gauge readings at the well  $P_{icp1} = 40$  atm,  $R_{mkl2} = 29$  atm. We bled pressure between the technical and production casing of AS-1 and between the surface casing and the intermediate casing of AS-2 to 0 atm. Inhibited solution (process water + BrinePac corrosion inhibitor) was pumped into AS-1/2 for flushing and filling of microcracks in cement behind the columns, as well as for improvement of quality of setting of chemical components. Pressure setting of AS-1, 17 liters, AS-2, 20 liters.

*Third day.* Pressure gauges  $P_{icp1} = 40$  atm,  $P_{icp2} = 29$  atm.

We pressurized AS-2 to 0 atm. Into AS-1 we pumped chemical component (liquid glass + domestic slag) in amount of 20 liters. We closed AS-1 under pressure of 95 atm. For reacting and setting of chemical components. In AS-2 we pumped a chemical component (liquid glass + bottom ash) in an amount of 7 liters. We closed AS-2 under pressure of 90 atm. For reactions and setting of chemical components. During 6 days the observation was carried out and the pressure readings of AS was  $P_{icp1} = 0$ ,  $P_{icp2} = 0$ , which testifies to the efficiency of the measures applied.

Gas composition in annular and inter casing annulus are identical. This indicates that the gas in the inter casing annulus is identical to the gas from the Permian Serpukhov horizons.

Due to a decrease in injectivity and for further work on liquidation of ICP injection of those solutions was stopped.

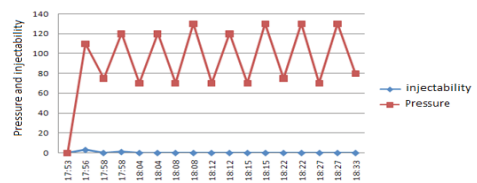


Figure 3. The diagram of dependence of AS injectivity on fluid injection pressure in the well No.103

### The carried out work on the well No.101 on research and liquidation of ICP

*First day.* Study of materials of the well case: materials of well drilling, conclusions of LLS and ACBL, characteristics of gases, materials of well construction, work done on the well. Manometers readings were as follows  $P_{icp1} = 22$  atm,  $P_{icp2} = 23$  atm. We bled pressure between the technical and production casing of AS-1, between the surface casing and the intermediate casing of AS-2 to 0 atm. When stripping AS-1 output was non-flammable gas, AS-2 output was non-flammable gas.

We pumped an inhibited solution (process water + BrinePac corrosion inhibitor) into AS-1/2 to flush and fill microcracks in the cement stone behind the columns, as well as to improve the quality of setting of chemical components. Pressure setting of AS-1, 25 liters, AS-2, 50 liters.

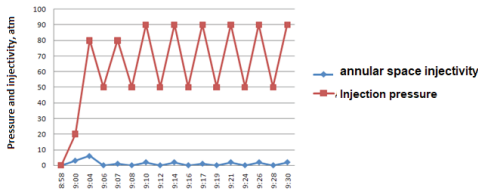
*Second day.* Pressure gauge readings  $P_{icp1} = 27$  atm,  $P_{icp2} = 30$  atm. We pressurized between the technical and production casing of AS-1 and between the surface casing and the intermediate casing of AS-2 to 0 atm. When stripping AS-1 output was non-flammable gas, AS-2 output was non-flammable gas.

We pumped an inhibited solution (process water + corrosion inhibitor BrinePac) into AS-1/2 to flush and fill microcracks in the cement stone behind the columns, as well as to improve the quality of setting of chemical components. Efficiency of AS-1 was 27 liters, AS-2 – 18 liters.

*Third day.* We depressurized AS-1 and AS-2 up to 0 atm. We pumped 12 liters of chemical component (liquid glass + bottom ash) into AS-1. We closed AS-1 under pressure of 100 atm. For reacting and setting of chemical components. In AS-2 the chemical component (liquid glass + domain slag) was pumped in an amount of 7 liters. AS-2 was closed at pressure of 90 atm. For reaction and setting of chemical components. During 7 days the observation was carried out, and pressure readings of AS were as follows. The pressure readings of the AS were  $P_{icp1} = 0$ ,  $P_{icp2} = 0$ .

Gas composition in annular and inter casing annulus are identical. This indicates that the gas in the inter casing annulus is identical to the gas from the Permian Serpukhov horizons.





**Figure 4. The graph of dependence of AS injectivity on fluid injection pressure in the well No.101**

Due to a decrease in injectivity and for further work on liquidation of ICP, injection of those solutions was stopped.

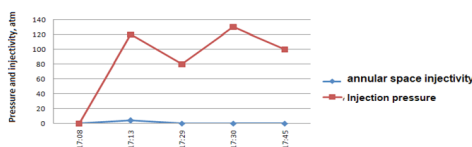
**The carried out work on the well No.105 on research and liquidation of ICP**

*First day.* Study of materials of the well case: materials of well drilling, conclusions of LLS and ACBL, characteristics of gases, materials of well construction, work done on the well. Manometers readings were as follows  $P_{icp1} = 15$  atm,  $P_{icp2} = 5$  atm. We bled pressure between the technical and production casing of AS-1 and between the surface casing and the intermediate casing of AS-2 to 0 atm. When stripping AS-1 output was non-flammable gas, AS-2 output was non-flammable gas.

We pumped an inhibited solution (process water + BrinePac inhibitor) into AS-1/2 to flush and fill microcracks in the cement stone behind the columns, as well as to improve the quality of setting of chemical components. Capacity AS-1, 6 liters per hour, AS-2, 8 liters per hour.

*Second day.* Pressure gauge readings  $P_{icp1} = 22$  atm,  $P_{icp2} = 5$  atm. We pressurized AS-1 to 0 atm. We pumped 12 liters of chemical component (liquid glass + bottom ash) into AS-1. We closed AS-1 under pressure of 100 atm. to react and setting of chemical components.

*Third day.* Varied the pressure in the AS-1 and AS-2 to 0 atm. In AS-1 we repeatedly pumped 9 liters of chemical component (liquid glass + bottom ash). We closed MCP-1 under pressure of 100 atm. for reacting and setting of chemical components. In AS-2 we pumped chemical component (liquid glass + bottom ash) in an amount of 21 liters. We closed AS-2 under pressure of 90 atm. For reaction and setting of chemical components.



**Figure 5. Dependence of AS injectivity on fluid injection pressure in the well No.105**

The gas composition in the annulus and intercasing annulus spaces are identical. This indicates that the gas in the intercasing annulus is identical to the gas from the Permian Serpukhov horizons. In connection with the reduction of injectivity and for further work on liquidation of ICP, injection of those solutions was stopped.

**Conclusion**

The AS has a microchannel through which gas migrates to the surface. The study revealed that the injectivity of microchannels is 6 liters per hour at a pressure of 70–95 atm. As a result of filling of the channel with chemical component, injectivity of AS and gas migration to the wellhead decreased.

According to the results of the study, the cause of intercasing pressure is migration of gas through the contact zones of cement rock from the formation to the surface through micro channels in AS from Permian and Serpukhov horizons.

Intercasing pressure appeared due to poor-quality cementing of technical and production casing and under-reaming of cementing slurry behind the casing strings.

While performing job on elimination of intercasing pressure at well No. 121 of Amangeldy oil field the chemical component ( $Na_2SiO_3$  + gelling material blast-furnace slag-vacuum) was injected, the injectivity of AS gradually reduced from 4 to 2 liters per hour. The chemical component filled in the microcracks of the cement stone, and it caused the stoppage of gas migration in AS-1/2.

The chemical component ( $Na_2SiO_3$  + gelling material – blast furnace slag – vinegar) was injected into well No.105 of Amangeldy deposit while performing work on liquidation of intercasing pressure, the flow rate of BF-1/2 was gradually reduced from 4 to 1/2 liters per hour. The chemical component filled in the microcracks of the cement stone, and this was the reason for stopping the migration of gases in AS-1/2.

At well No.103 of Amangeldy field while performing work on elimination of intercasing pressure, a chemical component ( $Na_2SiO_3$  liquid sodium glass + gelling material blast furnace slag-vinegar) was pumped, the flow rate of AS gradually decreased from 4 to 2 liters/hour. The chemical component filled in the microcracks of the cement stone, and it was the reason of stopping the migration of gases in AS-1/2.

At well No.101 of Amangeldy deposit while performing operations on elimination of intercasing pressure, the chemical component (sodium  $Na_2SiO_3$  + gelling material blast-furnace slag-vacuum) was injected, the rate of flow of AS gradually reduced from 3 to 2 liters/hour. The chemical component filled the microcracks

in the cement stone, and this was the reason for stopping the migration of gases in AS-1/2.

For effective setting of the chemical component in the inter casing annulus it is not recommended to carry out any

technological operations related to the inter casing annulus (bleeding, flushing, pressure testing, blowing) within 3 months from the date of delivery of the well.

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