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Arrangement of Concepts About Technological Processes of Limiting Water Inflow into Production Wells in terms of Reagents Used

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We consider water inflow control technology in terms of reagents used. The estimation of technological attractiveness vodoogranicheniya processes based on the use of the most commonly used reagents. According to the analysis reagent compositions are ranked and determined dominant. Recommendations are given to determine the purpose of measures in view of the reagents used, to analyze their effectiveness and, where appropriate, issue guidelines on the most promising technological processes. In view of this it seems appropriate to clarify the current classifier of geological and technical measures.

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PJSC Tatneft uses a wide range of technologies of water inflow limitation in producing wells. The works are classified in accordance with the accepted classifier. However, upon closer examination it appears that according to the reagent composition, much wider range of chemicals is used in the production than it is provided in the regulatory documentation. This suggests that the real production needs anticipate solutions available in the documentation, and the search for optimal formulations comes intuitively.

We considered 8071 activities, nominally conducted in order to limit the flow of water through the formation, for more accurate composition of the reagents used. Preliminary analysis showed that for 1035 activities reagent composition does not contain a component characteristic for inflow limitation technology from the reservoir; for 1370 activities reagent composition indicates the execution of insulating feeding channel not in the reservoir, but out of production string (it is composed of reagents such as cement, crumb rubber, sand, quartz, etc.).

At least 58 agents were used. The most common were: polyacrylamides – used in 2221 activities; crosslinkers – 1786; SNPKh-9633 – 1492; clay – 1136; liquid glass – 426; RDN – 623. In most cases, injected formulations are complex, usually combining two key reagent determining water limiting essence of exposure (eg, polyacrylamide and crosslinker). Water limiting essence of exposure was to reduce the impact of reservoir permeability by creating low-active highly viscous emulsion (SNPKh-9633, Neftenol, hydrolyzed polyacrylonitrile); scaling in the pore space (water glass, alkali); injection into the pore space of finely dispersed slurry (clay, flour); shutdown of portion of the pore space due to gelation (crosslinking agent with polymer).

Each of the directions is not free from drawbacks. Thus, moving emulsions when putting the well into operation input may partially return into the well, creating complications in production wells transportation. Scaling does not completely cover the pore space. Clay injection substantially alters reservoir characteristics; injected flour does not penetrate deeply into the formation. Gelling covers not only water feeding, but also oil feeding channels and are short-lived due to destruction. Needs to overcome these problems determine a great variety of reagents used.

During the analysis activities similar in reagent composition were grouped, allowing them to continue to be considered as conventional manufacturing processes.

After rejection for these reasons, 4917 activities left. Some formulations are very commonly used (hundreds of activities). However, 542 are few in number (less than 5 activities) and of interest only as a reflection of the attempt to pick up composition, which allows performing the task of limiting the water inflow in specific geological and field conditions of the well. The number of processes is excessively large and, most importantly, in most cases, does not conform to the established governing documents, i.e., illegitimate.

It is relevant to determine the purpose of activities in view of the reagents used, to analyze their effectiveness and, where necessary, to issue a guidance document on the most promising technological processes. In view of this it seems appropriate to clarify the current classifier of geological and technical measures.

Initially, preparation and additional processing of database information was performed. Of the data array on technologies of interest, activities were eliminated with questionable reagent composition, physically incorrect data on the flow rate and water cut. For more adequately characterization of technology, activities were excluded from consideration with too short-term manifestation of the effect (less than three months – the effect was not yet fully emerged) and too long term manifestation of the effect (more than 60 months – the accuracy of determining the end effect is getting worse with time from the date of activity).

For the remaining activities control testing was carried out for recording pump capacity changes after the activity (amount of oil flow rate prior to exposure and average during the exposure of oil flow rate growth should not exceed fluid flow rate prior to exposure).

Conventional technological processes were ranked by the parameter of technological attractiveness, calculated by the formula (1):

$$П_T = H \cdot K_{TУ} \cdot \log M \quad (1)$$

where $П_T$ is the rate of technological attractiveness, unit; H – relative increase in oil flow rate due to the activity, unit; $K_{TУ}$ – technological success factor, unit; $\log M_T$ – logarithm of the number of activities considered for determining technological attractiveness, unit.

Technological success factor is calculated using the formula (2):

$$K_{TУ} = \frac{M_Д}{M_T} \quad (2)$$

where $K_{TУ}$ – technological success factor, units; $M_Д$ – number of activities with a relative increase in oil flow rate exceeding the threshold, unit; M_T – total number of measures considered for determining technological attractiveness, unit.

Let us note that this analysis is deliberately removed from the economic characteristics of the results in order to avoid focusing on investment. To answer this question it is necessary to conduct further laborious serious evaluation of technological and economic results of the activities.

Table 1 shows the ranked results of certain processes applied.

The overall picture of water inflow limitation processes application shows that the dominant role in the number of activities is played by clay-based formulations, SNPKh-9633, polyacrylamide (Table 2).

It is interesting to consider a narrower group of processes that use common reagents.

Clay is a part of many technological processes used for water limitation. The technology uses clay property to reduce the reservoir permeability due to siltation. However, injection of clay has a negative side, namely permeability reduction occurs permanently, closing oil feeding channels for oil flow in the future. The use of these technologies at low water content entails the partial production of oil reserves.

A very large number of events are successfully performed using SNPKh-9633. Two main types of composition of SNPKh-9633 – with mineralized water and clay are basically used. Additional analysis shows that clay is used for further fastening of composition SNPKh-9633 injected into the formation in order to prevent its removal into the well at the start of its operation in (especially in fractured reservoirs). The main advantage of the composition based on SNPKh-9633 is its selectivity for water-saturated (formation of highly viscous emulsions in contact with saline water) and oil-saturated reservoirs (oil washing). Experience shows that a major deterrent of emulsion-based technologies application (SNPKh-9633 and others) is their cost. It seems appropriate to intensify efforts to create cheaper technology analogues.

There are advantages for less common processes based on the use of glass. Mainly two kinds of compositions are used: with liquid glass and hydrochloric acid and polyacrylamide to thicken the injected composition, as well as with the addition of flour to prevent removal of the composition into the well (to avoid gelation and salt formation directly in the well). The advantages of the technology with glass are in the relative environmental friendliness and the fact that the reservoir is not sealed tightly, leaving the possibility of further work with the formation.

A wide variety is observed in processes based on the use of crosslinked polymers (polyacrylamide, biopolymer, xanthan and so on). Their advantage is in reliable locking of water feeding channels. However, the effect is not selective, and oil feeding channels can also be locked.

The leading positions on the amount of performed works occupy formulations containing polyacrylamide, crosslinker and RDN (other compounds that do not contain the RDN are markedly inferior). Compositions containing other types of polymers (biopolymers BP-92, xanthan, cellulose) for the amount of work are significantly inferior to polyacrylamide compositions. Let us note that the highest ratings attract the attention on the basis of polyacrylamide formulations with RDN, the use of which traces its history from the time of cooperation with Tatarstan's oil institute "Giprovostokneft".

It seems appropriate to conduct detailed in-depth technological and economic evaluation of the results of these activities in Tatarstan fields. Upon confirmation of the high efficiency it seems appropriate to return to the study of composition and properties of the chemical reagents included in the composition of RDN series, with a view to developing their own technology peers.

Technology	Number of objects	Rank	Relative increase of oil production rate, un.	Technological attractiveness, un.	Technological success, un.
Clay, mineral water	114	1	9,6	19,9	100
Clay, mineral water, SNPKh-9633	465	2	6,5	17,3	100
Clay, ML, mineral water	17	3	11,1	14,0	100
Oil, Clay, polyacrylamide _ thick., water	31	4	7,5	11,2	100
HCl, МЛ, mineral water, SNPKh-9633	6	5	12,9	10,9	100
Clay, мука, polyacrylamide_crosslinker, crosslinkers	12	6	10,1	10,3	92
Mineral water, SNPKh-9633	498	7	3,9	10,2	96
Polyacrylamide_crosslinker, ML, crosslinkers, mineral water	21	8	8,4	9,7	86
ML, mineral water, SNPKH-9633	95	9	4,9	9,6	99
Oil, Clay, polyacrylamide_crosslinker, crosslinkers, water	73	10	5,1	9,5	99
Polyacrylamide_crosslinker, crosslinkers, mineral water	100	11	5,3	9,5	90
SNPKh-9633	231	12	4,4	9,0	92
Polyacrylamide_crosslinker, crosslinkers, mineral water, guar	29	14	4,6	6,8	100
Oil, Clay, polyacrylamide_crosslinker, crosslinkers, mineral water	30	15	4,6	6,7	100
HCl, product-119, HF, mineral water, water	8	18	7,1	6,4	100
Oil, Neftenol, mineral water	5	19	7,9	6,1	100
Polyacrylamide_crosslinker, RDN, crosslinkers, water	151	21	2,9	6,0	94
Oil, HCl, HF, RMD	11	24	5,1	5,5	100
RBK, crosslinkers, water	7	31	5,0	4,2	100
HCl, zeolite, water	17	35	3,7	3,8	82
Product-119	42	36	3,0	3,8	79
Biopolymers, crosslinkers, water	116	37	1,9	3,7	96
Glass, hydrolyzed polyacrylonitrile	13	40	4,6	3,5	77
Clay, alyumochloride, polyacrylamide_crosslinker, ML, crosslinkers, water	6	42	4,0	3,4	100
Oil, glass, HCl, polyacrylamide _ thick.	8	45	3,8	3,2	87
HCl, product-119	23	48	2,6	3,0	91
Glass, HCl, polyacrylamide _ thick., ML, water	5	53	3,5	2,7	100
Biopolymers, crosslinkers	52	54	1,8	2,7	87
VNP	8	61	3,0	2,5	87
Glass, HCl	37	62	2,3	2,5	70
NaOH, polyacrylamide _ thick., ATcF-75, mineral water, water	28	70	1,7	2,2	89
Crosslinkers, KF-Zh, water	18	76	1,8	2,0	89
Zeolite	13	81	1,8	1,9	92
Flour, polyacrylamide_crosslinker, crosslinkers	10	87	2,1	1,7	80
Hydrolyzed polyacrylonitrile, water	10	88	2,7	1,7	60
Glass, HCl, flour, polyacrylamide _ thick., mineral water, water	13	89	2,1	1,7	69
Oil, ahydron, mineral water	16	90	1,4	1,7	94
Polyacrylamide _ thick., ML, neonol-AF, others, water	5	103	1,7	1,3	100
Crosslinkers, xanthan, water	9	105	1,4	1,2	89
polyacrylamide_crosslinker, ML, neonol-AF, others, crosslinkers, water	5	113	1,2	0,9	100
Oil, Neftenol, distillate, CaCl2	6	120	1,3	0,7	67
Karfas	5	123	1,5		60

Table 1. The application results of certain technological processes. Note: polyacrylamide_thickened used to prevent premature sedimentation of composition components, polyacrylamide_crosslinker is used to form the gel.

	Reagent composition	Number of objects
1	mineral water, SNPKh -9633	498
2	clay, mineral water, SNPKh -9633	466
3	SNPKh-9633	232
4	oil, RMD	187
6	polyacrylamide_crosslinker, RDN, crosslinkers	143
7	biopolymers, crosslinkers, water	117
8	clay, mineral water	115
9	polyacrylamide_crosslinker, crosslinkers, mineral water	101

Table 2. The considered technological processes

Conclusions

1. According to the reagent composition much wider range of chemicals is used in the production of works than it is provided in the regulatory documentation. This suggests that the real production needs anticipate solutions available in the documentation and the search for optimal formulations comes intuitively.

2. Number of technological processes is too large and in most cases does not conform to the established procedure governing documents. It is relevant to determine the purpose of measures in view of reagents used, to analyze their effectiveness and, where appropriate, to issue guidelines on the most promising technological processes. In view of this it seems appropriate to clarify the current classifier of geological and technical measures.

3. The dominant role in the number of activities is played by clay-based formulations, SNPKh-9633, polyacrylamide. However, injection of clay, despite the low price, has the negative side – permeability reduction occurs permanently, closing the oil feeding channels for oil flow in the future. The main advantage of the composition based on SNPKh-9633 is their selectivity for water saturated and oil saturated reservoirs; the main constraint is cost. The main drawback of compositions based on cross-linked polyacrylamide is nonselective against oil-saturated and water-saturated reservoirs.

4. It is advisable to conduct detailed evaluation activities for a more adequate assessment of the advantages of technologies.

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