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WASTEWATER INJECTION INTO DEEP HORIZONS – CLOGGING AND DECOLMATATION PROBLEMS

L. Anichshenko

Kazakh National Technical University named after K. I. Satpaev, Almaty, Kazakhstan

Key words: industrial effluent, injection process, clogging, methods and technique of decolmatation, well screen.

Abstract. In this paper the possibilities of wastewater injection into the deep horizons through injection wells are developed. Industrial effluent is a technological solution, which during the injection processes forms precipitate in the borehole bottom, causing mudding of the receiving part of absorbing wells and essentially filter. The main attention is paid to vibration technology of clay cake removal and filters cleaning in wells in the oil and gas industry, which could be used for the most appropriate industrial wastewater injection into the deep horizons.

Introduction. Disposal of industrial effluents by means of injection wells is carried out in many various industries. In recent years especially toxic and difficult-to decontaminate industrial wastes in increasing frequency is disposed into the bowels of the Earth by means of disposal wells. In Kazakhstan on the Zhanazhol field industrial waste disposal is conducted into the flooded layers of carbonate strata KT-I, at the depth of 2.7 km. Utilization of the liquid wastes from the oil demercaptanization (sweetening) unit on the Zhanazhol field lead to contamination of the well down hole, clogging of the well screen and, as a result, reducing in well injection capacity. Currently using methods for well bottom hole cleaning do not give any appreciable effects, which is suggesting the need of its improvements or implement of the new ones. The article describes the usage of the proposed device that implements a combined decolmatation of productive formation.

Geological characteristic of operation area. Subsalt uplift of the Zhanazhol field is located in Aktobe region in Kazakhstan within Zhanazhol tectonic framework, one of the feature of which is developed thick carbonate strata which in turn complicated by brachyfold uplifts. Target carbonate strata (KT-1) in lithological aspect represented by bioherm clastic limestone with interlayers of hard and dense light dolomites, occasionally can be found coarse-grained karstenite with interstratified layers of argillic clays. In the sectional view KT-1 thickness varies from 350 to 500 m. Filtration-volumetric characteristics of the target strata is quite high, effective porosity varies in range 8.5 – 24 %, water permeability is 0,00332 – 0,01446 mkm^2. (Anichshenko, L., 2010).

Production formation B_1 of the KT-1 confined from the overlaying and underlaying strata by the sufficient thick (70,5 – 111,6 m) deposits of impermeable limestone and cube spar. Whereas KT-1 strata is separate from the overlaying layers by regional cap rock with thickness of 1220 m, which ensures full isolation of suprasalt aquifers from the penetration of injected into KT-1 waste water. (Grabovnikov V. A, 1993).

Generally, a subsalt deposit of the Zhanazhol field is characterized by high geothermal gradient; in a vertical sense temperature change is up to 2.4 °C/100 m). Temperature on the top of the formation of KT-1 varies from 59 – 60 °C on the uplift to the 67 °C on the peripheral, outside oil-water contact. Temperature on the depth of 2840 m is 64 °C, where on the 2720 m – 62 °C.

Formation water of the carbonate package, exposed by wells on the depths of 2835-3050 m is characterized as high-head and belongs to the bottom water type. Static water levels from the land surface are located on the depths from 57 to 143 meters. Basic hydrostatic time lag on the different wells is 2 – 21 days.

Formation pressure on the different depths differs little from hydrostatic pressure on the same depths. Formation pressure anomaly ratio does not exceed 1.11. Formation pressure on the well no.326 at the beginning of 2014 was 26 MPa, when the fracture gradient pressure only 32 MPa. These data indicate that carbonate formation KT-1 has a possibility to contain in it large volumes of wastewater in conditions of uniform injection to prevent from fracturing.

Information about fluids to be injected. Injection of waste water is carried out into the edge-water zone of the productive carbonate strata KT-1 by means of well no.326. Well no.326 until 2006 has been used as observation well, and then in 2006 it was perforated on the intervals 1740-2750 m, 2754-2777 m and 2783-2810 meters for the purpose of wastewater disposal. Injection of industrial effluents is performed only in conditions of it purification from mechanical impurities and dilution in ratio 1:3 with pure water.

Effluents from demercaptanization have an alkaline condition. Chemical activity of the effluents is reduced due to presence therein significant volumes of corrosion inhibitors. Waste water is preprocessed before injection, and it includes:

- mechanical impurities and petrochemicals removal in the settling ponds by filtration through gravel-sand-packed or quartz filters;
- removal of different iron compounds by water alkalinizing with ammonia;
- continuous addition of corrosion inhibitor in dosage of 25 g/m^3 for water lines inner surface protection;
- bacterial treatment in dosage of 100 g/m^3.

Industrial waste water that is injected into the reservoir represents technological solution formed as a result of the petroleum refining from hydrogen sulfide, ethyl- and methyl- mercaptans on the crude oil demercaptanization installation. The main physical-chemical properties are pH=12.3, the density is 10200 mg/dm^3, there is no dissolved carbon dioxide and oxygen, the concentration of hydrogen sulfide is 0.640 mg/dm^3. The amount of dissolved substances (solid residue, TDS) is 11022 mg/dm^3. The suspended solids content (colloidal particles, TSS) is 106mg/dm^3, calcium and magnesium are 40.0 and 24.0 mg/dm^3 respectively, chlorides content is 266 mg/dm^3, sulfates - 365 mg/dm^3, hydrocarbons – 366 mg/dm^3, carbonates 0.9780 mg/dm^3, phenols – 0.2189 mg/dm^3, petroleum products - 34.8 mg/dm^3, total iron content – 2.13 mg/dm^3, heavy metals (Pb, Cd, Cu, Zn) – respectively 0.0052 mg/dm^3, 0.0482 mg/dm^3, 0.0188 mg/dm^3, 0.0198 mg/dm^3 (Anichshenko, 2012).

Industrial effluents comply with the RDS 39-01-041-81 "Methodology of predictive determining of the wastewater quality standards for contour waterflooding of new oil fields" standards, which admit, in particular, the mechanical impurities and petroleum products content in the injected effluent of 15-50 mg/dm^3.

Causes of injection process difficulties. While injection of effluents into water bearing strata, takes place a mixing of injected water and formation water. (Goldberg V. M., 1994) And in case of inconsistence of effluents and formation water the colmatage of the bottom-hole area occurs. From known four types of colmatage in our case predominate mechanical and chemical. (Anichshenko, 2012) Despite the fact that held actions for effluents purification, in the bottom-hole area colmatage occurs, characterized by salting-up as well as settling and accumulation of the mechanical particles and microorganisms in the reservoir rock. Where consequences of colmatage most strongly manifested is in the radius of 1 meter of bottom-hole area of the well. Thus, negative influence appears as sand well screens silt up, as well as silt up and clogging by the carbonates and ferrum hydroxide of the well screen content. (Anichshenko, L., 2012). A continuous process of injection characterizes the working condition of absorbing wells. Wellhead pressure is raised with increasing of injection volumes, and increasing over time because of the presence of solids in industrial wastewater, and colmatation of wells receiving area. Based on the analysis of technical literature Sergienko et al. (1984) established that the reasons of failure are: colmatage of well screen – 40.9 %, clogging and sanding up in the well – 37.77 %, depreciation of pumping equipment – 12.52 %, other reasons – 8.81%. Thus, means to deal with the injection difficulties should be mainly focused on the periodic decolmatation of well screen and anti-clogging and sanding up (together these factors accounted for 78%).

In conditions of the Zhanazhol field according to the results of compatibility analysis revealed that formation water of KT-1 and injecting effluents are stable on calcium sulfate but unstable on calcium carbonate. Absolute oversaturation are in the range 485,2 до 1127,6 mg/dm^3. The amount of the calcium carbonate residue within 1-24 hours is from 49,1 to 307,8 mg/dm^3. (Gershtanskii O. S., 2002)

Compatibility analysis of the formation and effluent showed that the maximum residue appears when the mixing is carried out in ratio 50:50 and it is 5.50 g/dm^3. Looking at this amount of residue, we can easily assume that colmatage problem in injection well if obviously actual.

For the entire time of well no.326 usage as an injection well there was conducted many hydrochloric acidizing, as a results of which it often was no any tangible effects, and even if it is appear, it was ephemeral. This means that existing used methods in our case even if they cleans up and release of the pore space, the effect of this is not much considerable, therefore it should be proposed and introduced other methods of well bottom hole zone decolmatation. (Anichshenko, L., 2012).

Systematization of decolmatation methods. In practice in stimulation of hydrogeological and geotechnical wells used more than 20 ways of productive layers decolmatation. The multiplicity of decolmatation methods necessitates their systematization. Professor Fedorov B.V. (2010) proposed a new systematization of decolmatation methods. The main underlying principle – is a type of energy acting on the reservoir. In accordance with the principle all the methods of reservoirs completion are divided into physical, chemical and combined. Each of these methods, in turn, is divided by the techniques and means of formation stimulation.

The physical method of the stimulation is divided into mechanical, hydraulic and hydraulic pulse, the chemical - on the impact of a particular chemical agent, physico-chemical - to the specific technical and technological means of influencing on the reservoir. Group of physical methods of fluid loss recovery include techniques based on hydraulic and mechanical cleaning of well strainers and hydraulic pulse techniques. (Apel'tsin, M. E., 1960)

Vibrational well screen cleaning technique. The main attention in this work is paid to vibrational method, and more precisely to vibrational well screen cleaning technique in oil and gas industry. This method of cleaning can be used while reservoir completion in the producing well and in produced water disposal into the deep horizons.

There is one device which is used for clay cake removal of the water-bearing stratum (Beisebayev et al., 1990). The working body of this device presents a pipe string with fixed on it with a certain step thin disks (membranes). Working body is lowered into the well and located against the previously installed well screeners (filters). The upper end of the column is rigidly connected with a vibrator positioned on the surface. When you turn on the latter, working body commits longitudinal vibrations that are transmitted to fluid. Emerging high-frequency periodic pressure differences contribute to efficient clay cake removal of the aquifer and clean the filter. Products of destruction are removed from the well by air lift pumping out which is implemented by applying compressed air through compressor pipes located inside the working body. The main drawback of this device is a location of the source of vibrations (vibrator) on a surface. As a result, with increasing depth of the required for decolmatation reservoir, the amplitude of the oscillation and energy of the working body are reduced and become insufficient to create a pressure differences in liquid required for the destruction of the filter cake and filter cleaning. Therefore, this method is used for clay cake removal for reservoirs at depths no more than 200 m. A second disadvantage of the device is use of two types of energy: electrical - to drive the vibrator, pneumatic - for airlift.

Technical solution for well screen cleaning. Technical solutions for well strainer cleaning, device which excludes deficiencies, listed above - downhole hydraulic vibrator (Beisebayev et al., 1990). It made in the cylindrical housing within which the membrane is fixed. Through membrane passed rigidly fixed tube with fixed on it spring-loaded bypass valve overlapping the opening in the housing. Below said, hole installed closed chamber inside which the pipe has side vents. On the exiting from the chamber section of the pipe installed with a certain interval disks whose diameters are few smaller than the inner diameter of the filter. The pipe in the areas between the disks has side vents and is enclosed in the core body. The cavity formed by the membrane housing and the base of the latter, communicates with the drillstring. Hydrovibrator on the drill string is lowered into the wellbore and set in the filter, and then the water is pumped into the drill string by high pressure pump. The water pressure trapped in the cavity of the body, force the membrane to move upwards, and rigidly associated with it valve opens the hole in the housing. The water rushes into the closed chamber, fills it through the lateral holes, further passes through the tube and discharged through the side holes are located between the discs. Thereafter, the water pressure in the cavity drops. Under the action of the spring, membrane and the valve are returned to the initial position, covering hole in the base of housing. The cycle then repeats in the same sequence. There is an arising vibration of the pipe with the disks and cheeks in a liquid forms hydrodynamic impulses. Under the influence of the latter and pulsating jets of water, clay particles and sediments, clogging the filter and aquifer are break down and are carried out through the annulus. The disadvantage of this device is the complexity of the design, the lack of energy of vibrations and the unreliability of the working body. Because of small amplitude of oscillations of the hydrovibrator membrane, hydrodynamic energy of pulses in the number of cases is not sufficient for efficient cake removal in the aquifer.

A device for vibrational cake removal. The closest technical solution is a device - vibrational clay cake removal (USSR Standarts № 966174, 1982). The device consists of a drill string bottomhole pneumatic percussion machine and pneumatic unit, located from the bottom end of the bottom-hole machine. Vibrating unit perceives shock pulses of the piston striker of the hammer through the anvil, interacting with the vibrating mechanism and rigidly connected to the pipe. On the tube assembled membranes, which in the striking mode, interact with fluid in the borehole, by initiating in it shock waves acting on the filter surface and bushings, having an outlet openings for the spent fluid in the striker. Occurring vibrations on tube with disks in a liquid form hydrodynamic pulses under the influence of which there is a destruction of clayey deposits on the well strainer. The disadvantage of this device is the complexity of the design and low power hydraulic shocks in a liquid during the hydrodynamic vibrating affecting the filter and the filter cake.

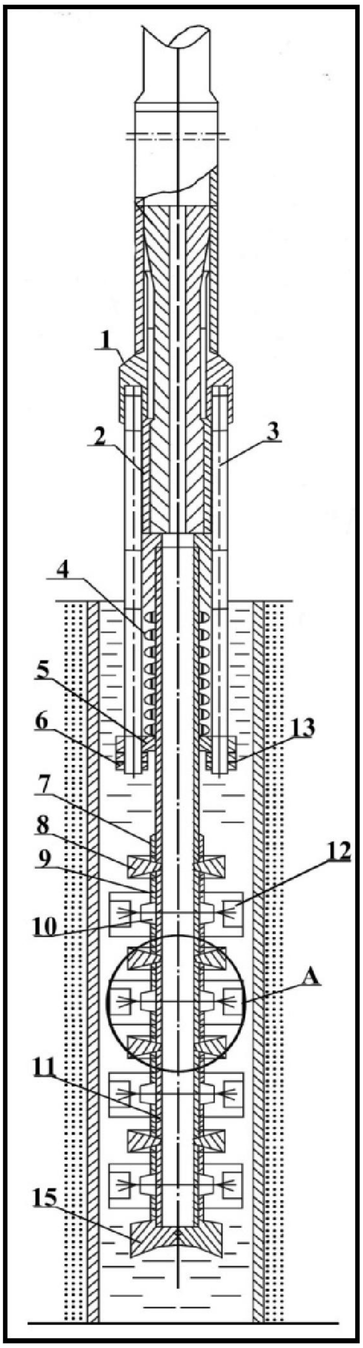
Methodology. Objective of the proposed technical solutions is to increase the power of the hydrodynamic fluid oscillations and creating of bulk field oscillations of the liquid column within the filter range, acting on the well screen and the filter cake.

A solution of the technical problem is achieved by a device for vibration well screen and well purification, and filter cake removal in aquifers. This device is composed of a drill string and vibration node representing the tube with membrane made in the form biconcave lens and separated by annular bushings placed in the core casing. Biconcave lenses act as hubs of shock pulses. The core housing comprises rods, an annular bottom and hydraulic submersible impact tool arranged between the drill string and the vibratory unit, in turn, vibrating unit is rigidly connected to the anvil of downhole percussion machine. (Anichshenko, L., 2012).

Vibrating unit located on spring suspension and is adapted to reciprocating movement relative to the casing of downhole percussion machine. The bottoms of the rod body are designed as hubs lens with a concave surface. The sleeves placed on the tube of vibrating node have a uniformly distributed through the 90^0 radial nozzles with tapering channels communicating with the anvil channel for waste water removing. Moreover, sleeves with narrowing nozzle implemented as an ultrasonic vibration source according to the type whistle "Hartmann". Source of oscillations is designed as a cup with a bottom in which from the nozzle jet of liquid is supplied under high pressure and at high speed. As a result, in the liquid ultrasonic vibrations are formed, i.e. the vibration volumetric field within the column of fluid along the length of the filter. A preferred choice of hydraulic hammer as a hydraulic impulses generator is justified by the fact that the design of these machines is developed and proven, it differs by reliability and simplicity, and the energy of individual impact reaches 150 J at frequencies up to 3,000 strokes per minute. Hydropercussion machine may provide vibrational filters cleaning located at a depth of 2000 meters or more, when for an air lift filter cake and sediments pumping out from the well screen can be used pneumatic

The technical result of the proposed technical solutions is to increase the filter cleaning efficiency of absorbing wells and reducing the time of their development and completion.

Results. The essence of the proposed device is illustrated by drawing given in Figure. The device consists of a hydraulic hammer (shown its lower end) and connected thereto by means of the adapter *1* hydraulic-vibratory working body *2*. Upper part of the latter through the thrust hub is connected with the anvil of a hydraulic hammer and by a spring *4*, studs *3* screwed into the adapter *1* and the flange *5* constitutes an oscillating system. For spring tension adjustment on the lower ends of the studs, passed through the flange *5*, are screwed nuts *6* and lock nuts *13*. Bushings mounted in a nozzle *10* (*4* nozzles are located uniformly along the lateral surface of the sleeve). In order to prevent uncontrolled leakage using the limiter *7*, bushings gaskets are clamped by hub made in the form of a concave disk, in this case playing



Scheme of the device for well screens cleaning in absorbing wells

the role of the clamping nut. Opposite the tapered nozzle *10* arranged at a certain distance hollow cylindrical sleeves *12* fixed on the yoke *13* attached to the tube *11*, by screw *14*.

Operation is as follows. After tailing-in of the reservoir on the walls of the well and on the well screen colmatation crust is deposited. To eliminate the negative colmatation effects and restore the natural permeability of the producing formation (water or oil), proposed device is lowered on drill pipes into the well. After setting of a hydraulic hammer with a vibratory unit at the bottom part of the well strainer, the liquid (water) is supplied into drill pipes. Piston-peen of a hydraulic hammer is beginning at a certain frequency (up to 3000 strokes per minute) hitting an anvil. The presence of spring *4* causes the vibrating assembly and membranes *8* - concentrators of shock waves to make reciprocating displacement. Fluctuations of membranes and emerging in liquid shock waves create in the latter alternating high pressure. Alternation high pressure through filter holes impact on colmatage sediment, causing their delamination and destruction. Discharged fluid while passing through the anvil channels and tube *11* is ejected through the radial nozzle openings *10*, screwed into sleeves *9* are uniformly distributed over its surface, forming an aerated liquid mix. Opposite sleeves *9* with nozzles 10 is located at concentrators of ultrasonic oscillations - hollow cylindrical sleeve *12* to which under pressure fluid jet is ejected, forming a an ultrasound field in the fluid column in a borehole, which vibrationally with a high-frequencies acts on the part of the well where well screen is located, purifying it from colmatation sediments and forming an aerated liquid mixture. As a result there an air-lift (gas lift) appears pumping out with clay and colmatation particles from the well. Thus, the use of the proposed device implements the combined reservoir decolmatation: effects on wells colmatation sediment by alternating pulses of high frequency and the impact on the borehole wall created in the well by volumetric ultrasound field. As a result of pumping out there is and occurrence of not only the removal of the colmatation particles, but also the creation conditions when reservoir pressure becomes greater than the hydrostatic pressure of the fluid in the well. Therefore, the well strainer cleaning process will be amplified. By moving the proposed device in the range of the well screen installation, pursue full clarification of water pumped out from the well. On this the well screens cleaning process and decolmatation of the productive formations ends.

Also, a vibration device in its lower part comprises a shock pulses hub with a concave surface for the amplification of shock pulses along the well, which allows maintaining the constant excited condition of the liquid column in the well. In the proposed device as a shock pulse generator – a bottomhole hydraulic submersible impact tool- is used. When using a hydraulic submersible impact tool, hydraulic pulse impact on the filter cake and colmatation sediment will increase due to the influence of ultrasonic vibrations on the wall of the wells formed by the ejected through the radial nozzle channels 10 fluid into a generator of ultrasonic oscillations - a hub 12. The speed of the ejected liquid in the nozzles is increasing due to narrowing design of the latter. For removal from the wellbore of the fluid, clay cake degradation products and filter deposits, using an additional descent into the well tubing string to organize an air lift pumping out. Thus, the method of vibration filter cleaning and device for its implementation will improve the efficiency and reduce the time of the cake removal and well screen cleaning in the absorbing wells during their construction and operation.

Conclusion. Proposed device is a solution, created based on experience of the other, previously and nowadays used devices for the decolmatation of the injection wells. The aim of the proposed technical solutions is to increase the filter cleaning efficiency by increasing the power of the hydrodynamic fluid oscillations and creating of bulk field oscillations of the liquid column within the filter range, acting on the well screen and the filter cake with high efficiency. The proposed device can be manufactured in accordance with all existing standards characteristic for productive formations completion equipment and may find advantageous application of their operation, as well as after their full working off, for injection into the formation of waste water processing products of oil emulsions. As proposed device at this moment are only development which has not yet any practical implement, it is difficult to comprehensively evaluate its efficiency, but still theoretical estimated economic efficiency is about 37 %. The projected skin-factor is -4.53.

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ЗАКАЧКА ПРОМЫШЛЕННЫХ СТОЧНЫХ ВОД В ГЛУБОКИЕ ГОРИЗОНТЫ НЕДР – ПРОБЛЕМЫ КОЛЬМАТАЦИИ И ОЧИСТКИ

Л. В. Анищенко

Казахский национальный технический университет им. К. И. Сатпаева, Алматы, Казахстан

Ключевые слова: промышленные сточные воды, процесс закачки, кольматация, методы и техника декольматации, фильтры.

Аннотация. Освещена возможность закачки промышленных стоков в глубокие горизонты через поглощающие скважины. Промышленные стоки представляют собой технологический раствор, который в процессе закачки образует осадок в призабойной зоне скважины, вызывая кольматацию принимающей части поглощающей скважины и собственно фильтра. Основное внимание уделено технике вибрационной разглинизации и очистки фильтров скважин в нефтегазовой отрасли, что может быть использовано для наиболее оптимальной закачки промышленных стоков в глубокие горизонты.

ҚОЙНАУЫНЫҢ ТЕРЕҢ ГОРИЗОНТЫНА ӨНДІРІСТІК АҒЫНДЫ СУДЫ АУДАУ – КОЛЬМАТАЦИИ ЖӘНЕ ТАЗАЛАУ МӘСЕЛЕЛЕРІ

Л. В. Анищенко

К. И. Сәтбаев атындағы Қазақ ұлттық техникалық университеті, Алматы, Қазақстан

Тірек сөздер: өнеркәсіптік ағынды сулар, егіп айдау үдерісі, кольматация, декольматацияландыру әдістері мен техникасы, фильтрлар.

Аннотация. Мақалада өнеркәсіптік ағыстарды терең деңгейжиектерге сіңіргіш ұңғылар арқылы егіп айдау мүмкіндігі көрсетілген. Өнеркәсіптік ағыстар егіп айдау барысында сіңіргіш ұңғының түбі маңында технологиялық ерітінді тұңбасын пайда қылып, сіңіргіш ұңғының қабылдау бөлігінің және фильтрдің кольматациялануына итермелейді. Басты назар өнеркәсіптік ағыстарды терең деңгейжиектерге аса оңтайлы егіп айдауға пайдалана алатын вибрациялық саздансыздандырылу және мұнайгаз саласындағы ұңғылардың фильтрлерін тазарту техникасына аударылды.

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