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AN EFFECTIVE DEVICE FOR THE DEVELOPMENT OF SHALLOW AQUIFERS

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Abstract. The basic problem is the colmatation of the bottomhole zone of aquifers and oil reservoirs, which reduces the flow rate and efficiency of wells. This problem is especially relevant for shallow aquifers (up to 400-500 m), where there are no simple and reliable implosion devices capable of providing a sharp pressure drop and effective reservoir cleaning. Solving this problem is critical for increasing the productivity of water intake wells and reducing operating costs. A structurally simplified implosion device has been proposed and patented, including a large-diameter production column, a smaller-diameter filter, a packer, a partition with a spring-loaded shut-off valve and a chute interacting with it. To study the device,

methods of modeling the implosion process, calculating columns for crumpling, taking into account the liquid level and its own weight, analyzing pressure losses in the intake valves, as well as optimizing the geometric parameters of the openings were used. Calculations have been performed for specific geological conditions, including the Tonirekshin deposit. The key hypothesis is that the short-term instantaneous connection of high and low pressure zones creates an implosion effect of sufficient intensity to destroy the colmated zone around the filter. The research results confirmed this hypothesis: implosion ensures effective cleaning of the reservoir, and the destruction products are removed during subsequent pumping. Optimal design parameters and conditions for repeated implosion effect are also substantiated. The practical significance of the results lies in the possibility of using the developed device and its calculation methods in the construction of shallow water intake wells. This makes it possible to improve their performance without using complex and expensive equipment, ensure safe operation of the columns, reduce the cost of reservoir cleaning and increase the durability of water intake facilities.

Key words: implosion effect, development, aquifer, shut-off valve, vent, decollimation

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ТАЯЗ ЖАТҚАН СУЛЫ ҚАБАТТАРДЫ ИГЕРУГЕ АРНАЛҒАН ТИІМДІ ҚҰРЫЛҒЫ

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Аннотация. Негізгі проблема-ұңғымалардың өнімділігі мен тиімділігін төмендететін сулы және Мұнай қабаттарының кенжар аймағын колматизациялау. Бұл мәселе әсіресе таяз сулы горизонттарға (400-500 м дейін) қатысты, мұнда қысымның күрт төмендеуін және қабаттың тиімді тазалануын қамтамасыз ететін қарапайым және сенімді имплозиялық құрылғылар жоқ. Бұл мәселені шешу су ұңғымаларының өнімділігін арттыру және пайдалану шығындарын азайту үшін өте маңызды. Жұмыста үлкен диаметрлі жұмыс бағанасын, кіші диаметрлі сүзгіні, пакерді, серіппелі өшіру клапаны бар бөлімді және онымен өзара әрекеттесетін желонканы қамтитын конструктивті жеңілдетілген имплозиялық құрылғы ұсынылды және патенттелді. Құрылғыны зерттеу үшін имплозия процесін модельдеу, сұйықтық деңгейі мен өз салмағын ескере отырып, мыжылған бағандарды есептеу, кіріс клапандарындағы қысымның жоғалуын талдау, сондай-ақ тесіктердің геометриялық параметрлерін оңтайландыру әдістері қолданылды. Тонирекшин кен орнын қоса алғанда, нақты геологиялық жағдайлар үшін есептеулер жүргізілді. Негізгі гипотеза – жоғары және төмен қысымды аймақтардың қысқа мерзімді лезде қосылуы сүзгінің айналасындағы қадалған аймақты бұзу үшін жеткілікті қарқындылықтың әсер етуін тудырады. Зерттеу нәтижелері бұл гипотезаны растады: имплозия қабаттың тиімді тазалануын қамтамасыз етеді және жойылу өнімдері кейіннен сорылған кезде жойылады. Сондай-ақ, оңтайлы дизайн параметрлері мен қайталанатын әсер ету шарттары негізделген. Нәтижелердің практикалық маңыздылығы – таяз су ұңғымаларын орналастыру кезінде әзірленген құрылғыны және оны есептеу әдістемесін қолдану мүмкіндігі. Бұл күрделі және қымбат жабдықты пайдаланбай олардың өнімділігін жақсартуға, бағандардың қауіпсіз жұмыс істеуін қамтамасыз етуге, қабаттарды тазарту шығындарын азайтуға және су қабылдау қондырғыларының беріктігін арттыруға мүмкіндік береді.

Түйін сөздер: жарылу эффектісі, игеру, сулы горизонт, өшіру клапаны, байлер, деколматация

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ЭФФЕКТИВНОЕ УСТРОЙСТВО ДЛЯ ОСВОЕНИЯ НЕГЛУБОКО ЗАЛЕГАЮЩИХ ВОДОНОСНЫХ ПЛАСТОВ

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Аннотация. Базовая проблема заключается в кольматации призабойной зоны водоносных и нефтяных пластов, что снижает дебит и эффективность скважин. Эта проблема особенно актуальна для неглубоких водоносных горизонтов (до 400–500 м), где отсутствуют простые и надёжные имплозионные устройства, способные обеспечить резкий перепад давления и эффективную очистку пласта. Решение данной задачи критично для повышения производительности водозаборных скважин и снижения эксплуатационных затрат. В работе предложено и запатентовано конструктивно упрощённое имплозионное устройство, включающее эксплуатационную колонну большого диаметра, фильтр меньшего диаметра, пакер, перегородку с подпружиненным запорным клапаном и взаимодействующую с ним желонку. Для исследования устройства применялись методы моделирования имплозионного процесса, расчёта колонн на смятие с учётом уровня жидкости и собственного веса, анализа потерь давления во впускных клапанах, а также оптимизации геометрических параметров отверстий. Проведены расчёты для

конкретных геологических условий, включая месторождение Тонирекшин. Ключевая гипотеза заключается в том, что кратковременное мгновенное соединение зон высокого и низкого давления создаёт имплозионный эффект достаточной интенсивности для разрушения кольматированной зоны вокруг фильтра. Результаты исследований подтвердили эту гипотезу: имплозия обеспечивает эффективную очистку пласта, а продукты разрушения удаляются при последующей откачке. Также обоснованы оптимальные конструктивные параметры и условия для повторного имплозионного эффекта. Практическая значимость результатов заключается в возможности применения разработанного устройства и методики его расчёта при обустройстве неглубоких водозаборных скважин. Это позволяет улучшить их производительность без использования сложного и дорогостоящего оборудования, обеспечить безопасную эксплуатацию колонн, снизить затраты на очистку пласта и повысить долговечность водозаборных сооружений.

Ключевые слова: имплозионный эффект, освоение, водоносный пласт, запорный клапан, желонка, декольматация

Introduction. Numerous methods have been created to date for the development of aquifers in the construction of water intake and technological wells, each of which contains development methods (Akramov et al., 2022: 2432, Dong et al., 2018: 1326-1339), which, in turn, are divided into methods of influencing the colmated seam.

Methods and tools based on vibrations transmitted by a colmated ring region around the filter, which is destroyed in fatigue mode, are widely used in the development of deep wells. This procedure takes a long time, but it is, since it occupies an appropriate place in the overall balance of time during the construction of deep wells (Akhundov et al., 2023: 22-35, Zhang et al., 2023). Another pattern is observed in the construction of shallow water intake wells, when the used aquifers lie at depths up to 300-400 m. Simple, structurally inexpensive means should be used to de-line aquifers in such conditions, providing a very large pressure drop between the enclosed area adjacent to the outer surface of the filter and the inner zone of the filter and the production column, where minimum pressure is created (Zhang et al., 2023, Rakishev et al., 2014: 22-27, Hayitov et al., 2020: 2327-2332). A large pressure drop often exceeds the strength of the colmated crust. As a result, the products of destruction enter the column and are subsequently removed from the well.

The group of means providing the mentioned pressure drop includes: pumping by airlift or flow pump, back-suction flushing, developed by VSEGINGEO (Grydzhuk et al., 2019: 6-14, Kholismatov et al., 2022). The most effective are hydro-pulse methods based on the impact of shock waves combined with pumping on the opened aquifer. The implosion method occupies a special place among the mentioned methods; the essence of it is the instantaneous creation of a pressure

drop between the colmated crust of an aquifer under reservoir pressure and the low pressure zone created inside the filter and production columns (Khayitov et al., 2022: 247-260, Koroviaka, et al., 2023: 127–139). Methods and devices have been developed to create an implosion effect, which are used in deep wells to increase oil production, for example, (Rakishev et al., 2022), the Russian patent "Method of hydroimpulse implosion treatment of wells", RI2750978C2 (2019-2-10, authors Gerasin A.S. Kuzik L.V.), Russian patent "Device for multiple implosion", RI12099I1 (2012-10-10, author Kuzik L.V.). A tubing column, an implosion chamber, pressure concentrators, a plunger and valve, a geophysical device are used to create an implosion effect. The analysis of the design indicates the complexity and high cost of the device, which are justified by the intensification of oil production.

Materials and methods of research. The relevance of the work lies in the proposal for the practical development of shallow aquifers opened by rotational drilling using flushing with clay solution, a simple and effective device using an implosion effect during operation. It is proved that the latter creates one of the largest, instantaneous pressure drops, intensively destroying the colmated area around the filter (Ratov et al., 2021a, Ratov et al., 2021b, Ratov et al., 2023c).

The objectives of the work are:

- description of the schematic diagrams and operation of the patented device;
- investigation of the effect of an unfilled «empty» space filled with liquid to initiate the

implosion effect on the strength of the production column;

- analysis of the interaction of the vent valve with the intake valve;
- the effect of the size of the intake valve, which affects the required weight of the valve and the

pressure loss in the valve;

- the effect of repeated implosion effects on the decolmation process;
- justification of the practical application of the device when drilling water wells at the

Tonirekshin field (Mangystau Peninsula).

We have proposed and patented a device for stimulating the implosion effect in the development of shallow water intake wells (Ratov et al., 2023d, Ratov et al., 2023e). The device is simple in design and less expensive to manufacture. Its schematic outline is shown in Fig. 1. The diameters of the filter and production columns, the depth of the well and the occurrence of the aquifer, the height of the solution above the partition and the critical length of the "empty" (unfilled with drilling mud) production column are also indicated here.

An empty space 10 is left in the production column 1 in this device. The receiving part of the well 2 is separated from the column 1 by a partition 6. An inlet valve 7 is mounted on it. It is shown in Figure 2 how, when the valve is closed, its disc 7 covers the holes 12 in the partition 6. The disk is pressed against the partition by

reservoir pressure and also by a spring 11. There is a sharp inflow of water from the reservoir when connecting the receiving part with a low pressure zone (Driscoll, 1986). The tubular space of the receiving part is isolated from the same space of column 1 (Fig.1) by an elastic packer 5, triggered by the weight of the casing. (Fig.1)

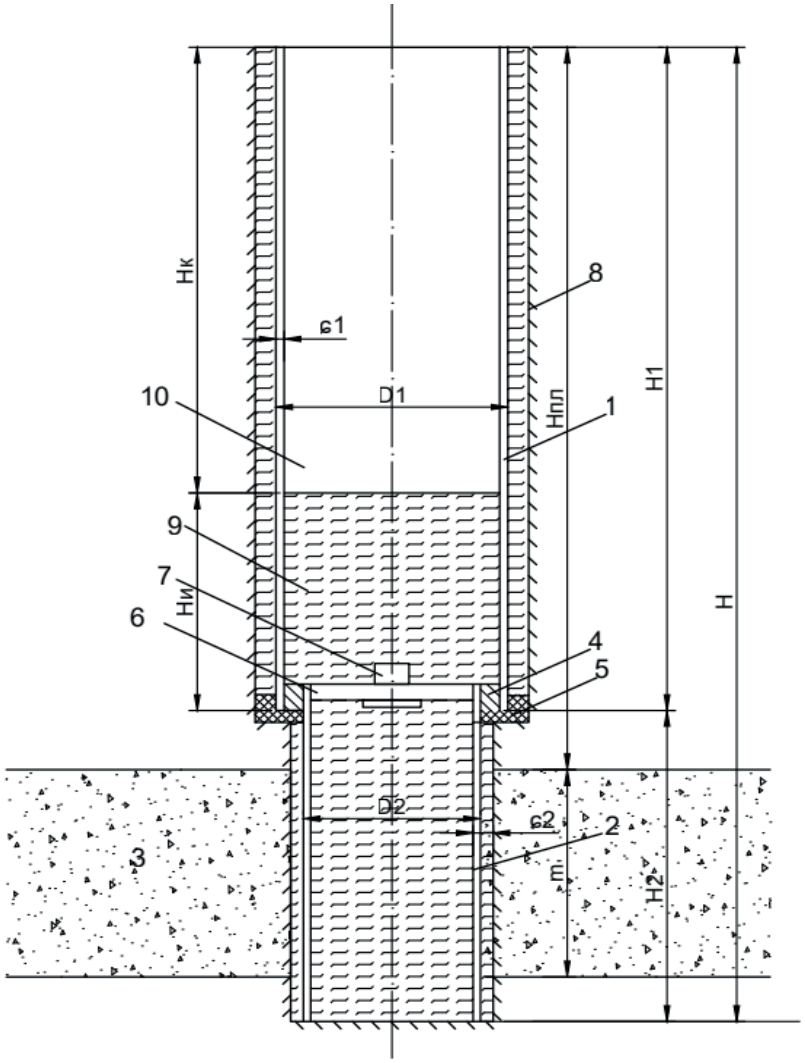

Fig. 1. A device for creating an implosive effect

1 – production column; 2 – filter column; 3.– aquifer; 4 – adapter; 5 – packer; 6 –partition; 7 – inlet valve; 8 – well wall; 9 – solution; 10 – air; 11 – water barrier; H – well depth; $H_{ПЛ}$ – depth of the aquifer; m is its capacity; H_1 – the length of the production column; H_2 – the length of the filter column; $H_{СН}$ – the static pressure of the formation; $H_К$ – the critical length of the empty part of the column; $H_И$ – the height of the solution above the partition; D_1 – the outer diameter of the production column; D_2 – the same filter column □1 is the wall thickness of the production column; □$_2$ – the same filter column

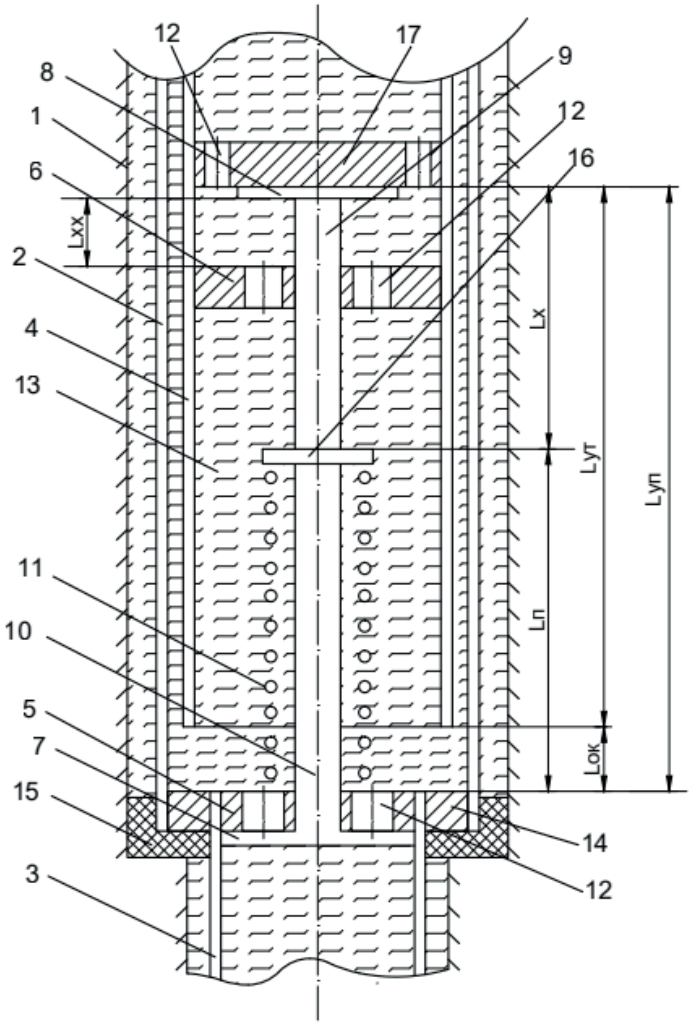

Fig. 2. The beginning of the implosion effect
1 – well wall; 2 – production column; 3 – filter column; 4 – chute; 5,6 – partitions; 7 – inlet valve disc; 8 – chute valve disc; 9 – shank; 10 – rod; 11 – spring; 12 – holes; 13 – drilling mud; 14 – adapter; 15 – packer; 16 – washer; 17 – stop; $L_{уп}$ – the initial distance from the stop to the partition 5; $L_{ут}$ – the distance from the stop to the end of the chute; $L_{х}$ –the length of the shank; $L_{п}$ – the length of the uncompressed spring; $L_{ок}$ – the amount of lowering of the intake valve disc

The solution displaced by column remains in the tubular space and fills it to the mouth when the column is lowered. The hydrostatic pressure created by this solution, acting externally on the left unfilled part of the column, can cause its crumpling.

The safety factor of the casing for crumpling (Ratov et al., 2020: 141-147, Togizov et al., 2023):

$$n_f = \frac{p_{map}}{Ð_f}, \quad (1)$$

where p_{map} – maximum allowable pressure, and P_f – the actual pressure difference between the outside and inside of the column.

Following parameters are needed to determine p_{map}: σ_m – yield strength of steel; E – its modulus of longitudinal elasticity; $D_н$ – nominal outer diameter of the tube: $D_{\min}$ and $D_{\max}$ – permissible limits of this diameter according to the manufacturing conditions; σ, σ_0, $\sigma_{\min}$ – nominal, average and minimum permissible wall thicknesses are recommended to have following values: $\sigma_0 = 0.905\sigma$, $\sigma_{\min} = 0.875\sigma$ (Pavlychenko., 2022, Istekova et al., 2022. Petrov et al., 2021).

In conditions of a well:

$$P_K = \rho_P g H_K, \quad (2)$$

where ρ_P - density of solution, g - acceleration of free fall;

H_K – the permissible height of the "empty" space 10 (Fig.1).

$$H_K = \frac{p_K}{\rho_P g}; \quad (3)$$

$$H_i = H_1 - H_K; \quad (4)$$

The implosion-inducing depression is equal to:

$$P_d = P_{sp} - P_P g H_i, \quad (5)$$

where P_{sp} - seam pressure.

It is necessary to pour into it a volume of solution, when lowering the column, which is equal to:

$$V_i = \frac{\pi}{4}(D_1 - 2\sigma_1)^2 * H_i. \quad (6)$$

Results and discussion.

An algorithm and a corresponding computer program have been compiled to calculate the wall thickness for a column with a diameter of 168 mm for drilling conditions of water intake wells at the Tonirekshin deposit. The length of the "empty" (unfilled with solution) interval with a wall thickness of 8 mm is 256 m, and with a wall thickness of 9 mm it is almost 300 m, which corresponds to the

conditions for the development of an aquifer lying at a depth of 400 m. Calculations also showed, that pipes with a diameter of 122 mm showed a 40% higher crumple resistance.

Additionally, the corresponding Archimedean force has been calculated, which reduces the weight of the column due to the presence of an "empty" interval in the column by 43-47%. This is important for calculating the required winch power when using light drilling rigs (Menezes 2017).

An analysis of the interaction of the vent valve with the intake valve has been carried out. The inlet valve is closed under the action of a bottom-up differential pressure P_d directed at its disc 7 (Fig. 2) when there is no contact with the bailer, and it is equal to:

$$P_d = P_{sp} - \rho_p g H_i, \tag{7}$$

as well as the tension of the spring 11. Differential pressure creates a force:

$$F_3 = \frac{\pi}{4} D_{dv}^2 P_d, \tag{8}$$

where D_{dv} – diameter of the valve disc.

The weight of the disc with the rod 10 (fig. 2) acts towards the opening of the valve, but it is small compared to the force of the differential pressure.

It is necessary that the weight Gж of the bailer exceeds the force F_3 to open the valve with a bailer:

$$G_j > F_3 \tag{9}$$

The bailer is lowered into the well with a sharp slowdown in the rate of descent and reaches the moment when the shank 9 of the bailer valve touches the upper end 16 of the spring 11 (Fig. 2). The spring 11 and the intake valve itself remain stationary during further downward movements, but at the same time the shank 9 with the disc 8 moves up relative to the end of the bailer. This movement continues until it stops 17. Then the weight of the bailer begins to act on the rod 10, opening the inlet valve (Fig. 2). The pressure under the partition is rapidly falling, and the reservoir pressure is instantly replaced by the differential pressure of the P_d, creating an implosion effect.

The bailer is lowered between the moments of the first contact of the shank 9 with the spring 11 and the opening of the intake valve, by a distance equal to:

$$L_j = L_i + L_{lv}, \tag{10}$$

where L_i – «idling» (without load) of a disc 8 from the partition 6 to the stop 17 (Fig. 2), L_{lv} – lowering of the intake valve disc 7 when it is fully open. If the full possible compression of the spring turns out to be too short, then the bailer will hang on the spring, and its end will not reach the partition. As a result, the spring may be broken. Therefore, the L_{OK} path should be only a part of its possible compression, taking into account the pre-compression to keep the valve closed. The required length of the spring is determined based on these conditions.

The specified opening of the valve L_{OK} will be ensured if the stop 17 is mounted at the next distance from the end of the bailer:

$$L_{UT} = L_S + L_L - L_{OK}, \tag{11}$$

Where L_L – the length of the spring before contact with the bailer,

L_S - the length of the shank 9.

Formulas (8) and (9) make it possible to determine the force required to open the intake valve by a given diameter of the disc. If the own weight of the bailer is insufficient, then it should be weighted down by lowering the drill tubes fixed on top of the rope.

Pressure losses at the openings are determined by the formulas of the inlet valve:

$$P_{PL} = \frac{Q^2 \rho_B}{2\alpha^2 S^2}, \text{ or } P_{KЛ} = \frac{V_{MT}{}^2 \rho_B}{2\alpha^2}, \tag{12}$$

where Q – seam water consumption; V_{MT} – the speed of water movement through the holes; ρ_B – water density; α – consumption coefficient is equal to α = 0.67; S – the total area of the holes.

As a flow rate, its maximum value under these conditions is taken, determined by:

$$Q = \pi D_F m V_F \quad \text{м}^3/\text{ч} \tag{13}$$

where D_F – filter diameter; m – thickness of water seam; V_F – acceptable filtration rate.

The latter is determined by the formula:

$$V_F = 2.71\sqrt[3]{K_F}. \tag{14}$$

The maximum possible hole area for a given diameter of the inlet valve disc is equal to:

$$S = \pi / 4(D_{KH}^{2} - D_{KB}^{2}) - 3(D_{KH} - D_{KB})\sigma_{П} / 2 \ . \quad (15)$$

Pressure losses in the valve at maximum inflow were calculated according to the developed algorithm and computer program, which, with valve diameters of 30 mm and 40 mm, turned out to be excessively large. The diameter D_{KH} = 70 mm is accepted as a rational value. The pressure loss is only 0.054 MPa with this diameter, and the bailer should be weighted with the addition of six drill tubes with a diameter of 73 mm.

The calculation of the repeated implosion effect on the colmated seam in the case of incomplete removal of the colmatant is carried out. The bailer is extracted from wells for this purpose and the bailer is extracted from the well. The spring 11 (fig. 2) closes the inlet valve, the water is bailed out until the height of the water above the partition reaches the set value H_{IB} . The latter is calculated using the formula:

$$H_{IB} = \frac{H_I \rho_P}{\rho_B}, \quad (16)$$

because with repeated implosion effects, the solution must be removed. Next, the bailer is lowered back onto the intake valve and the implosion effect is repeated.

When bailing out, the number of runs with the bailer should be equal to:

$$N_{Ж} = \frac{\pi / 4D_{D1}^{2}(H_{CH} - H_{IB})}{\pi / 4(D_b - 2\sigma_b)^2 L_b}, \quad (17)$$

where D_{D1} – inner diameter of the casing, D_b and σ_b – the outer diameter and wall thickness of the bailer; L_b – length of the bailer.

The developed algorithm and the corresponding computer calculation program are performed in relation to typical conditions of the Tonerekshin area.

The following calculated data are shown at the output:

- force F_3, acting from below on the intake valve;
- metric $L_{бк}$ of tubes with diameter 73 mm, with which it is necessary to weigh down the bailer;
- the total area of the inlet valve openings and the water velocity in the mentioned openings;
- pressure loss $P_{кл}$ on the intake valve;
- the total number of runs of the bailer (without weights) is 33, with a solution interval above the partition H_I=136 m.

Conclusion

1. Permissible dimensions of casing columns necessary to create an implosion effect of unfilled liquid intervals have been investigated according to the condition of preventing their crumpling.

2. The weight reduction of casing columns under the influence of the Archimedean force due to the presence of "empty" (not filled with liquid) intervals in them is investigated.

3. An optimal well design is proposed for the conditions of the Tonerekshin deposit, including the device proposed by the authors for creating an implosion effect.

4. The value of reducing the weight of the casing in the well due to the Archimedean force is calculated.

5. The interaction of the vent valve with the intake valve to induce an implosion effect is studied.

6. The dependence of the required weight of the valve on the size of the intake valve disc is studied.

7. Pressure losses on the intake valve depending on its area are studied.

8. The conditions providing a repeated implosion effect are determined.

9. The calculations of the main design parameters of the proposed device, taking into account the real hydrogeological conditions of the Tonerekshin deposit, indicate a great effect when used for groundwater extraction at this deposit.

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