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**ВЕСТНИК**

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РЕСПУБЛИКИ КАЗАХСТАН

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### **PROTECTION OF CENTRIFUGAL PUMPS FROM ABRASIVE WEAR USING A VACUUM HYDROCYCLONE**

**Abstract.** The design features of the existing design and technology for the protection of downhole pumps of the ECV type from abrasive wear during operation are considered and analyzed. Based on the analysis, a new method for capturing solid impurities on the suction line of a borehole pump of the ECV type using a pressure-vacuum hydrocyclone is proposed.

It is specified that at field tests of a prototype of new installation technological process is estimated on the pressure-expense characteristic and technological-operational indicators according to requirements of GOST 6134-81 " pumps dynamic. Test method. " In this case, the flow rate of the base pump on water is determined by means of a turbine water meter mounted on a water-lifting pipe with a valve. The performance of the hydraulic elevator is established by the volumetric method, and the head in front of the valve of the pump pressure pipe using an approximate pressure gauge.

It is established that the flow-pressure characteristics of the base submersible pump ECV are provided in full (water flow 60-70 m<sup>3</sup>/h, head - 110-118 m), overload on the electric motor is not detected (ammeter readings are within the permissible limits-68-71 amperes), the degree of water purification is 95-96%.

It is noted that the implementation of a flexible packer device with slots and the presence on the surface of the second minihydrocyclone-thickener significantly improves the functioning of the adopted scheme of water treatment. It turned out that with this technology, the overload of the pump motor is reduced by cooling with water without mechanical impurities.

**Keywords:** well, sanding, submersible pump, abrasive wear, vacuum hydrocyclone, test, degree of purification

**Introduction.** The relevance of the topic under consideration is that in most operated water wells on a global scale, depending on the state of the annulus, sanding of various degrees often takes place [1-5].

For example, in Kazakhstan at present about 60% of wells of municipal services work in the sand mode. This is due to the violation of the interaction mode of the system "well-pump" in use, the decrease in the efficiency of the filter and for other reasons of a hydrogeological nature. Therefore, in some wells, especially those located in the desert and semi-desert zones of the Republic, the content of solid particles can exceed the norm of solid particles for centrifugal pumps (less than 0.05 g/l) by 3-5 times [6-8].

As a result, sanding occurs intensive wear of the working elements of the used pump type ECV (figure 1) and their failure before the service life. Reduces the overhaul period of the well. Restoration of the base pump requires a lot of costs, because overhaul of the pump type ECB costs 70-80% of its base cost. Untimely provision of settlements with drinking water due to the pump stop prevents the solution of a social problem of great importance.

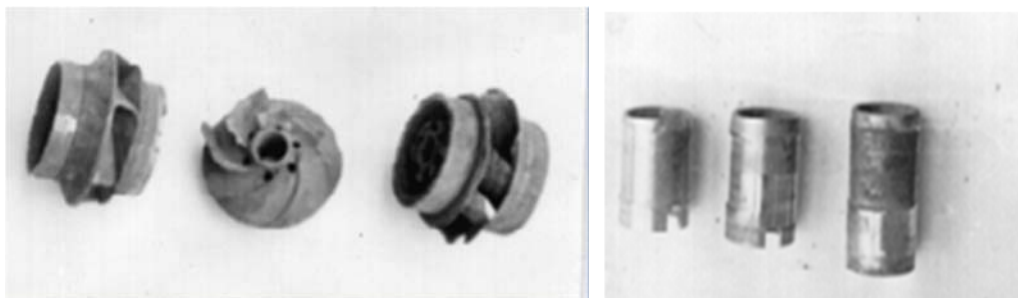


Figure 1 – Types of wear of impellers (a) and submersible pump bushings (b)

One of the effective solutions to this problem is to supply the submersible pump with a hydrocyclone receiving chamber (separator) for separating sand from water in the well [6-9]. The captured Sands are usually not left in the well, but are brought to the surface with the help of ejecting devices bypassing the working bodies of the pump.

In work [6] methodical instructions on maintenance of normal operation of borehole submersible pumps that can reduce level of sanding and abrasion of a surface of impellers of the pump by mechanical impurity are stated.

The main advantage of the LAKOS(R) separator, as in other devices of similar action, is to prevent the possibility of abrasion of the surfaces of the impellers and bearings of the submersible pump [7]. However, the presence of it leads to a loss of pressure from 2 to 7 pounds per square inch. The maximum particle size is 1/4". According to the authors of this work, after installation, the separators do not require daily maintenance.

The technical result of the invention described in [8] is achieved by the fact that in a downhole pumping unit, the chamber for collecting mechanical impurities of the hydrocyclone and the ejector are made together in one volume along the flow of the liquid, and the hydrocyclone is located with the cone part upwards.

The technical solution according to model No. 108104 [9] is aimed at increasing the efficiency of separation of mechanical impurities by reducing hydraulic head losses in the flow part of the separating unit. The dependences of the separator performance characteristics on the granulometric composition of mechanical impurities contained in the extracted fluid are revealed.

In studies conducted in LLC "PC "Borets" (Russia), it was found that the developed design of the separator with hydrocyclone separation of mechanical impurities with a density of 2000 mg/l provides cleaning efficiency in the range of 95-97% [10]. It differs from others in the absence of rotating parts.

The hydrocyclone separator described in [11,12] differs from the existing ones in that it has an inner diameter, which decreases as the fluid moves along the inner perimeter of the hydrocyclone. The design includes a pressure reducing device located near the inlet end of the discharge pipe to facilitate the movement of solid particles through the discharge pipe.

In General, the analysis of the above technical solutions and other submersible pumps with hydrocyclone separators used in practice shows the effectiveness of this technology for protecting the base pumps from abrasive wear.

Hydrocyclone method of fight against wear is justified also at water purification from mechanical impurity in systems of renewable energy sources, in particular at improvement of the technological scheme of mini hydroelectric power station [13-15].

However, further improvements are still required, taking into account the wide variety of construction and operation of water wells.

Based on this, we set the task of improving the action of the packer device for separating the hydrocyclone from the pump during its operation. This is necessary to force water with mechanical impurities into the hydrocyclone device and prevent sand from entering directly into the submersible pump. Another task was to obtain the maximum thickening of the ejected pulp after cleaning on the surface by additional installation of a minihydrocyclone. This significantly reduces the loss of water when the condensed mass is ejected into the dump.

**Description of the essence of development and testing methods.** The essence of the developed water intake technology, designed to improve the performance of a submersible pump with a hydro-cyclone-seperator, is as follows [16-18].

The unit, unlike the existing ones, on the suction line is equipped with a vacuum hydrocyclone Hc with a packer device Pp in the form of an elastic cuff (figure 2). Next to the submersible pump Ps, lowered into the well Wl, there is a pulp suction pipe Pt, hydraulically connected to the hydraulic Elevator He, located at the pump outlet.

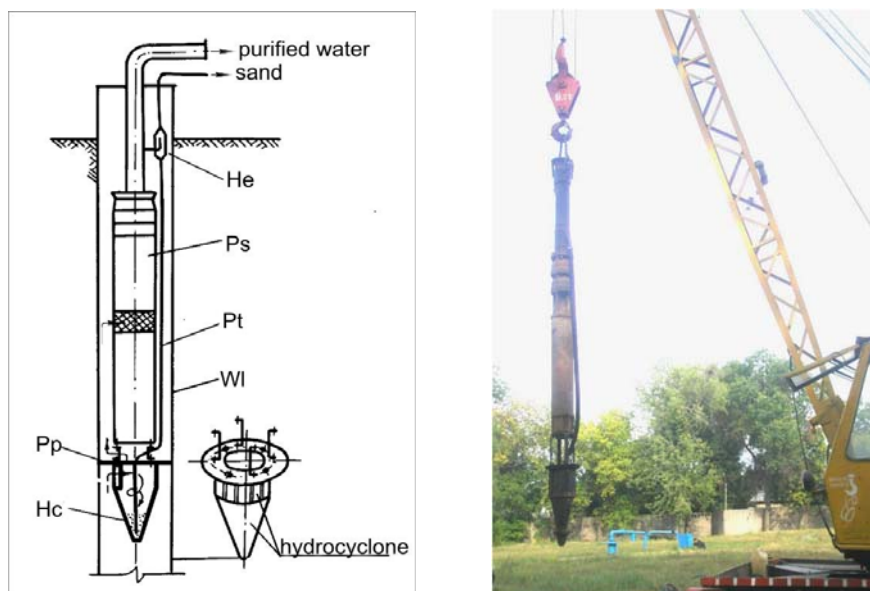


Figure 2 – A structural diagram (a) and the prototype pump of the ECW is provided with a vacuum hydrocyclone

*Principle of operation.* When starting the pump Ps liquid with mechanical impurities enters through the holes in the hydrocyclone Hc, because the wellbore Wl blocked packer device Pp. In the hydro-cyclone, the absorbed liquid, due to the strong rotational movement, is divided into liquid and solid phases. Solid particles are thrown to the top of the cone and accumulate in the condensation chamber.

The clarified part of the water through the drain neck of the hydrocyclone is sucked off by a submersible pump and fed to the surface to the consumer. In this case, a small part of the water, seeping through the slots of the flexible cuff, keeps it in a balanced state.

The condensed mass from the chamber is ejected through the pulp suction pipe Pt by the hydro-elevator He to the surface, bypassing the working bodies of the pump. On the surface of the pulp enters minimization and undergoes a secondary treatment.

To conduct the test, the base submersible pump installed in the well was first pulled out of the well. Then a hydrocyclone chamber and a hydraulic Elevator were connected to the pump. The finished installation with the help of a crane was lowered back into the well to a depth of 25-30 m and the water-lifting pipe was rigidly fixed with a special clamp on the head. The upper end of the water-lifting pipe was directed to the discharge tray for water removal, and the pulp-removing hose was directed to the mini-hydrocyclone. The static water level in the well was 3-4 m, and the dynamic decrease ranged from 10-13 m.

In order to more accurately determine the head at nominal supply, the analytical characteristic of the pump for the working section of the characteristic was calculated by the method of least squares.

During field tests of the plant, the technological process was evaluated by the pressure-flow characteristics and technological-operational indicators. The timing of the working time of the shift was considered by lifting (extraction) of the operated pump unit to the surface, assembling and mounting the hydrocyclone with a hydraulic Elevator, installing the unit in the well, starting the pump and pumping out the pulp.

The tests were carried out in accordance with the requirements of GOST 6134-81 "dynamic Pumps. Test method."



The flow rate of the base pump on water was determined by means of a turbine water meter mounted on a water-lifting pipe with a valve. The performance of the hydraulic Elevator on the pulp was set by the volumetric method, and the head before the valve of the pressure pipe of the pump with the help of an exemplary pressure gauge. The characteristic of the installation was removed during crane operation.

**Test results and discussion.** The purpose of the test is to clarify the pressure-flow characteristics of the submersible pump ECV10-65-110 when supplying it with a hydrocyclone and determine the degree of water purification.

The geometrical parameters of the unit with a hanging hydrocyclone and a cuff were as follows: the diameter of the cylindrical part of the hydrocyclone chamber was 300 mm (the diameter of the elastic cuff was taken on the basis of the inner diameter of the well), the diameters of the drain pipe and the sand hole were 240 mm and 50 mm. The dimensions of the last variant – 30x220 mm. The Specified parameters of the hydrocyclone apparatus were determined according to the method of calculation of centrifugal action units, based on the features of their application [19,20].

The results of the acceptance test in conjunction with the operated facility are shown in table 1.

Table 1 – Results of acceptance test of the pump with a hydrocyclone

Pressure at the outlet of the well (before the valve), NN, m	121,0	118,0	115,0	110,0	95,0
Flow rate of the base pump ECV10-65-110, Q, m <sup>3</sup> / h	55,0	60,0	65,0	70,0	75,0
Water flow through the mini-Elevator, q, l / s	0,60	0,55	0,50	0,45	0,40
The degree of purification of water (by pump),C,%	95,0	96,0	96,0	95,0	96,0

As can be seen from table 1, the developed installation fully corresponds to the initial parameters for raising water from sand wells. The achieved degree of water purification allows to preserve the passport service life and to carry out preliminary cleaning of the well from mechanical impurities.

Analysis of the composition of the removed part of the sand deposits shows that the degree of capture of mechanical impurities using hydrocyclone-thickener at the required level. The flow of water through minihydropower equal to 0,45-0,65 l/s.

After operation for 5500 hours and external inspection and removal of some basic parameters submersible pump with hydrocyclone was re-lowered into the well with the help of a crane for further testing and testing of the process of raising water from the sand wells.

At the same time, in order to more accurately determine the head H at the nominal supply Q, the analytical characteristic of the pump for the working section of the operating mode by the method of least squares was calculated, which was equal to:

$$H = 97,83 + 5,524 * Q - 0,2751 * Q/2 \quad (1)$$

Computing deviation values of the pressure of H<sub>wic</sub> from experienced H<sub>ad</sub> was calculated by the formula:

$$H_o = (H_{wic} - H_{ad}) / H_{ad} * 100\% \quad (2)$$

The calculated pressure of the pump made:

- 1) with a minimum feed (13.48 l/s) - 121.24 m;
- 2) at nominal feed (18.63 l/s) - 106.18 m;
- 3) at maximum feed (22.25 l/s) - 90.41 m.

The achieved values of deviations within the permissible limits (2-3,5%) indicates a high accuracy of measurements during the test of the pump.

The second stage of tests was carried out on the rise oversanded water with a significant concentration of sand (1.23-1.30 m<sup>3</sup>/t), ie, in the mode of cleaning the well with the help of the basic pump.

The technological process was worked out using the installation on the basis of the pump ECV 10-160-35G with the following main dimensions: the diameter of the cylindrical part of the hydrocyclone 245mm, the diameters of the drain pipe and the sand hole, respectively, 165mm and 36 mm. the Total height of the hydrocyclone was 610mm. The test results are shown in table 2.

As can be seen from the table, the presence of a hydrocyclone does not lead to a special deviation of the parameters of the base pump and they vary within acceptable limits.

Table 2 – Test results of the installation for raising water from sand wells on the basis of the pump ECV 10-63-110G

The time of filing water, T, s	Pressure gauge reading, R, m	Pump flow, Q, l/s	The pump head, H, m	Note
0	138	0,00	138,45	The valve is closed
94,2	129	9,59	130,02	
69,5	121	13,28	120,88	
57,6	108	18,05	109,00	
57,6	108	18,26	108,25	
52,5	99,8	19,32	100,02	
45,1	91	20,27	91,05	
42,5	79	21,95	80,10	
39,6	67	23,41	68,25	The valve is open
39,9	67	23,25	68,26	
41,6	73	21,42	74,10	
43,4	83	21,00	84,11	
47,1	92	19,17	93,12	
51,7	103	17,25	104,23	
62,0	113	14,62	114,25	
79,1	122	12,52	123,80	
135,1	133	7,55	134,75	
0	138	0,00	138,15	The valve is closed

It was found that the performance of the minihydroelevator on the ground varies within 0.75...1.08 m<sup>3</sup>/h. the Volume concentration of the raised pulp (14.3...15.0 %) is within the permissible limits for transportation, which allowed to ensure uninterrupted supply of the mixture to the surface. This once again confirms the need for a hydrocyclone-thickener (figure 3).



Figure 3 – The types of the end walls of the well with minimization – thickener (a) and work well with purified water (b)

The continuity of pulp transportation, which is associated with the unhindered suction of solid particles from the mouth of the hydrocyclone, contributed to an increase in the degree of water purification on the suction line of the pump. Due to this, only dusty Sands with dimensions of 0.005...0.05 mm, having the least abrasiveness, pass through the working body of the pump. The main components and parts of the pump unit are practically not subjected to mechanical wear.

Increasing the pressure head after the displacement chamber of the minihydroelevator is achieved by overlapping the water-lifting pipe of the pump with the help of a valve. Then the flow rate of the base pump for clean water is reduced by the volume of pulp transported through the sand hole of the minihydroelevator (5.5...6.0 m<sup>3</sup>/h). Reduction of the pump flow rate on water during cleaning does not affect the mode of

pumping groundwater from wells, because it is short-term and is restored after the completion of cleaning works.

During the tests, it was found that there is also a decrease in the overload of the motor. The specific consumption of electricity per 1 m<sup>3</sup> of water ranged from 0.11 ... 0.12 kW/m<sup>3</sup>, which does not exceed the indicator of the pump unit without a hydrocyclone.

No less important point is also the fact that the additional supply of pumping units with hydro-cyclones does not prevent their connection to the scheme of contactless automatic control of the PUMP.

The granulometric composition of the sand deposits brought to the surface by the hydraulic Elevator from the well consists of medium-grained (31.2 %) and coarse-grained (48.6 %) Sands.

During the testing period, due to the improvement of working conditions (protection against mechanical impurities, removal of overload of the electric motor), there was an improvement in the operation of submersible pumps.

During operation, the base pump was not subjected to noticeable overload, because it operates on purified water. Readings of the ammeter and voltmeter corresponded to the nominal values of the motor current and operating voltage specified in the passport.

It turned out that during the cleaning of the well, the installation can be serviced by two people – the operator and the driver of the crane. After cleaning, the unit is operated as a submersible water lifting unit.

Experiments in production conditions generally confirmed the possibility and feasibility of using submersible water-lifting pumps of the ECV type. The economic effect of the use of a new submersible pump unit with a hydrocyclone is achieved by reducing operating costs and increasing the service life of the pump while maintaining its quality characteristics (annual operating time, durability, etc.). Commercialization of the project results at this stage is carried out by the developers and Technopark.

#### **Conclusion:**

1. Flow and pressure characteristics of the basic submersible pump ECV provided in full (the water flow rate is 60-70 m<sup>3</sup>/h, head – 110-118 M.);

2. Overload on the electric motor is not detected (ammeter readings are within the permissible limits - 68-71 amperes);

3. The degree of water purification is 95-96%. Undetectable parts in the form of clay particles (less than 50.0 microns) do not cause abrasive wear of pump elements;

4. The presence of a rubber packer on the cylindrical part of the hydrocyclone allows to reduce vibration especially at the time of starting the submersible pump in operation.

5. The pump head in the entire working area of the pump corresponds to GOST 10428-89E "downhole electric pump Units for water".

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#### **ВАКУУМДЫҚ ГИДРОЦИКЛОН КӨМЕГІМЕН ОРТАДАН ТЕПКІШ СОРАПТЫ АБРАЗИВТІ ҚАЖАЛУДАН САҚТАУ**

**Аннотация.** Мақалада ЭЦВ типтес ұңғыма сораптарын абразивті қажалудан сақтаудың белгілі құрылғылары мен технологияларының құрылымдық ерекшеліктері қарастырылып, талданған.

Мұндай жағдайға басты себеп – Қазақстан Республикасының сумен жабдықтау нысандарында жыл сайын су ұңғымаларының құмдануына байланысты, онда орнатылған ЭЦВ-6 және ЭЦВ-8 маркалы сораптардың 40-50%-на дейін істен шығады, ал олардың 4 мыңға жуығы жаңаларына ауыстырылады және осы шамада жөндеуге беріледі. Бұзылған ұңғыманы және су көтеретін қондырғыларды қалпына келтіру аса көп шығындарды талап етеді. Мысалы, ЭЦВ типті ұңғыма сорабын күрделі жөндеуден өткеру оның базалық құнының 70-80%-ын құрайды.

Осы талдаулардың негізінде вакуумды гидроциклонды қолдана отырып, ЭЦВ типтес ұңғымалық сораптың сору желісінде қатты қоспаларды ұстап қалудың жаңа әдісі ұсынылған.

Жаңа қондырғының тәжірибелік үлгісін өндірістік жағдайда сынау кезінде технологиялық процестің тегеуріні және су беру мүмкіндіктері, технологиялық және пайдалану көрсеткіштері келтірілген және ГОСТ 6134-81 «Динамикалық сораптар. Сынақ әдістері» талаптарына сәйкес бағаланған. Осы жағдайда базалық

сораптың су шығыны турбиналы су есептегіштің көмегімен есептелген. Гидроэлеватордың қойыртпақ көтеру өнімділігі көлемдік анықтау әдісімен, ал қысым – сынақтан өткен манометр көмегімен анықталған.

Сынақтан өткеру нәтижесінде базалық сораптың ағынды – қысым сипаттамалары толық сақталатын-дығы (су өтімі 60-70 м<sup>3</sup>/сағ, тегеурін 110-118 м аралығында), электр қозғалтқышына артық жүктеме болмайтындығы (амперметр көрсеткіштері рұқсат етілген диапазонда 68-71) ампер), суды тазарту деңгейі 95-96% құрайтыны анықталған. Сорап қозғалтқышының шамадан тыс жүктемесін азайту негізінен оның негізгі бөліктерін механикалық қоспасыз сумен салқындатуға байланысты екендігі көрсетілген.

Саңылау бекітетін пакердің майда тесіктермен жасалғаны және жоғарғы жақта екінші минициклоны қосу қажеттігін көрсетті.

Өндіріс жағдайындағы сынақ нәтижелері, негізінен, гидроциклонды қабылдау камерасымен жабдықталған ЭЦВ типтегі сораптардың жұмыс сипаттамаларының жақсаратындығын растайды.

Жаңа сорап қондырғысының экономикалық тиімділігіне, пайдалану шығындарын азайту және сораптың сапалық сипаттамаларын (жылдық жұмыс уақыты, ұзақтылығы және т.б.) сақтау жағдайында, оның қызмет ету мерзімін арттыру арқылы қол жеткізіледі.

**Түйін сөздер:** ұңғыма, құмдану, ұңғыма сорабы, абразивті қажалу, вакуумды гидроциклон, сынақтан өткеру, тазалау деңгейі.

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### **ЗАЩИТА СКВАЖИННЫХ ЦЕНТРОБЕЖНЫХ НАСОСОВ ОТ АБРАЗИВНОГО ИЗНОСА С ПОМОЩЬЮ ВАКУУМНОГО ГИДРОЦИКЛОНА**

**Аннотация.** Рассмотрены и проанализированы конструктивные особенности существующих конструкций и технологии по защите скважинных насосов типа ЭЦВ от абразивного износа при эксплуатации.

Это связано с тем, что на объектах водоснабжения РК по причине пескования водозаборных скважин ежегодно выходят из строя до 40...50% установленных насосов ЭЦВ-6 и ЭЦВ-8, из которых до 4 тыс. штук заменяется на новые и примерно такое же количество ремонтируется. Восстановление работоспособности скважины и водоподъемного устройства связано с большими затратами на ремонтные работы. Например, капитальный ремонт погружного насоса типа ЭЦВ обходится 70...80% его базовой стоимости.

На основе проведенного анализа предложен новый способ улавливания твердых примесей на всасывающей линии скважинного насоса типа ЭЦВ с помощью гидроциклона напорно-вакуумного действия.

Указано, что при полевых испытаниях опытного образца новой установки технологический процесс оценен по напорно-расходной характеристике и технологическо-эксплуатационными показателями в соответствии с требованиями ГОСТ 6134-81 "Насосы динамические. Методы испытаний".

При этом расход базового насоса по воде определен при помощи турбинного водомера, установленного на водоподъемной трубе с задвижкой. Производительность гидроэлеватора по пульпе определена объемным способом, а напор перед задвижкой напорного патрубка насоса – с помощью образцового манометра.

Установлено, что расходно-напорные характеристики испытуемого базового погружного насоса ЭЦВ обеспечиваются в полной мере (расход воды 60-70 м<sup>3</sup>/ч, напор – 110-118 м), перегрузки на электродвигатель не обнаружены (показания амперметра находятся в допустимых пределах - 68-71 ампер), степень очистки воды составляет 95-96%. Снижение перегрузки электродвигателя насоса преимущественно происходит за счет охлаждения его основных частей водой без механических примесей.

Отмечено, что выполнение гибкого пакерного устройства с прорезами и наличие на поверхности второго минициклона – сгустителя значительно улучшает функционирование принятой схемы водоподготовки.

Результаты испытаний в производственных условиях в целом подтверждают возможность и целесообразность использования погружных водоподъемных насосов типа ЭЦВ с гидроциклонной приемной камерой.

Экономический эффект от применения нового погружного насосного агрегата с гидроциклоном достигается за счет снижения эксплуатационных затрат и увеличения срока службы насоса с сохранением его качественных характеристик (годовая наработка, долговечность и т.д.).

**Ключевые слова:** скважина, пескование, погружной насос, абразивный износ, напорно-вакуумный гидроциклон, испытание, степень очистки.

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