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DEVELOPMENT AND RESEARCH OF A TECHNOLOGICAL SCHEME FOR CHAMBERLESS FILTERING WATER TECHNOLOGICAL ENVIRONMENTS

РОЗРОБКА ТА ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОЇ СХЕМИ БЕЗКАМЕРНОГО ФІЛЬТРУВАННЯ ВОДНИХ ТЕХНОЛОГІЧНИХ СЕРЕДОВИЩ

This robot has developed a technological scheme for tubeless purification of water media from mechanical houses and oil materials. This technology allows for the purification of synthetic and cotton-paper filter materials for purification. A method has been developed to increase the productivity of chamberless purification and removal of analytical deposits and the productivity of filtration depending on the operating modes of the filter unit and the type of filter material.

***Keywords**: filtration, productivity, flow stream, filter material, tubeless purification.*

Експлуатація, технічне обслуговування та ремонт автотранспорту призводять до утворення різних виробничих відходів, які за певних умов шкідливо впливають на навколишнє середовище. Вони можуть забруднювати ґрунт, водні басейни та атмосферу. Найбільш поширеними та масовими виробничими відходами є відпрацьовані водні технологічні середовища (технологічна вода, спеціальні мийні розчини) від мийних установок для зовнішнього миття автомобілів та їх складових частин.

У процесі миття автомобілів водні середовища насичуються не тільки твердими речовинами (гравієм, піском, глиною, мулом, колоїдними частинками, залишками сипучих вантажів, що перевозяться в кузовах автомобілів), а й мастилами, залишками палив. Для миття знятих з автомобілів при ремонті деталей, вузлів та агрегатів застосовуються спеціальні мийні машини, в яких використовуються в розчиненому вигляді миючі засоби — каустична сода, тринатрійфосфат, рідке скло, синтетичні поверхнево-активні речовини та інші луги. Після певного часу експлуатації миючий розчин вимагає заміни на новий, а миючий розчин, що відпрацював, повинен утилізуватися, так як до його складу входять шкідливі речовини.

Очищення рідини від твердих забруднень та нафтопродуктів має здійснюватися постійно. Наявність забруднень знижує якість мийних операцій, погіршує експлуатаційні та функціональні властивості самих водних технологічних середовищ. Для очищення водних технологічних середовищ застосовують баки-відстійники, магнітні сепаратори, центрифуги, флотатори, фільтрувальні установки, магнітні фільтри, гідроциклони. Однак через певні вимоги до якості та тонкості очищення великих витрат рідини не всі з цих пристроїв можуть бути ре-

комендовані. Пристрої для очищення водних технологічних середовищ мають бути безперервно діючими. В іншому випадку потрібно виділення додаткових площ для встановлення накопичувальних ємностей. Найбільш преспективними для очищення миючих розчинів є фільтрувальні установки.

У роботі наведена розробка технологічної схеми безкамерного очищення водних середовищ від механічних домішок та мастильних матеріалів. Дана технологія дозволяє використовувати для очищення рідини синтетичні та бавовняно-паперові фільтрувальні матеріали. Наведена методика визначення продуктивності безкамерного очищення та отримані аналітичні залежності продуктивності фільтрування в залежності від режимів роботи фільтрувальної установки та типу фільтрувального матеріалу.

***Ключові слова**: фільтрування, продуктивність, струмінь рідини, фільтрувальний матеріал, безкамерне очищення, водне середовище.*

Problem's Formulation

Operation, maintenance and repair of vehicles lead to the formation of various industrial wastes, which, under certain conditions, have a harmful effect on the environment. They can pollute the soil, water bodies and atmosphere. The most common and massive industrial waste is waste aqueous technological media (process water, special washing solutions) from washing installations for the external washing of cars and their components.

During the car washing process, aqueous environments are saturated not only with solid substances (gravel, sand, clay, silt, colloidal particles, residues of bulk cargo transported in car bodies), but also with lubricating oils and fuel residues. To wash parts, components and assemblies removed from vehicles during repair, special washing machines are used, which use detergents in dissolved form — caustic soda, trisodium phosphate, liquid glass, synthetic surfactants and other alkalis. After a certain period of operation, the cleaning solution must be replaced with a new one, and the used cleaning solution must be disposed of, since it contains harmful substances.

Analysis of recent research and publications

The authors in the works [1, 2] study the research of wastewater filtration using traditional methods and technologies, which require bulky systems and equipment, reliable sealing between pressure and filter elements. The disadvantages of these technologies are the low filtering performance and periodic operation of the installations.

In the works [3, 4, 5] the authors reveal the technology of cleaning mechanical impurities using gravity cleaning. This technology has many disadvantages when used in industry. Such cleaning systems are very cumbersome, require constant cleaning and human intervention, are inefficient and have a low degree of cleaning, and require constant improvement and modernization.

In the work [6, 7] the author reveals and conducts research on the technology of bio-logical wastewater treatment of enterprises. This technology requires the use of a wide range of biological and chemical reagents. This technology leads to the formation of harmful waste, which is quite difficult to dispose of.

The technology of wastewater treatment by the method of flotation, which is considered in the work [8] allows to increase the productivity of cleaning and to mechanize technological processes. But the disadvantages of this technology include the average degree of purification of water environments from lubricants and their increased emulsification during pumping by pumping stations.

Formulation of the study purpose

Cleaning the liquid from solid contaminants and petroleum products must be carried out constantly. The presence of contaminants reduces the quality of washing operations and impairs the operational and functional properties of the aqueous technological media themselves. To purify aqueous technological media, settling tanks, magnetic separators, centrifuges, flotators, filter units, magnetic filters, and hydrocyclones are used. However, due to certain requirements for the quality and fineness of cleaning large flows of liquid, not all of these devices can be recommended. Devices for cleaning aqueous process media must be continuously operating. Otherwise, the allocation of additional space for the installation of storage tanks is required. The most promising for cleaning washing solutions are filter units

Presenting main material

The traditional technological scheme of the filtration process is based on creating a difference in liquid pressure before and after the filter partition. This technological scheme requires the use of discharge and drain chambers, between which a filter baffle is located. This, in turn, requires the creation of effective and reliable sealing devices for the discharge and drain chambers. In addition, the process of purifying liquid from mechanical impurities becomes periodic and difficult to automate.

These disadvantages can be eliminated by using the energy of a swirling free jet of liquid. A diagram of the filtration process using the energy of a swirling free jet of liquid is presented in Fig. 1.

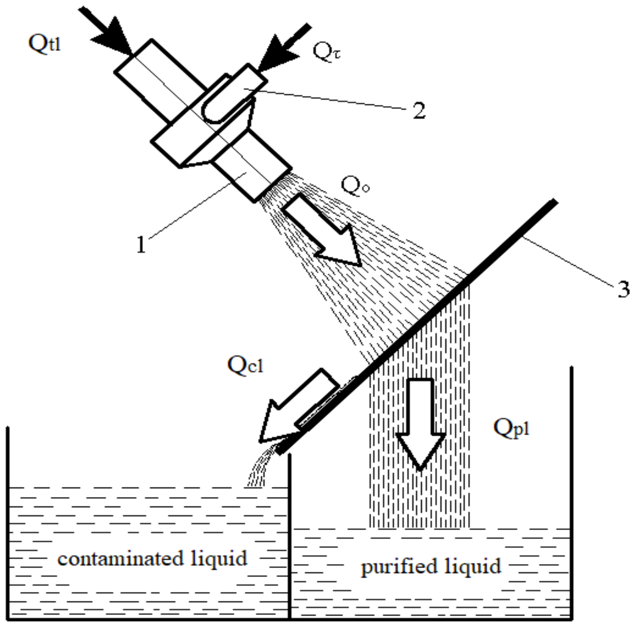


Fig. 1. Scheme of the chamberless filtration process: 1 — nozzle; 2 — tangentially embedded pipe; 3 — filter partition

Liquid contaminated with mechanical impurities is fed into the nozzle through a tangentially embedded pipe 2, which serves to screw the liquid flow. During the filtering process, under the influence of the pressure of a jet of contaminated liquid, part of the total volume of liquid penetrates through the filter partition 3. In this case, the solid particles contained in it are retained on the partition, and the purified liquid enters a container located behind the partition. The rest of the liquid volume, without penetrating the partition, is discharged back into the container with the contaminated liquid, while simultaneously washing away the layer of sediment formed on the filter partition. Filter partition 3 consists of a support mesh on which various filter fabrics are installed. The filter partition can be fixed relative to the nozzle axis at an angle α = 0...90° [9].

The design of the nozzle used in the installation is shown in Fig. 2. The nozzle operates in such a way that contaminated liquid is supplied simultaneously through nozzle 1 and tangentially embedded pipe 2. The main volume of liquid is supplied through nozzle 1 and represents a liquid flow, the speed of which is directed along the axis of the nozzle.

Through pipe 2, an additional flow of liquid is supplied, which, due to the tangential location of the pipe relative to the nozzle, twists and, penetrating into the main flow of liquid, leads to the appearance of a tangential component of the speed of its movement in the nozzle. At the exit from the nozzle, the liquid flow is a helical twisted compact jet, which has a large opening angle and a shorter range compared to a straight jet.

The use of a nozzle of this type in a filter installation leads to a reduction in its overall dimensions while maintaining the required performance, as well as an increase in the service life of filter materials.

Let's consider the movement of liquid in a filter unit. An obstacle is installed in the path of liquid movement — a plane perforated with holes (Fig. 3).

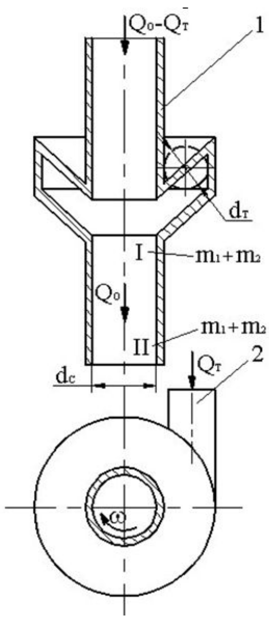


Fig. 2. Nozzle design: 1 — nozzle; 2 — tangentially embedded pipe

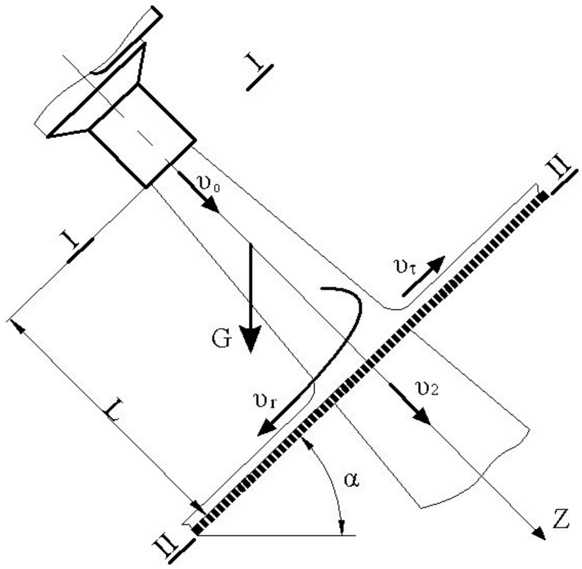


Fig. 3. Fluid movement in the filter unit: υ_0, υ_τ, υ_r, — fluid velocity, m/s; L — distance from the nozzle to the filter partition, mm; α — angle of inclination of the filter partition relative to the horizontal plane, degrees; G — is the total weight of the liquid between sections I-I and II-II

The equation for the momentum of a fluid in the direction of its movement has the form:

$$c \cdot w_1 \cdot x_0^2 + G \cdot \cos a = R_{\Pi} + c \cdot \sum w_2 \cdot x_2^2 \, , \qquad (1)$$

where w_1 — is the area of the part of the filter partition onto which the liquid stream falls, m^2; $\sum w_2$ — total area of open pores of the filter partition over an area w_1, m^2; υ_0, υ_2 — speed of liquid movement before and in the filter partition, m/s; ρ — liquid density, kg/m^3; R_n — filter septum reaction, H; G — is the total weight of the liquid between sections I-I and II-II, H; α — angle of inclination of the filter partition relative to the horizontal plane, degrees.

When calculating the reaction R_n, it is logical to assume that the pressure P_R acting on the area of the filter partition is determined as when flowing around an obstacle, and is equal to:

$$P_R = c \cdot x_0^2 + \frac{G}{w_1} \cdot \cos a \, , \qquad (2)$$

and, accordingly, the reaction itself is equal to:

$$P_R = P_R \cdot \left(w_1 - \sum w_2 \right), \qquad (3)$$

$$R_{\Pi} = c \cdot w_1 \cdot x_0^2 + G \cdot \cos a \cdot \left(1 \text{-} \frac{\sum w_2}{w_1} \right). \qquad (4)$$

The resistance coefficient of the filter partition is determined from the following relationship

$$R_f = 1 \text{-} \frac{\sum w_2}{w_1} \, . \qquad (5)$$

Substituting expression (3) into the momentum equation (1), after some transformations we obtain:

$$x_2 = \sqrt{x_0^2 + \frac{G \cdot \cos a}{c \cdot w_1}}. \quad (6)$$

The total liquid flow rate Q_{tl} emanating from the nozzle during the filtration process is divided, as shown above, into two components:

$$Q_{tl} = Q_{pl} + Q_{cl}, \quad (7)$$

where Q_{pl} — is the flow rate of purified liquid, m^3/s; Q_{cl} — discharge rate of contaminated liquid, m^3/s.

The flow Q_{pl} rate can be expressed through speed υ_0 and $\sum w_2$:

$$Q_{pl} = \sum w_2 \cdot x_2 \cdot k_n, \quad (8)$$

where k_n — is a coefficient that takes into account the permeability of the filter fabric.

Taking into account dependence (6), we obtain an equation for determining the flow rate of purified liquid during the filtration process without clogging the pores of the filter partition:

$$Q_{pl} = \sum w_2 \cdot \sqrt{x_0^2 + \frac{G \cdot \cos a}{c \cdot w_1}} \cdot k_n. \quad (9)$$

When conducting experimental studies, two types of filter fabric were used: calico and kapron mesh [10]. In order to determine the resistance coefficient of the filter partition, the diameters of the threads at the base and the wick were measured using an electron microscope, as well as the number of threads on the area $F = 10^{-4}$ m^2.

The total diameter of the threads on $F = 10^{-4}$ m^2:

calico fabric: $\sum N_0 = N_o \cdot d_o = 3.2$ mm; $\sum N_y = N_y \cdot d_y = 4.77$ mm;

kapron mesh: $\sum N_0 = N_o \cdot d_o = 5.4$ mm; $\sum N_y = N_y \cdot d_y = 7.2$ mm.

Mesh size:

calico fabric: $a_0 = \frac{10 - 3.2}{10 - 1} = 0.756$ mm; $a_y = \frac{10 - 4.77}{9 - 1} = 0.654$ mm;

kapron mesh: $a_0 = \frac{10 - 5.4}{20 - 1} = 0.242$ mm; $a_y = \frac{10 - 7.2}{15 - 1} = 0.2$ mm.

To determine the performance of the filtering unit, the amount of purified liquid was measured. To study the modes of the filtering process, we adopt the following parameters:

1) Q_{tl} — total fluid flow, Q_{tl} = 0.8; 1.0; 1.2 l/s;

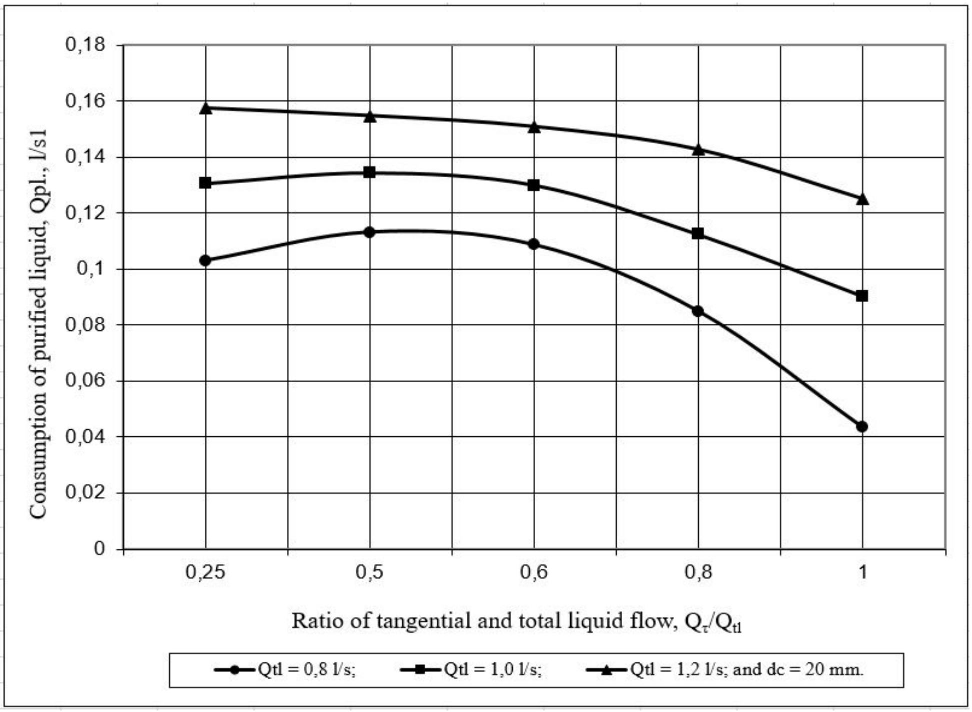
2) ratio Q_τ/Q_{tl} (Q_τ — fluid flow through a tangentially cut nozzle), Q_τ/Q_{tl} = 0.25; 0.5; 0.8; 1.0.

In order to prevent premature failure of the filter partition, we place it on a metal mesh with a mesh size of 10^{-3} m. The permeability of the filter material at the same time remains unchanged.

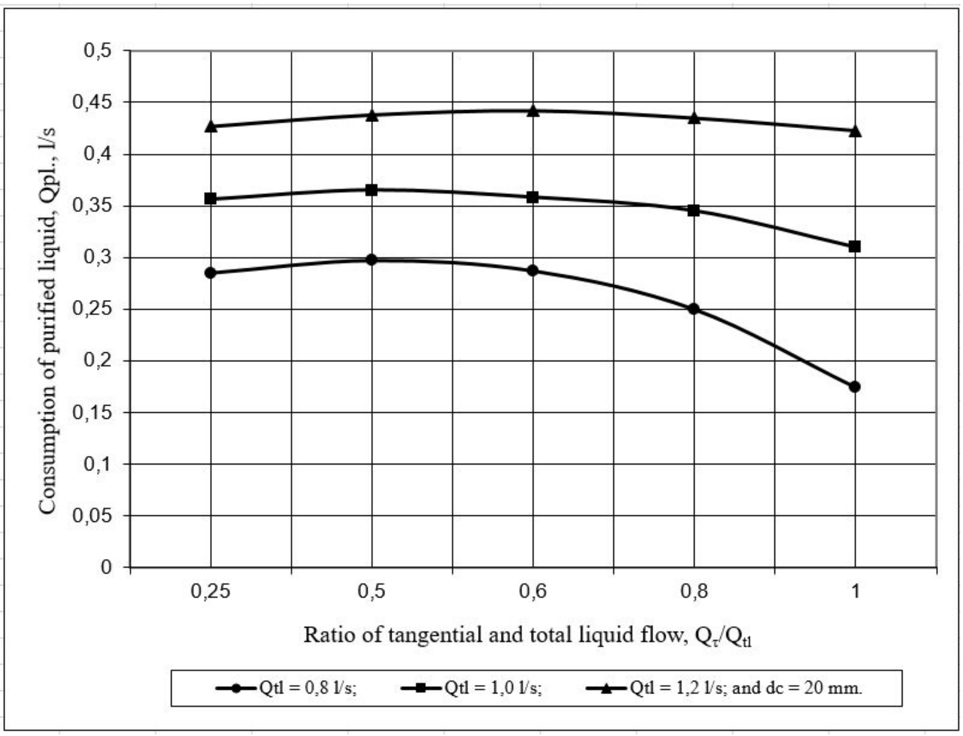
According to the data of experimental data processing, graphical dependencies were constructed, which are presented in Fig. 4. The analysis of the results of experimental studies shows that with an increase in the ratio of tangential and total flow of liquid, the area of filtration increases due to the opening angle of the liquid jet, and as a result, the productivity of the filtering partition increases. With a ratio equal to 0.6—1.0, the productivity decreases, because the liquid jet goes beyond the attachments of the filter partition and the hydrodynamic pressure of the jet decreases.

Conclusions

When using a new filtering technology (chamberless filtering using a free stream of liquid), the flow rate of purified liquid initially decreases for a few minutes, and then remains stable for a long time. This is achieved due to the fact that, under the influence of the tangential component of the velocity, the denser particles of impurities located in the liquid jet are placed on the periphery of the jet without interfering with the passage of the main mass of the liquid through the filter partition. Also, particles of pollution that remain on the filter partition are partially washed away by the volume of liquid that did not pass through the partition.



а)



б)

Fig. 4. Dependencies of the performance of the filter installation on the ratio Q_τ/Q_{tl}: a) for calico fabric; b) for kapron mesh.

References

[1] Jim Lauria. (2018). Water filtration: Using water treatment to tackle the environmental footprint issue. *Filtration*. Vol.7. 20–23.

[2] Ken Sutherland. (2016). Water filtration: Bulk water filtration techniques. *Filtration and Separation*. Vol.9. 17–19.

[3] Kulalaeva N.V., Marmazynskyi O.A., Mykhailiuk V.A. (2011). Improving the means of ensuring the environmental safety of municipal wastewater [Sovershenstvovanye sredstv obespechenyia эkolohycheskoi bezopasnosty munytsypalnukh stochnukh vod]. *Elektronnyi visnyk NUK*. Vol. 1. 56–62. [in Ukrainian].

[4] Kalitsun V.I., Zapornikov V.P. (2013). Construction of horizontal sand traps [Konstruyrovanye horyzontalnыkh peskolovok]. *Vodosnabzhenye y sanytarnaia tekhnyka*. Vol. 9. 69–75. [in Ukrainian].

[5] Demydov O.V. (2015). Methods for calculating sand traps and experimental results [Metodы rascheta peskolovok y rezultatы opыtov]. *Sbornyk nauchnыkh trudov: Horodskaia kanalyzatsyia*. Vol. 4. 65–69. [in Ukrainian].

[6] Karimov R., Shulaev M., Morozov D. (2014). Biotechnology and The Environment Including Biogeotechnology. *Nova Science Publ*. Vol. 6. 79–88.

[7] Daigger G.T. (2012). The dynamics of microbial growth on soluble substrats. *Water Research*. Vol.16. 365–382.

[8] Manch R. (2010). Wastewater Fractions Add to Total Treatment Picture. *Water and Sew. Works*.. Vol. 8. 89–92.

[9] Korobochka O.N., Oliinyk L.O., Averyanov V.S. (2009). Installation for filtering liquid [Ustanovka dlia filtruvannia ridyny. Patent Ukrainy na korysnu model № 39634]. Vol. 5. [in Ukrainian].

[10] Skobeev I.K. (2008). *Filter materials [Filtruvalni materialy]*. Kyiv: Nedra. [in Ukrainian].

Список використаної літератури

1. *Jim Lauria*. Water filtration: Using water treatment to tackle the environmental footprint issue. *Filtration*. 2018. Vol.7. P. 20–23.
2. *Ken Sutherland*. Water filtration: Bulk water filtration techniques. *Filtration and Separation*. 2016. Vol.9. P. 17–19.
3. *Кулалаева Н.В., Мармазинский О.А., Михайлюк В.А.* Совершенствование средств обеспечения экологической безопасности муниципальных сточных вод. *Електронний вісник НУК*. 2011. № 1. С. 56–62.
4. *Каліцун В.І., Запорніков В.П.* Конструирование горизонтальных песколовок. *Водоснабжение и санитарная техника*. 2013. № 9. С. 69–75.
5. *Демидов О.В.* Методы расчета песколовок и результаты опытов. Сборник научных трудов: Городская канализация. 2015. № 4. С. 65–69.
6. *Karimov R., Shulaev M., Morozov D.* Biotechnology and The Environment Including Biogeotechnology. *Nova Science Publ*. New York, 2014. Vol. 6. P. 79–88
7. *Daigger G.T.* The dynamics of microbial growth on soluble substrats. *Water Research*. 2012. Vol.16. P. 365–382.
8. *Manch R.* Wastewater Fractions Add to Total Treatment Picture. *Water and Sew. Works*. 2010. Vol.8. P. 89–92.
9. Коробочка О.М., Олійник Л.О., Авер'янов В.С. Установка для фільтрування рідини. Патент України на корисну модель № 39634 10.03.2009. Бюл. № 5/2009.
10. Скобеєв І.К. Фільтрувальні матеріали. К.: Недра, 2008. 256 с.

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