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HEAT PUMP OF WATER DESALINATION

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Abstract

An energy efficient heat pump water desalinating installation, which use heat of condensation-evaporation processes in a heat pump to produce distilled water, is proposed. The consumption of energy to drive the heat pump significantly lower than the energy consumption for production of distillate. The topic is bounded with justification and development of improved technologies and combined purification of natural water in conditions of increased anthropogenic loads on natural water sources, which is a priority in the field of water preparation for heat power engineering installations. The performed overview of current situation in technogenic zone of Aral Sea region illustrates a critical need of promotion of modern methods and technologies of water preparation. It is shown the current ways of water treatment, which are recommended by Classifyer of ground water purification and their disadavnatages with considerable operational cost. For instance, in membarne distillers, which are based on reverse osmosis, mineralized water is pumped through semipermeable membranes, which are made of cellulose acetate or polyamide tar. In this case energy consumption is lying in diaposone of 5-15 kWt h/м^3. With increase of salinity the pumping pressure through membrane is increasing too as well as energy consumption. In the pressure range, when the operation of analyzed equipment is possible, the phase properties of water are preserved. The common disadvantage of these installations is high energy consumption for production of one unit of distillate. That is why a decrease of energy consumption in such installations is still an issue. In this article we present an energy efficient solution of existing problem of water dessalination with low power consumption in combined water treatment device. Technological complex scheme includes: block of preliminary purification in ultra-filtration module UFI; heat pump water desallinating device HPD (heat pump distiller), using evaporate-condensing processes for distillate production. The application is directed on provision of regeneration heat of water evaporation-condensation processes while receiving the distillat. Heat pump distiller in the comlpex of combined device is an evaporating distiller. Within it the generation and recuperation of heat of water phase trasnsformation is performed with reverse thermal dynamic cycle of heat pump. The reverse thermal dynamic cycle is performed with participation of the working medium of the heat pump, in this ceratin case it is R134A refrigerant. The techological schemes of proposed experimental installation is presented as well as schemes of water distillers: - ultrafiltartion module UFI: - heat pump distiller of water HPD. The received results of experimental research of reverse distillate quality indicators after water treatment installation are to prove it's operationability and effectiveness for small power engineering and systems of heat supply. The complex shows an energy consumption decrease, allows to exclude the use of chemical reagents, the volumes of waste waters, to reduce considerably consumption of rinse water for own needs and cost of dessalination and purification of water, as well as cost on its warming.

Keywords - heat pump, desalination plant, distiller, evaporator, exchanger.

Introduction

At present time, water resources are on second place after oil and gas resources by the significance for development of world economy. At this point, the role of technically fresh (sweet) water is very important for agriculture, for hydro energy, for production of bio-fuel and other water consuming industrial fields.

An issue of desalination of sea water, waste and mineralized waters is topical and urgent for industrial areas with hot and dry climate of Aral sea region with limited natural resources of sweet water.

Today there is a number of methods of water demineralization as distillation, reverse osmosis, ionization and electro-dialysis, which is in industrial scale use. In foreign and domestic practice installations with vapor compressing and jet devices are widely applied [1;2]. In Russia and most of CIS countries the thermal distillation units are extensively operated [3;4].

The common disadvantage of these devices is relatively high energy consumption for production of unit mass of distillate. In the range of pressures, where operation of analyzed facilities is possible the phase properties of the water must be preserved. That is why the issue of an essential reduction of energy consumption in the given types of devices is hard to get.

For example, in membranous desalter, which is based on phenomenon of reverse osmosis the salt water pumped through semi-permeable acetate cellulose membranes. In this case, the energy consumption is about 5-15 kWt h/m^3. With water salinity increase the pressure of pumped water through membranes grows and energy consumption increases.

Due to the fact that for receiving of demineralized water under circumstances of all possible varieties of water compositions in water source, the main goal of water treatment system is production of water with permanently high quality. It requires the constant monitoring of water quality source and correction of mode of water preparation installation on industrial enterprises and heat power plants.

Especially it applies to the impurities coagulation process of the water in the flood period, when it requires the use of chemical reagents in large volumes, which leads to significant grows of operational costs, costs of shipping and services, because of complexity and bulkiness of main and auxiliary equipment and the needs of defining the dose of coagulant, and the degree of alkalizing of source water and permanent control of the treated water pH indicator.

The other problem, which appears with treatment of surface water in conventional Water Treatment Device (WTD), is processing and recovery of sump residuum and filters rinse waters. The volume of residuum on such installations is about 3-4%, the amount of reverse water is up to 10-15% of the whole power plant output.

The scrutiny of results and data of different researchers does not always lead to indisputable conclusion of applicability of one or another proposed circuit particular case.

In the process of the water preconditioning there are series of water quality indexes that directly affect desalination process, which determine the operation mode of installations and materials as well as their operation time.

In the designing of water preparation processes it should be taken into consideration the purpose of the water, requirements to its composition on the subsequent purification steps, that are matching the physical, chemical and bacteriological indicators, as well as water quality of the water supply source in different seasons of the year, the degree and potential possibility of contamination of it by the municipal and industrial wastewater etc.

A continuous complication and the range of the objects of scientific research require the development of new efficient methods and techniques of water treatment. Existing schemes of water preparation, which are used on many boiler houses and Industrial enterprises, use chemicals and subsequent chlorine disinfection. These methods have a number of drawbacks such as: low efficiency of purification of water comparing to membrane technology, high capital expenditures of the construction of new and reconstruction of old WPD, the high net cost of water due to a significant volume increase of the reagents (flocculants, coagulants, acids, alkalis), consumption of energy and the amount of water consumed during the regeneration of ionite filters, the inability to fully automate and monitor the effectiveness of the filtering process, large size layout and equipment of chemical manufactory.

In connection with the above-mentioned problems with demineralized water, it is necessary to use new technological methods and settings, because the old installations proposed by Natural Waters Purification Classifier are out of date and practically do not refine water of specific and anthropogenic pollution of Aral Sea region territory.

At present time in domestic practice a paradoxical situation appeared, the widely spread application of ultra filtrating membrane and heat pump installations requires an operational experience working on such devices. At the same time to gain an experience, it requires implementation of them on a number of kinds of natural waters.

A promising experience in this direction might be the use of membrane installations, followed by distillation desalinating system, which are supposed to be based on the large and small boiler houses, heat power plants and industrial enterprises for the environment of the Aral Sea region.

The highest quality of desalinated water can be achieved in the distillation distillers. Within them, a mineralized water must be supplied with significant volume of heat to proceed an evaporation process and then practically the same amount of heat must be withdrawn. In this case, the degree of recuperation depends on the principle and structure of a particular desalter. In a single-stage desalter the consumption of heat in a way to get 1 kg of fresh water is about 2400 kJ. In the case of multistage desalter the heat consumption for preparation of 1 kg of fresh water falls to 250-300 kJ due to heat recuperation of the water phase transition [4].

Experimental

In this article, we present energy-efficient combined installation of desalter and heat pump. Its application is directed to provide the heat recovery of evaporation-condensation processes of water while getting the distillate. In this complex of combined installation, the heat pump water desalter is an evaporating tool. Within it generation and heat recovery of the phase transformation of water performed by reverse thermodynamic cycle heat pump. Reverse thermodynamic cycle performed by the working fluid of the heat pump, in this certain case, by R-134A refrigerant.

The technological scheme includes a block pre-treatment in the form of an ultra filtration module Ultrafiltration installation - UFI; Heat pump desalter of water-HPD, which uses evaporation- condensation processes in order to get the distillate.

The proposed experimental installation of water desalination is shown in Figs. 1 and 2.

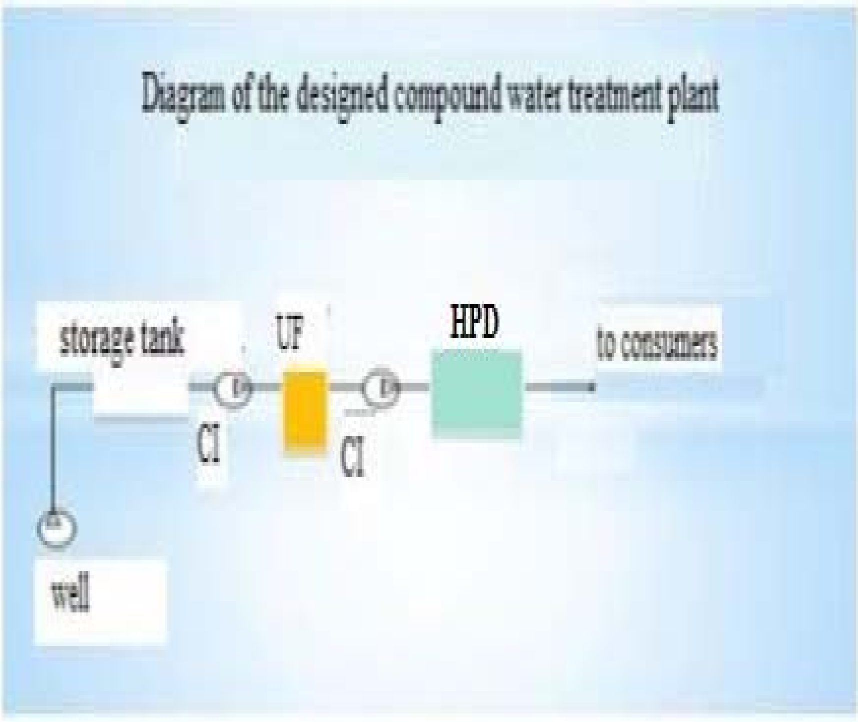


Fig. 1 – Technologic block-scheme of WPD.

Equipment of the heat pump distiller (Fig. 2) consists of a single-stage vapor compression heat pump (HP) with its mandatory elements - condenser - Cr; evaporator - Ev, regenerative heat exchanger HE; Compressor - CM; built - in throttle valve - TTv of evaporator condenser - EP. As well as an auxiliary equipment: feeding water pumps FP-1, FP-2, receivers for receiving of fresh water FWR and mineralized water MWR , pipes and valves .

After the pre-cleaning unit UFI natural water pumped by feeding device FP-1 to the condenser of the heat pump. Evaporation tubular unit EU that is a part of a condenser is configured with external heating chamber and the boiling zone. In the evaporator as a result of the effortless circulation and heat absorption of the heating medium (working substance of the heat pump - the refrigerant R-134A) the mineralized water starts boiling and then a vapor-liquid mixture enters the separator, where the steam and liquid are separated - vapor goes into the steam line, further it moves to tube bundled heat exchanger, where steam condenses giving out its heat to warm raw water from natural water source. The condensate in the form of fresh water is diverted into the receiver of freshwater FWR. Condenser’s heating chambers Ch of heat pump has a special tube for boiling process that connects the upper part of the chamber and the middle part of the separator.

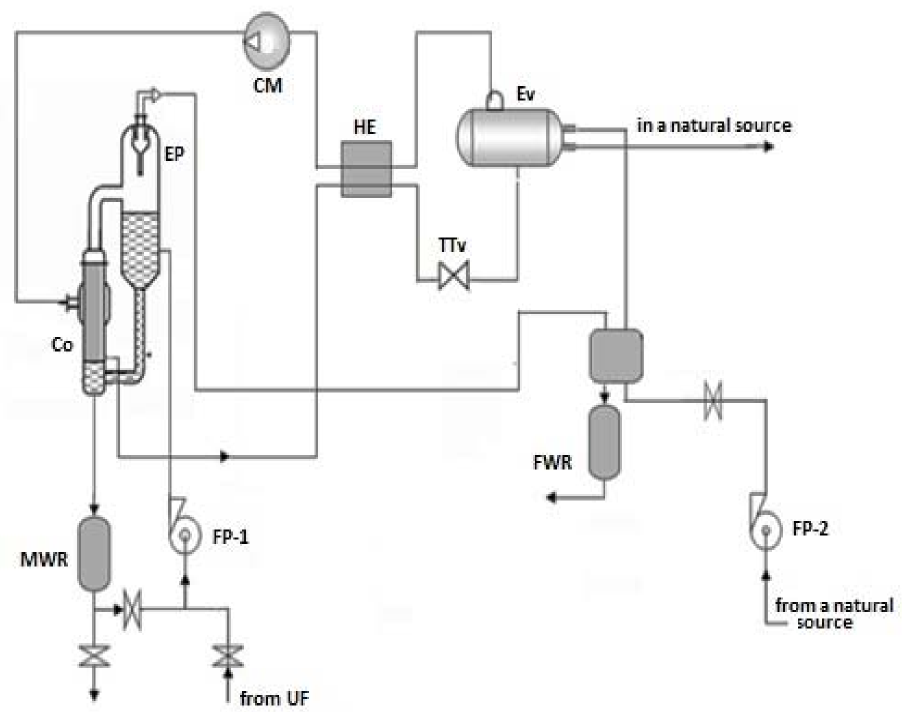


Fig. 2 – Heat pump desalter of water-HPD

The heat pump in desalter installation 1 provides the heat regeneration of mineralized water vapors evaporation – condensing process under atmospheric pressure in the heating chamber of the evaporator. Thus, the energy consumption is carried out only on the heat pump and on drive of other pumps. Energy drive of the heat pump is much lower than "carried" heat of water condensation - evaporation, which defines the energy efficiency in the production of distillate. Calculation of performance, operational parameters and sizes of the technological equipment are performed according to standard methodic.

The proposed block of water pre-treatment on UFI is shown in Fig. 3.

Pre-treatment of water ultra-filtration installation is required to ensure a deeper concentration of salts in the heat pump desalination device UFI.

Water preliminary treatment block of UFI provides an operation of heat pump with higher performance. During the work on the purified water, the capital expenditures for the construction of HPD reduce. At the same time, it allows to get a higher quality treated water. Ultrafiltration modules can effectively to block the suspended matters and the smallest particles of colloidal iron, due to the size of the membrane pores of d = 30-1000. In the case when an operating pressure is about 0.2-1.0 MPa it removes particles down to 0.005 mkm.

UFI conducted studies indicated that processing of an organic substance solution the selectivity lies in the scale of 90% and higher.

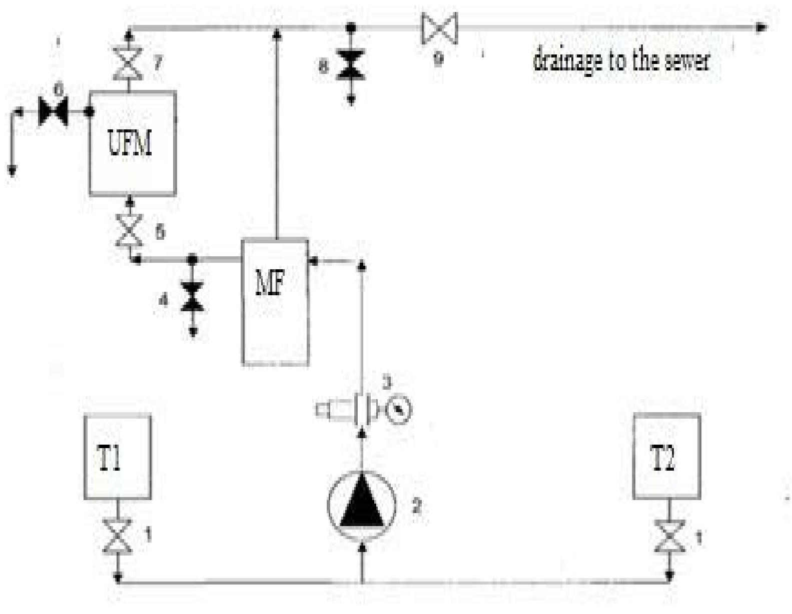
Results and discussion

The results of an experimental study of the quality of freshened distillate are shown on Fig. 4 and 5.

In order to get research aims in technical experiment the following dependency ratio were analyzed: the performance of heat pump - Q dm^3/h; the total amount of dissolved substances - TDS g/dm^3; testing is conducted with heat pump performance standing in the range of 10 –100 dm^3/h.

In Table 1 it is shown the ratio of the performance and the total amount of solutes in the water, desalination TDS after desalination of the water of underground sources.

According to results shown on Figs. 4 and 5, with installation performance values up to 100 dm^3/h the TDS Maximum Allowed Concentrations (MAC) are exceeded, and the other inference that an increase of performance values leads to proportional increases of TDS concentration in desalinated water, which brings to the necessity of conducting of desalination process on the heat pump installation (HPI) in two stages.



1 – valve at the outlet of the tank, 2 – pump 3 – pressure regulator with pressure gauge, 4 – sampling valve,
5 – valve inlet ultrafiltration membrane , 6 – sampling valve at the outlet of the ultrafiltration membrane,
7 – the valve on drain line ultrafiltration membrane 8 – sampling valve on the drain line
9 – shut-off valve on the drain line

Fig. 3 – Scheme of Ultra Filtration Installation Block

Table 1 – Ratio of the performance of the device - Q, dm^3/h and the total dissolved solids - TDS, g/dm^3. Performance of installation

# experiment	Device performance Q, dm^3/h	The total dissolved solids - TDS, g/dm^3
1	10	0,4
2	20	0,59
3	30	0,68
4	40	0,97
5	50	1,20
6	60	1,48
7	70	1,85
8	80	1,92
9	90	2,25
10	100	2,50

Thus, the results of experiments proves the need of conducting of desalination process on Heat Pump Desalination Installations in two stages, since under the performance more than 50 dm^3/h the TDS AMCs are exceeded.

Due to this fact in the proposed technological scheme, we developed desalination on HPI, which carried out in two stages.

Conclusion

Based on a complex assessment of reagent-free methods of water treatment and quality indicators of raw water, which are to be treated at the Water Treatment Installation using the membrane and heat pump desalination methods, we got the results of an experimental study of the quality of freshened distillate.

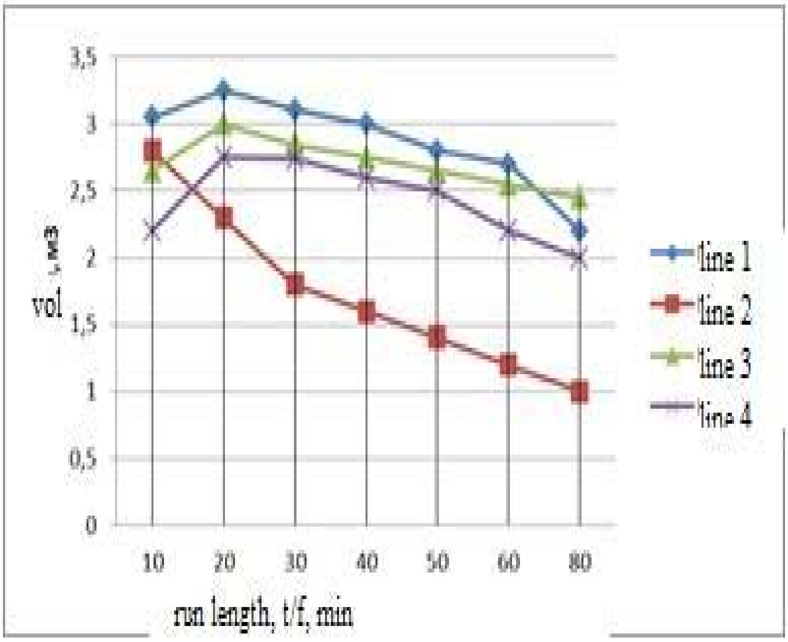


Fig. 4 – Determination of the filter cycle optimal operation period and back rinse of UFI

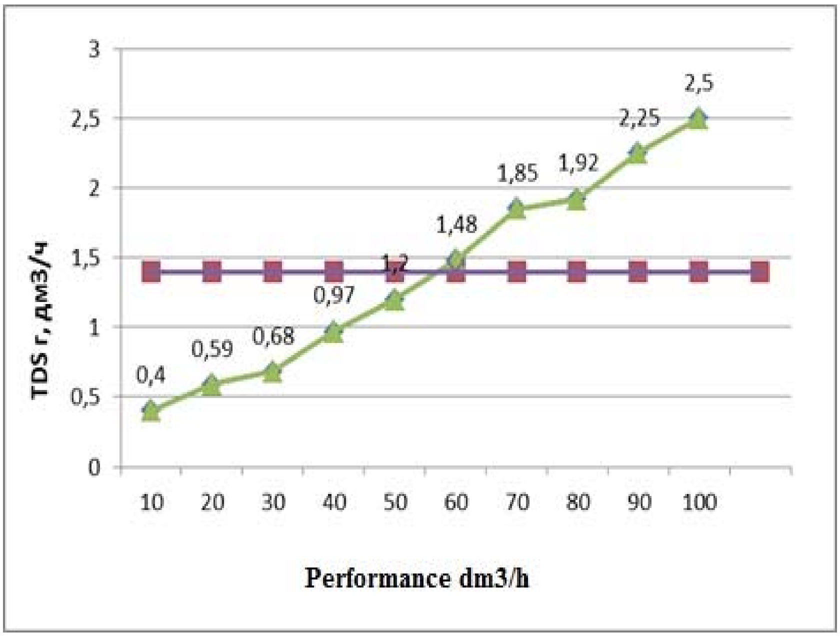


Fig. 5 – Performance of HPI regarding the total amount of dissolved solids TDS

The received results confirm HPI desalter industrial applicability and show the water desalination efficiency on such installations for object of small-scale power engineering enterprises and power industry and for objects of heat supplying systems.

The main advantage of this technological scheme is a low specific energy consumption and relatively low specific capital costs, as well as simple, convenient and cost-effective installation, which does not require the use of reagents and subsequent after-treatment technologies to produce high quality water preventing the formation of corrosion processes of pipes in the heating system and heat energy installations (HEI).

This developed by us combined water treatment installation could be manufactured locally, autonomously or assembled in container design, because of its low energy consumption, compactness and small sizes.

It is recommended to use it in the locations of heat power engineering industrial enterprises, where there is no direct access to purify technological and especially fresh and drinking water. To determine the control water quality after a certain stage of its treatment there are sampling devices for water tests and as well as devices and systems of an automatic control.

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ОПРЕСНЕНИЕ ВОДЫ С ИСПОЛЬЗОВАНИЕМ ТЕПЛОВЫХ НАСОСОВ

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Аннотация
Тематика связана с обоснованием, разработкой усовершенствованных технологий и комбинированной очистки природных вод, в условиях повышенных антропогенных нагрузок на природные источники воды, являющаяся приоритетной в области водоподготовки для теплоэнергетических установок. Проведен обзор существующего положения в техногенной зоне Приаральского региона, иллюстрирующие острую необходимость продвижения современных методов и технологий. Представлены используемые способы обработки воды предлагаемые классификатором очистки поверхностных вод и их недостатки со значительными эксплуатационными затратами, к примеру, в мембранных опреснителях, основанных на явлении обратного осмоса соленую воду прокачивают через полупроницаемые мембраны, изготовленные из ацетилцеллюлозы или полиамидных смол. При этом затраты энергии соответствует 5-15 кВт·ч/м^3. С повышением солесодержания растет давление прокачки воды через мембраны и увеличиваются энергозатраты. В диапазоне давлений, при котором возможна работоспособность анализируемого оборудования, сохраняются и фазовые свойства у воды. Общим недостатком этих установок является высокое энергопотребление для выработки единицы массы дистиллята. Поэтому вопрос о существенном снижении энергопотребления в данных типах установок получить затруднительно. Предложен энергоэффективный вариант для решения существующей проблемы по опреснению воды, с незначительным энергопотреблением в комбинированной водоподготовительной установке. Технологическая схема комплекса включает: блок-предварительной очистки в виде ультрафильтрационного модуля УФУ; теплонасосный опреснитель воды ТНО, использующий испарительно-конденсационные процессы для получения дистиллята. Применение направлено на обеспечение регенерации теплоты испарительно-конденсационных процессов воды при получении дистиллята. Теплонасосный опреснитель воды в составе комбинированной установки является выпарным опреснителем. В нем генерация и рекуперация тепла фазовых превращений рабочего вещества осуществляется с помощью обратного термодинамического цикла теплового насоса. Обратный термодинамический цикл осуществляется с участием рабочего вещества теплового насоса, в данном случае это хладагент R-134A. Кипение и последующее испарение обессоливаемой воды происходят в условиях разрежения, поэтому качество получаемого дистиллята очень высокое. Получены результаты экспериментального исследования показателей качества обработанного дистиллята после водоподготовительной установки,

подтверждающие ее работоспособность и эффективность для малой энергетики и систем теплоснабжения. Комплекс обеспечивает энергозатраты на 10-15%, меньше чем в водоочистительных установках обратного осмоса и исключает применение химических реагентов,уменьшает количествообразуемых сточных вод. Потребление промывочной воды на собственные нужды, затраты на опреснение воды существенно снижаются в виду особенностей применяемого метода.

Ключевые слова: тепловой насос, опреснитель, дистиллят, теплообменник, испаритель

ЖЫЛУ СОРҒЫСЫН ҚОЛДАНУ НЕГІЗІНДЕ СУДЫ ТҰЩЫЛАУ

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Аннотация

Мақала тақырыбы табиғи суларды тазартудың қиюласқан технологияларын жетілдіру, негіздеу және жетілдіру мәселелеріне арналған. Осы мәселелер табиғи су көздеріне түсетін антропогендік жүктемелер үдеген кезде жылуэнергетикалық қондырғылар үшін су дайындау саласында аса өзекті болып табылады. Арал өңірін қатитын техногендік аймақта орын алған жағдайға шолу жасалған. Шолудан суды тазарту үшін қазіргі заман талабына сәйкес әдістер мен технологияларды қолдануды алға тарту қажеттігі анық байқалады. Беттік суларды тазарту үшін классификатор ұсынған, қазіргі кезде қолданылатын су тазарту тәсілдері және оларды пайдалануда кездесетін ауқымды шығындарға байланысты кемшіліктері атап өтілген Мысалы мембраналық тұщыландырғыштың жұмысы тұзды суды жартылай өткізгіш мембраналардан арқылы айдайтын кері осмос құбылысына негізделген. Мембраналар ацетилцеллюлозадан немесе полиамид шайырларынан құрастырылады. Суды тазартуға 5-15 кВт·сағ/м^3 энергия шығындалады. Судың тұздылығы күшейген сайын мембранадан суды айдау қысымы ұлғаяды және энергия шығындары артады. Жұмысы талқыланған қондырғыларда, судың фазалық қасиеттері тек оның жұмыстық қысымна сәйкес дипазонда ғана сақталады. Аталмыш қондырғылардың жалпы кемшілігі болып дистиляттың бірлік массасына қарасты аса жоғары энергия шығындары саналады. Сондықтан осы типтегі қондырғыларда энергия шығындарын азайту мәселесін шешу өте қиын. Суды тұщылау мәселесін шешу үшін энергетика тұрғысынан тиімді шешім ұсынылған. Қиюласқан су тазалаушы қондырғы аз мөлшердегі энергия шығындарын қажет етеді. Қондырғының технологиялық сұлбасына ультрафильтрациялық модуль УФҚ жылусорғылық суды тұщылатқыш ЖСТ кіреді. Ультрафильтрациялық модуль УФҚ суды алдын-ала тазартудан өткізеді. Жылусорғылық суды тұщылатқыш ЖСТ суды буландыру-шықтату процестерін қолдану негізінде дистиллят алуды көздейді. Жылусорғылық тұщылатқышта буландыру-шықтату процестерінің қысымсыздық жағдайында өтуіне байланысты алынатын дистиллятың сапасы өте жоғары. Жылу сорғысында жұмыс денесінің фазалық өзгерістерінің жылуы судың қайнауына, булануына және алынған будың шықтануына жеткілікті болады. Қиюласқан қондырғыға кіретін жылусорғылық тұщылатқыш буландырғыш типтегі қондырғы. Мұнда булану, шықтану процесстері кері Карно айналымына сәйкес өтеді.Кері Карно айналымын іске асыру үшін қондырғыда жұмыс денесі ретінде хладагент R-134A қолданылады. Су дайындаушы қондырғыдан алынған дистилляттың сапа көрсеткіштерін тәжірбелік зерттеулер нәтижелері, оның шағын энергетика мен жылумен қамтамасыз жүйелері үшін тиімді қолданыс табатынын дәлелдейді. Қиюласқан суды тұшылату қондырғысының энергия шығындары кері осмостық қондырғылармен салыстырғанда 10-15% - ға кем, химиялық реагенттерді қолдануды қажет етпейді, сонымен қатар қондырғының өз мұқтаждарына, яғни жууға-шаюға кететін сулар мөлшері едәуір аз, суды алдын-ала тазартуға, қыздыруға, тұщылатуға жұмсалатын энергия шығындары да төмен.

Түйінді сөздер: жылу сорғы, тұщылатқыш, дистиллят, жылуалмастырғыш,буландырғыш