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THE IMPROVMENT OF WATER TREATMENT TECHNOLOGIES FOR SALINE WASTES DISCHARGE REDUCTION

We compared performance parameters of membrane units using "Filmtec and "Hydranautics" calculation programs. We analyzed the influence of membrane equipment connection technological charts on equipment performance, content of separate ions in permeate and power inputs.
Keywords: solar evaporator, reverse osmosis, reactor, ion exchange.

During last 10 years in industrial practice the scope of water treatment membrane technologies application in chemical industry ("Styrol", Gorlovka), in metallurgy ("ISTIL", Donetsk; Joint-stock company "Azovmash", Mariupol), in food production ("Sandora LTD.", Nykolaev) has broadened considerably.

In thermal and atomic power engineering ion-exchange technology of water treatment is the basic one. Productivity of ion-exchange units at large thermal and nuclear power plants is about some hundred m^3 per hour.

However, ion-exchange filters consume a great amount of reagents, which come to surface reservoirs as diluted saline flows. It results in superficial water sources degradation and, in some cases, eliminates the possibility of using water by priority consumers.

Strict requirements to saline flows discharge lead to the necessity of replacing current ion-exchange technologies with membrane ones, which have a number of advantages such as: excluding reagents from water desalination process, high desalination rate and reduction of salts discharge to the amount equal to salt content in source water. The considerable losses of water on own needs are the features of exploitation of membrane options. There is also the necessity of more careful water pre-treatment.

Use of reverse osmosis equipment, in spite of some simplicity of vehicles connection chart and service requires knowledge of load partition between corps and membranes. Otherwise there are the losses of operating properties of technological process: increase of expenses of electric power, decline of degree of ionexchange and output of clean water-permeate or increases of capital costs on options.

Defining the influence of reverse osmosis elements connection configuration on the technological indexes of the process of water desalination in membrane equipment, defining the possibility of reducing the amount of flows during waters desalination, and also defining the possibility of the use of mine waters for thermal networks was the purpose of this work.

Membrane elements in the reverse osmosis setting can be arranged according to different patterns. For example, in the process of desalination of brackish waters with total dissolved solid 2000 ppm membranes can be arranged in a few units connected parallel (to increase the productivity of equipment) and successive (to increase the output of desalinated water-permeate). Figures 1 and 2 show different patterns of membrane vehicles connection and the possibility of rapid transition to another configuration.

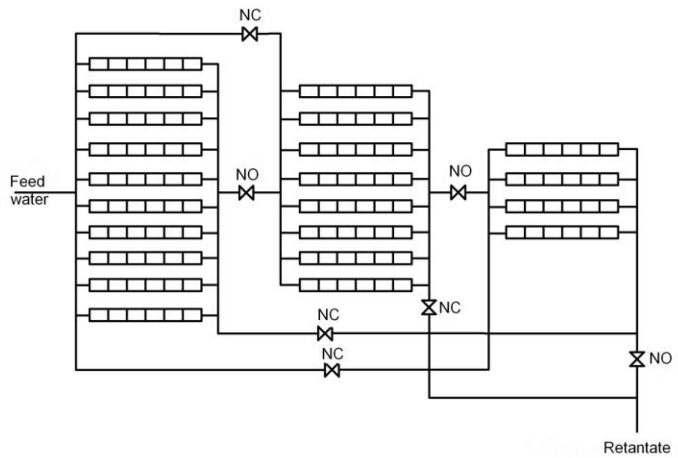

Figure 1 – Transition from three-stage chart to two stage one (NC and NO are normally closed and opened valves)

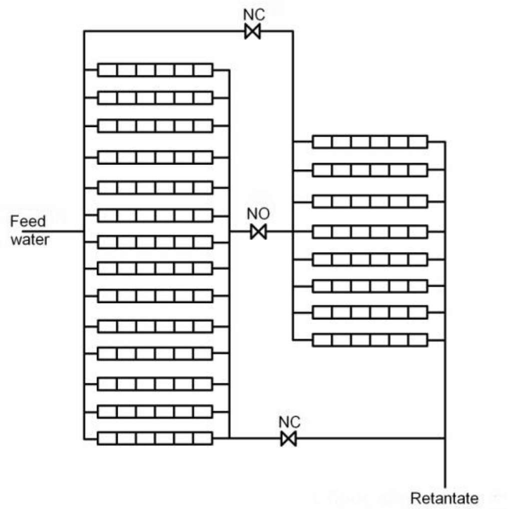

Figure 2 – The change of cases connection for a two stage unit from successive (by concentrate) to parallel

Obviously, in case of desalination of highly mineralized water successive connection of reverse osmosis elements by concentrate will cause permeate quality worsening and contamination hazard.

Using the “ROSA (reverse osmosis system analysis) programs” developed by the “Dow Chemical company”, we calculated the perfomance of options with different configurations of membrane vehicles connection in the process of mine water desalination.

For the reverse osmosis equipment the share of total output of desalinated water is related to its output on every element as follows:

$$1-(1-\alpha)^n = r\,, \tag{1}$$

where α is the shareof permeate output for the whole setting;
r is the shareof permeate output for the whole setting;

It is thus assumed that α is a constant value, i.e. it does not vary much in the process of water desalination. Thus, interconnection between α and r is described by the equations:

$$(1-\alpha)^n = (1-r)\,, \tag{2}$$

$$\alpha = 1 - (1 - r)^{1/n}. \qquad (3)$$

For example, if n=12 and r = 0,75, α=0,11.

Weight average output per one element makes 0,15. The required number of desalination stages is:

$$n = \frac{\ln(1-r)}{\ln(1-\alpha)}. \qquad (4)$$

For the permeate output r = 0,75, $n = \frac{1,386}{0,162} = 8,5$ stages.

The estimation of reverse osmosis options operation showed that under identical pressure of acting water and the same number of cases the change of connection configuration allows to increase the expense of desalinated water-permeate.

Thus, in the process of transition from the three-stage chart of water ion exchange to the single-stage one the output of permeate falls from 76 to 60 % and the amount of its total dissolved solid also decreases. Overall consuption of permeate increases by 1,3 times. With two stage chart of membrane vehicles connection there is the most complete and evenly distributed loading on separate elements.

With the same water consuption and output permeate, the transition from the three-stage chart of cases connection to single-stage one allows reducing the pressure of acting water approximately from 13 to 10 bar and power consumption from 0,55 to 0,43 kVt·h/m^3.

The change of configuration of reverse osmosis vehicles cases connection makes possible flexible regulation of equipment productivity by changing permeate output. Thus it is possible to save considerable amounts of electric energy, whereas the productivity remains the same.

The above decision provides the possibility for permeate quality control. It is most reasonable to use the two-stage chart of membrane vehicles connection, which helps to obtain the best permeate results as compared to the other chart.

For the desalination of water with salt content up to 2000 ppm the optimum configuration of membrane vehicles connection will be as follows: n × 6/0,6n × 6 or 1,5(n × 4/0,6n × 4) for equal productivity of equipment (n is the amount of vehicles cases).

Taking into account current prices for electric power and membrane vehicles the pressure of acting water 14 bar should be considered optimal.

In order to reduce the concentrate volume and thus to decrease the loading on the most expensive processes with phase transition we calculated the process of salts concentration in membrane vehicles with concentrate flow recirculation.

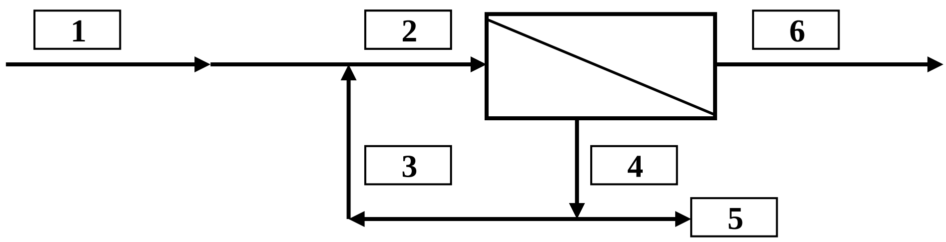

Figure 3 – Technological parameters of brine concentration after water reverse osmosis desalination of (names of positions and parameters of flows are provided in table. 1)

Table 1. Basic parameters of membrane setting streams

Stream	Name of stream	Flow, m^3/h	Pressure, bar	Total dissolved solid, mg/l (ppm)
1	Input stream	25,00	21,00	5602
2	Input stream with recycling	45,00	20,75	12927
3	Recirculation	20,00	19,74	22138
4	Brine (total stream)	26,25	19,74	22138
5	Brine	6,25	19,74	22138
6	Permeate	18,75	-	31
6/1	Output, %		75	

In accordance with the provided data, membrane concentrate connection allows saving the amount of water from 25 to 6,25 % per each 100 ton of desalinated water. It increases the total output of permeate up to 93,75 %.

For concentrated flows processing the use of renewable energy sources is expedient.

The most simple salt flows desalination method is sun desalination.

Sun desalination equipment consists of a pool covered with film or glass. The bottom of the pool is covered with black polyethylene film, ceramic tiles or thin layer of asphalt. Condensate evaporated from the thin layer of salt water goes to collectors. Sunbeams get through transparent covering, reach the bottom and heat salt water. Water evaporates and vapor and air mixture contacts a relatively colder film or glass surface and condenses. Condensate drops flow down the tape or glass, come to a chamfer and are let out from the desalinator. The brine obtained after evaporation is periodically blown through. The level in the pool is maintained by a simple regulator. Saline water goes to the tank, then it comes to the desalinator through the regulator.

Sun desalinator performance depends on the intensity of sun radiation. It depends on daily and annual wheather changes.

The annual sum of direct sun radiation on the TSRD territory makes up 4100-4700 m J/m^2 /year. It corresponds to average daily productivity of desalination equipment 4-5 l/m^2. Although this value is by 150-200 times less then specific productivity of industrial thermal desalinators we should mind a free energy source. A 100x60 m desalinator can provide a small mine settlement with population about 3000 with drinking water (with 20 l/day/person consuption rate).

Specific productivity can be increased by several times through increasing the evaporation saurface during liquid disperson and through water transpiration with plant leaves.

Concentrate of reverse osmosis vehicles of sulfate and sulfate-chlorine class with salt contents up to 3-4 g/l with ions correlation $Na/(Ca + Mg) < 0,7$ suitable for black earth soils watering can be used as “nourishing” water of sun vaporizers of hotbed type.

Stabilization of industrial enterprises opens wide prospects for investments aimed at aplying the technologies for mine waters desolination. It will provide one more source of water-supply.

Conclusion

Highly mineralized mine water can be used for preparing make up water of thermal networks, when the eqipment with nanofiltration elements is used.

The change of reverse osmosis vehicles case connection configuration allows regulating equipment productivity. Thus it is possible to save considerable amounts of electric energy, whereas the productivity remains the same.

To introduce the systems of water treatment, which exclude saline flows discharge, it is reasonable to apply the reverse osmosis systems of salts concentration using the membranes for waters of high mineralization.

The amount of waste waters directed to phase transition vehicles can be reduced by desalination of concentrates of reverse osmosis equipment with concentrate recirculation. A more effective concentration process requires 1:1 ratio between recirculating solution and the amount of coming water.

In the process of desalination of water with initial mineralization 2 g/l (typical of mine waters) the amount of water coming to phase transition vehicles can be reduced up to 3,75% with total salt content in the brine 20 g/l. The increase of the level of recirculation in relation to the input stream up to 1,6/1 results in the growth of expenses for electric power approximately by 1,3 times.

Taking into account current prices for electric power and membrane vehicles the pressure of acting water 14 bar should be considered optimal.

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СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИЙ ОЧИСТКИ ВОДЫ ДЛЯ СНИЖЕНИЯ СБРОСА ЗАСОЛЕННЫХ СТОКОВ

Выполнено сравнение эксплуатационных параметров мембранных установок при использовании расчетных программ фирм «Filmtec» и «Hydranautics». Проведены анализ влияния технологических схем подключения мембранных аппаратов на производительность оборудования, содержание отдельных ионов в пермиате и затраты электроэнергии.

Ключевые слова: идеальное вытеснение, солнечный испаритель, обратный осмос, высокоминерализованные стоки, реактор, ионный обмен

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УДОСКОНАЛЕННЯ ТЕХНОЛОГІЙ ОЧИЩЕННЯ ВОДИ ДЛЯ ЗНИЖЕННЯ СКИДУ ЗАСОЛЕНИХ СТОКІВ

Виконано порівняння експлуатаційних параметрів мембранних установок при використанні розрахункових програм фірм «Filmtec» і «Hydranautics». Проведено аналіз впливу технологічних схем підключення мембранних апаратів на продуктивність устаткування, зміст окремих іонів у пермиате і витрати електроенергії.

Ключові слова: ідеальне витиснення, сонячний випарник, зворотний осмос, високомінералізовані стоки, реактор, іонний обмін