Desalination, 45 (1983) 315—320
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

INVESTIGATION OF WATER DESALINATION BY DISTILLATION TECHNIQUE

N.M. SINEV, SCUAE USSR
V.G. SHATSILLO, V.B. CHERNOZOBOV, SverdNIIchimmash (The USSR)
A.A. SAMARKIN, Ju.S. BARANOV, Mangyshlakenergokombinat (The USSR)

ABSTRACT - RESUME - KURZFASSUNG

The information is given on the main large stationary desalination units of different types (evaporating, instantaneous boiling) developed in the USSR and used in the design of the largest plant in Shevchenko having the output of 100000 m^3/day of distillate; it operates in close interrelation with an atomic thermoelectric БН-350 fast reactor plant and back pressure turbines. Some results are discussed of constantly performed studies into heat transfer, vapour separation, control of scale deposits and corrosion, search for new thermal systems and instruments to be used for the improvement of operating distillation desalination units and development of new ones. Further prospects of thermal desalination are associated with the use of multi-stage units equipped with horizontally-arranged-tube-film evaporators.

L'exposé donne l'information sur les principales grandes installations de distillation d'eau salée fixes de différents types (évaporatrices, à effervescence instantanée), fabriquées en URSS, et sur l'importante usine érigée à leur base à Chevchenko, produisant plus de 100000 m^3/24 h du distillat, fonctionnant en bloc avec une centrale atomique au réacteur nucléaire sur neutrons rapides БН -350.

On décrit quelques résultats des études permanentes concernant l'échange de la chaleur, la séparation de la vapeur, la prévention de l'entartrage et de la corrosion, ainsi que les recherches de nouveaux schémas thermiques et d'appareillage, utilisés pour perfectionner les installations de distillation de l'eau en action et en essai.

Les perspectives de la distillation thermique de l'eau salée sont basées sur emploi des installations multiétagées équipées d'évaporateurs à film liquide à tubes horizontaux.

Es sind die Angaben über die grundsätzlichen, in der UdSSR entwickelten, grossen, feststehenden Entsalzungsanlagen verschiedener Bauart (Verdampfer, Entspannungsverdampfer) und über die auf ihre Grundlage in der Stadt Schevchenko geschaffenen grössten Werk mit der Leistung von mehr als 100000 m^3 Destillat pro Tag, der in engen Zusammenhang mit dem mit dem Schnellreaktor БН -350 ausgerüsteten Atomwärmekraft-und Fernheizwerk arbeitet, gegeben. Es sind einige Ergebnisse der ständig durchzuführenden Versuche auf dem Gebiet der Wärmeübertragung, Dampfabscheidung, Kessel-

0011-9164/83/$03.00

steinverhütung und Korrosionsbekämpfung, der Suche von neuen Wärmeschaltungen und Vorrichtungen, die für die Entwicklung der neuen Destillationsentsalzungsanlagen und Vervollkommnung der arbeitenden genutzt sind, geschrieben. Die Fernperspektiven der Entwicklung der thermischen Entsalzung sind mit der Verwendung von mehrstufigen, mit den horizontal-rohren Dünnschichtverdampfern ausgerüsteten Anlagen, verbunden.

Water desalination is widely used in the Soviet Union. The most part of desalinated water is produced in stationary distillation desalination units (DDU). Many prototypes of such units are for the first time constructed and tested at Shevchenko desalination factory, the most large-scale one in the USSR.

Its significance results not only from large-scale fresh water production of sea (total output is more than 100000 m^3/day), but also from operation of the plant in close interconnection with nuclear thermoelectric station (NTES). The latter is equipped with sodium coolant (FR-350) fast reactor and steam turbines with backpressure. Steam from turbines enters the desalination units and part of deep desalted distillate from there returns together with heating steam condensate to NTES to feed steam generator. Such interconnection impose specific requirements to distillation desalination units from which the most marked are high reliability during long-term continious operation, deep desalted water (distillate) production and stability of distillate quality to outside disturbances in unit heat conditions (for example, heating steam pressure, vacuum in the last evaporation stage and so on). It is 10-stage DDU with cocurrent feed, equipped with vertical evaporators with forced circulation, that satisfies the requirements in the best way.

Operational experience of desalination factory is a permanent data source for DDU improvement and modernization, and the factory itself is a testing ground for new desalination equipment: water deaeration and vapour separation systems, circulating pumps, corrosion protection means, etc.

In general more than 20 stationary distillation desalination units, erected in 1963-1982, are in operation in the Soviet Union and some new ones are building. Most of them are relatively large-scale units: with the output from 13000 to 20000 m^3/day, some of them have the output from 1000 to 3000 m^3/day and recently a small-scale transportable unit has been developed which has the output 240 m^3/day and intended for a wide range of consumers.

Table

Some DDU, operatihg ih the USSR

Location	Start-up year	Applicatiom	Technical characteristice					
			DDU tvpe	main apparatus tvpe	stage number	Output, m^3/dav	thermal energv specific rate; kL/kg of distillate	salt content in the product, mg/l (ppm), not more
1	2	3	4	5	6	7	8	9
Shevchenko	1969-1970	ПВ,ПК	МПВУ	ИВК	5	2x14000	550	8
Shevchenko	1971-1975	ПВ,ПК	МПВУ	ИПЦ	10	3x14500	315	3
Shevchenko	1972	ПВ		АМВ	34	15000	325	10-20
Shevchenko	1980-1982	ПВ,ПК	МПВУ	ИПЦ	10	2x14500	300	3
Turkmen Soviet Socialist Republic	1973	ПК		АМВ	42	2400	210-335	20
Turkmen Soviet Socialist Republic	1980	ПВ,ПК	МПВУ	ИПЦ	10	14500	300	5
Ukranian Soviet Socialist Republic	1976-1978	ОС	МПВУ	ИВК+ИПЦ	6	2x3800	480	20
Uzbek Soviet Socialist Republic	198o-1981	ОС,ПК		АМВ	34	2x14000	295	5

Table 1 gives information about main DDU, operating in the USSR. Abbreviations given in the table denote: ПВ- drinking water supply; ОС-industrial waste water desalination; ПК-boiler (steam generator) make-up with deep desalted water; МПВУ- cocurrent multi--stage evaporation unit; ИПЦ -evaporator (evaporation unit) with forced circulation of brine; ИВК -evaporator (evaporation unit) with natural circulation and brine boiling after heat exchange tubes; АМВ-flash evaporation unit. The table doesn't illustrate the first out of date units, built in 60s as well as the units which simply duplicate the mentioned ones in the table.

As is seen from the table the use of water distillation desalination technique in the Soviet Union doesn't come only to fresh water production of the sea to satisfy water supply needs of the towns. There are two more trends in DDU use: production of deep desalted water for thermal power and nuclear stations to make-up steam generators and processing of saline industrial waste waters to prevent contamination of ponds. Both trends are promising because DDU or at least some of their variants have a number of useful characteristics, that are first of all:

1. Production of deep desalted distillate "at one go" which is applicable to make up high pressure steam generators, at the same time the depth of desalination doesn't influence significantly the product cost. This results in effective water reuse when processing industrial wastes.

2. Adaptability of DDU and power station thermal flowsheets; it is possible to insert DDU to power station flowsheet so as to return maximum heat, consumed by the unit with desalted distillate to power cycle, and hence to reduce sharply expenses on thermal energy and cooling water for desalination.

3. High-extent concentrating of discharge brine up to salt crystallization, which minimize salt waste volume with little additions in flowsheet and equipment of desalination unit.

Such variety of DDU operational conditions and their application forces not to limit ourselves to development of the only unit type (for example, multi-stage flash unit) or one scale control system use (for example, antiscaling compound dosage), but make efforts to obtain certain "assortment" of technical means and procedures to select desalination plant suitable type. Thus operating units given in the table are of two types: multi-stage evaporators with forced circulation and multi-stage flash units. According to the

flowsheet of multi-stage evaporation there are units under construction that are equipped with apparatus with film flow of water being desalinated on the outside of heat exchange surface. Three methods of alkaline scale control were tested and found their application: seed crystals recirculation, scale inhibitor dosage (polyphosphates) and continuous acid dosage (sulphuric or chloric acid).

Research data and industrial operational experience revealed the following. Seed crystals recirculation shows its advantages and gives good results in the units equipped with apparatus with forced circulation but it may be applied in flash evaporators as well, though with less effect of scale formation inhibition. For them preference shoul be given to scale inhibitors; some inhibitors were examined in the USSR which gave stable effect at temperatures up to 110-120^{o}C. To day some of them are under commercial tests. Continuous chloric acid dosing is recommended to units with film evaporators where the problem of scale formation prevention is solved with great dificulty and seed crystals as well as scale inhibitors don't give the effect needed. The next step in this direction is the discontinuous (pulse) chloric acid dosing, it is projected, its parameters are determined experimentally.

Improvement of operating DDU types and new developments are based on the results of permanent studies of heat transfer, vapour separation, corrosion and scale prevention, looking for new thermal flowsheets and equipment. The leading participants in performing these studies are the Sverdlovsk research center (Sverd-NIIChimmash) where investigations are carried out in all trends mentioned, and testing ground on water desalination in Shevchenko, which allows to test pilot units in natural conditions. The following progress is attained in these investigations:

- research, development and application of fluted heat exchange tubes for the most Soviet DDU which give operational heat transfer coefficients of 4-6 kW/m^{2}K;
- description of chemical activity and kinetics of alkaline skale formation that allows to predict calcium carbonate and magnesium hydrate scale deposition rate in different elements of evaporation equipment;
- research, commercial use and essential improvement of scale control process by means of seed crystals recirculation, which needs no permanent chemical reagent dosing and doesn't pose a

problem of their discharge to sea;

- research and basing of materials of construction for DDU equipment, operated with ocean-and sea-waters: aluminium brass - for heat exchange tubes, carbon and stainless steel - for the shells and internal devices, development of simple and inexpensive corrosion protection processes for them;

- development of vapour separation devices and their design procedure which allows to get deep desalted distillate;

- development of production technique of hydrocarbonate class potable water from distillate; this water should meet the requirements of international standard on potable water.

We belive that distillation method doesn't exhaust its potentialities and has fair prospects in the sense of reduction of capital outlays and thermal energy consumption. These prospects are connected to development and application of multi-stage units, equipped with film-type horizontal-tube evaporators (with refluxed heat exchange surface), that may be made compact with minimal specific quantity of metal per structure and insignificant losses of heat potential. Owing to these characteristics it is possible to decrease thermal energy consumption up to 125-170 kJ per 1 kg of product in evaporators with horizontal-tube refluxed bundles at the same time decreasing considerably the capital outlays for their construction compared to flash evaporators, for example. It should be noted that the main object of the programme of development of new DDU with horizontal-tube refluxed bundles, realised in the Soviet Union, is the development of large-scale multi-stage evaporators (15000-25000 m^3/day). For this purpose the problems of refluxion of bundles with a great number of heat exchange tubes, vapour separation and heat transfer intensification are solved. The first production prototypes of horizontal-tube evaporators are developed and now prepared to test.