Part 2

# WATER PROTECTION FROM DISCHARGES

## 2.2. Contemporary water treatment technologies at power plants and their environmental impact assessment

### 2.2.3. Technology of thermal treatment of make-up water for feeding power boilers

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Thermal water treatment is based on water distilling. Water vaporizes in one apparatus- vaporizer and condenses in another-condenser. In a vaporizer minimum salt contained in the raw water get into steam. Besides, steam is cleaned from admixtures in a special device before a condenser. Quality of distilled water, produced in a condenser meets the requirement to make-up water for power steam boilers of super-high pressure.

Currently boiling type vaporizers, used to produce secondary steam from chemically softened water are applied in power engineering. Demineralization is performed in vaporizes, which are simultaneously condenses for the heating steam and vaporizers. To provide reliable operation of vaporizers raw water is to be passed through clarifiers, Na-cationic exchangers and de-aeration. Distilled water is utilized in a power plant cycle to compensate steam and water losses [29, 30].

Modular evaporation units (MEU) are applied at thermal power units of 200, 300 and 800 MWt capacity and heating power plants. A unit is connected to the turbine steam extraction for primary steam, secondary steam is directed to the vaporizer condenser (VC), included in the line of main turbine condensate (fig. 2.3). MEU can be of one or two stages.

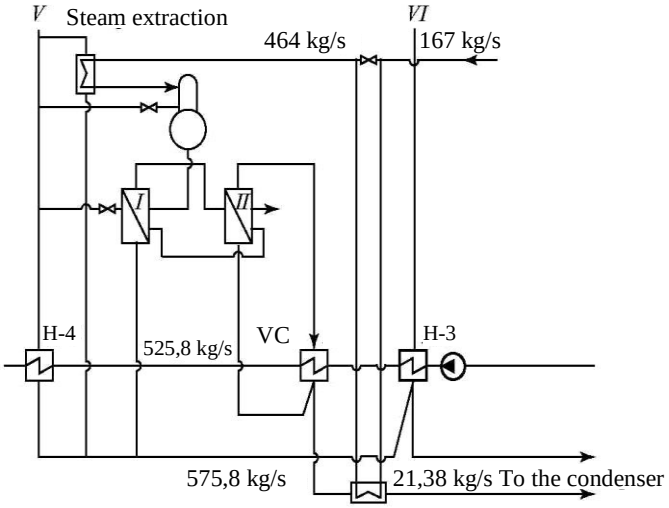


**Fig. 2.3. Modular evaporation unit in a condense power unit scheme:** H- heater; VC- vaporizer condenser

At condense power plants vaporize units are included in the main condensate cycle without thermal efficiency losses (with a condenser installed prior to a low pressure heater, receiving steam from the same steam extraction as a vaporizer) and with a pressure in a vaporizer higher than atmospheric under all power unit loads. Choice of a vaporization scheme and its type is determined by the demand in the make up water and necessity to keep temperature difference in a vaporizer $\Delta t_{и} > 5$ °C under an operation load range.

At 800 MW power units of Permskaya SDTPP and Surgut SDTPP-2 (fig. 2.3.) two stage evaporation units with vaporizes of I-1000 type are installed.

Heating steam comes from the turbine extraction V to the heating section of the first stage. Secondary steam produced in the first stage goes to the second stage as a heating steam. Secondary steam of the second stage comes to a vaporizer condenser, where condenses. A condenser is installed in a heat regeneration system between the third (H-3) and fourth regenerative heaters of low pressure.

At heating and industrial-heating thermal power plants multi-stage units are applied shown at fig. 2.4. Primary heating steam is directed to the first stage and condenses. From initial chemically treated and de-aired water secondary steam is produced, that is after cleaning is directed to the second stage. For the following stages secondary steam becomes heating. In heat sections of the vaporizer it condenses producing distilled water. Multi stage units provide several times utilization of evaporation heat, brought to the fist stage.

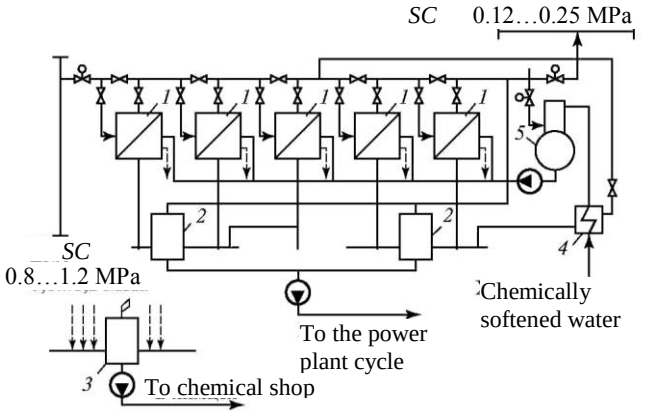


**Fig. 2.4. Multi-stage evaporation unit at an industrial-heating thermal power plant:** *1* — vaporizer; *2* — distilled water expansion tank; *3* — blow-off water expansion tank; *4* — chemically softened water heater; *5* — deaerator; *SC* - steam collector

At industrial power plants with a large steam supply to the heat consumers and low return of steam condensate it is recommended to install steam convert units. Steam convert units are designed to generate steam for industrial consumers from chemically softened water and save steam condensate within a thermal power plant. Thus losses of the power plant working agent are eliminated. Steam converter design is similar the vaporizer design, excluding the fact that they are designed for higher pressure of the heating and secondary steam.

Design of vaporizes for thermal power engineering is regulated by GOST 10731-85. Vaporizes and steam converters are manufactured by "TKZ "Krasny Kotelschik in Taganrog

Besides boiling type vaporizers flash type vaporizes and horizontal-tube film vaporizers are applied for boiler water treatment in power engineering. Primary steam for them is steam with pressure of 0.12…0.2 MPa or high temperature water.

Horizontal-tube film apparatus (HTFA), utilized in distillation-desalting units, are designed to obtain distilled water suitable for power boiler make-up water and preparation of drinking water from the sea and salted water (Fig. 2.5). They are also applied in many designs for processing of mineralized waste water of different enterprises, thermal power plants, mines, coal mines aimed at water re-use and environment protection.

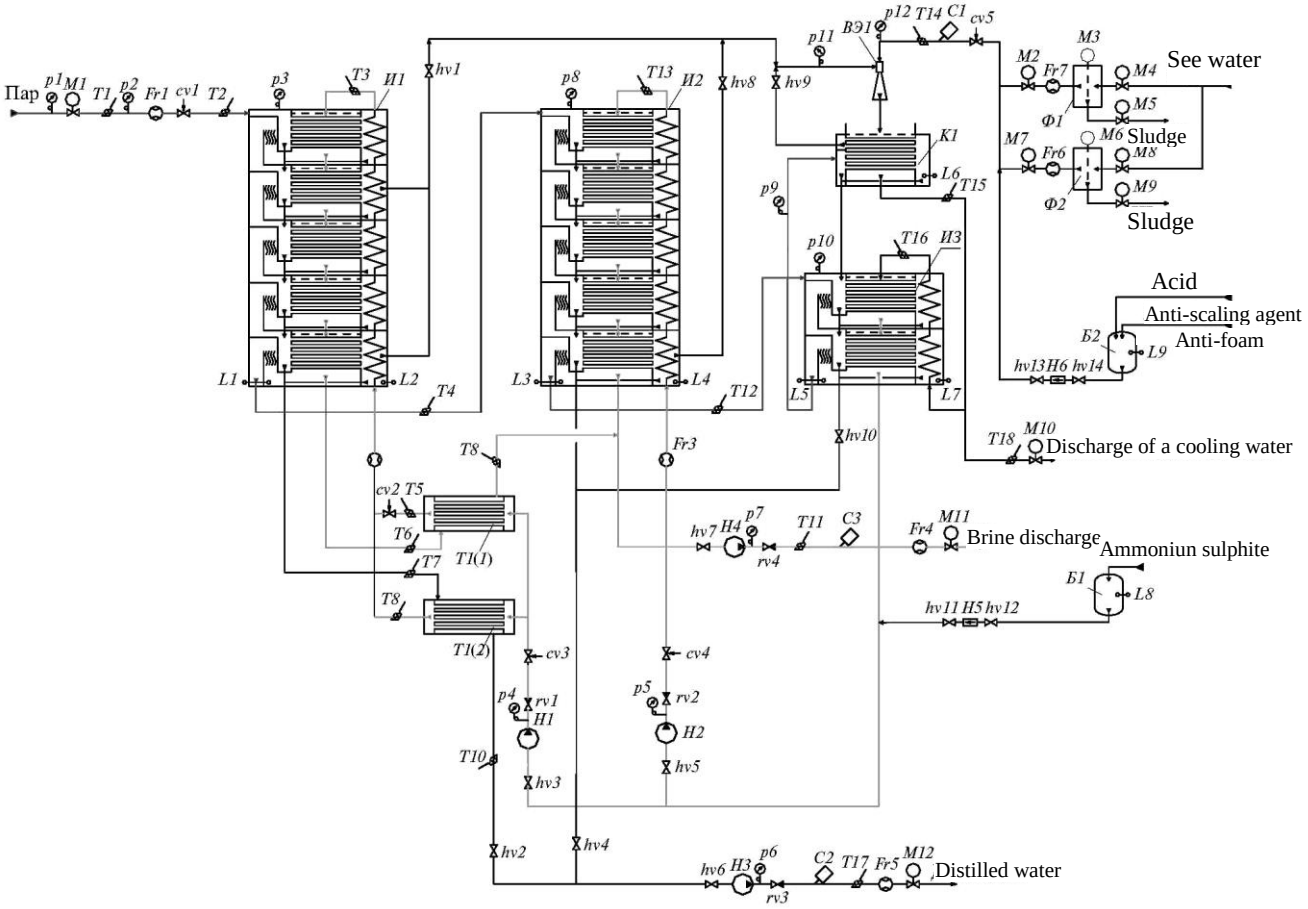


**Fig. 2.5. Distillation-desalination unit with horizontal tube film apparatus:**
*1* — main heater; *2* — vaporizer; *3* — ejector; *4* — circulating pumps; *5* —pump for distillate

Horizontal- tube film apparatus are assembled in multi stage units. The heating steam comes to the steam chamber, distributes to the tubes of a heat exchange collector and partly condenses in it. Part of the heating steam comes to regenerative heaters. Outward surface of tubes of the heat exchanger is showered by water by means of a distribution unit. Distribution units provide even distribution of feed water along outer heat exchange surface of the steam chamber. Water forms film at the heat exchange surface and evaporates from a film. Water from the fist row of pipes flows to the second row and etc. The secondary steam passes separation unit where is cleaned from carried water drops and comes to the next stage. Water that was not evaporated flows to the bottom part of the apparatus and is supplied to the distribution unit of the second stage for showering of heat exchange collector, then passed through all stages, is pumped from the last stage. Feed water of GTFA is preliminary heated in the regenerative heaters up to the temperature close to the heating steam saturation temperature. The secondary steam of the first stage is directed to the second and becomes its heating steam, etc. The secondary steam of the last stage condenses in the end condenser.

Horizontal-tube film apparatus (and their prototype - distillation –desalting unit with horizontal tube film apparatus DDU GTFA) are designed by “Mashprom” SC, Ekaterinburg.

Horizontal-tube film apparatus and flash type vaporizes operate at low pressure that makes them efficient for utilization of heat exhausted in other units. They are applied at thermal power plants both in independent and combined units, including multi stage boiling type evaporation units and such apparatus. Besides GTFA and FTV are easily incorporated to feed water treatment systems at thermal power plants, heat regeneration in boilers-utilizers of steam-gas units.

Effective ways of incorporation of thermal water demineralization into thermal power plants cycles have been developed at a Thermal power plant department of Moscow power engineering institute.

Multi stage evaporation units are economically efficient when total content of strong acidic anions in raw water is higher that 5 mg-eqv/dm$^3$. At increased content of organic compounds thermal demineralization may be efficiently applied for any type of water irrespectively to raw water mineralization and strong acid anions content. Modular type evaporation units may be applied for water with any mineralization irrespectively to strong acid anions content.

Another type- flash vaporizes- multi stage unit for production of cleaned distilled water, based on adiabatic boiling of superheated water. Such vaporizes have been designed by SC “Ural VTI”-JC “Ecoteh” and are supplied as modular type. In the last years a technological processed was worked out for them to produce distillate suitable for thermal power plant boilers feeding. At Kazan thermal power plant No 3 two flash type vaporizers of 50 t/h production are in operation. A flash type vaporizer consists of an expansion chamber and condensation chamber, which are divided by a screen. A screen has a steam channel with built in jalousie separator. Superheated water comes to the expansion chamber through special cross flow units and boilers in it. Steam produced goes to the condense chamber through the steam channel and jalousie separator. Part of not evaporated water is directed to the following stage with lower pressure through the cross flow units. From the last stage steam produced is directed to

the end condenser. Scheme of modular evaporation unit with boiling type vaporizers is shown at fig. 2.6.

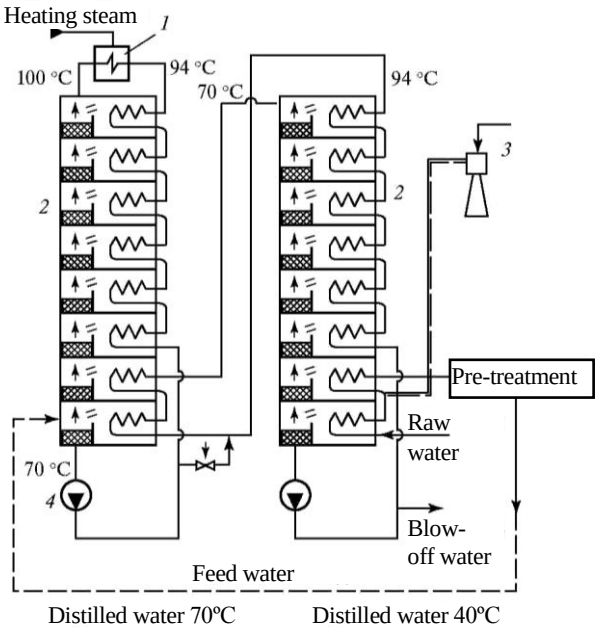


**Fig. 2.6. Flash type vaporizer IMB-50:** *1* — main heater; *2* — vaporizer; *3* — ejector; *4* — circulation pump

Multi stage evaporation units with boiling type vaporizes are applied at industrial- heating thermal power plants. Modular evaporation units with boiling type evaporators are applied at condense power plants. At heating power plants in a system of heating system water heating MEU with flash type vaporizes and HTFA are recommended. Flash type vaporizes are applied together with multi stage evaporation units with boiling type vaporizers for utilization of exhaust heat of multi stage evaporation units.

At power plants evaporation units of all types (multistage, modular, steam converting) apply vertical water-tube boiling vaporizes. Thus evaporators are well-designed and are sufficiently operating in a pressure range of secondary steam, higher than atmospheric. At the same time design of vertical-tube vaporizers of boiling type is not provided for operation at vacuum, when their operation gets worse (instability, production decrease at temperature differences lowering at a heating section, failure of level measuring instruments, decrease of distilled water quality).

At heating power plans in winter operation turbines operate at backpressure and pressure in the upper heating system extraction exceeds atmospheric. In such modes vaporizes of modular evaporation units, satisfy their requirements. In summer pressure in heating steam extraction considerably decreases, herewith temperature difference of vaporizers decreases and modular evaporation unit efficiency goes down. Besides in some summer operation modes upper heating steam extraction of the turbine and upper heating system heater are shut down. When the upper heating system heater is shut down, vaporizer is re-connected to the lower heating steam extraction and of the vaporizer condenser is reconnected to be cooled by return heating system water prior to lower heating system heater. Therewith high heat efficiency remains. However achievement of the required production fails. Pressure of secondary and in some cases heating steam turns to be lower than atmospheric.

Modular evaporation units, designed for operation at low steam pressure (0,01…0,1 MPa), exactly flash type vaporizers and HTFA must be applies and a thermal cycle of modular evaporation units must be worked over in accordance with design peculiarities of such apparatus in order to take full advantage of modular evaporation units for heating power plants, connected without heat efficiency losses (scheme of Moscow power engineering institute) and eliminate disadvantages and failures in operation at a vacuum range of heating steam extraction.

Compared to chemical demineralization thermal demineralization allows maximum reduction of chemical reagents consumption and waste water, and also re-treat soft waste water into distilled water of high quality. The method yields comparable to chemical demineralization efficiency, and at high salt content of raw water exceeds chemical demineralization in efficiency. Vaporizers are frequently applied for utilization of waste water and chemical substances (sodium chloride, sodium sulfate).

To the disadvantages are: excess of secondary steam, that must be utilized in a power plant cycle and high specific quantity of metal.

Multi stage evaporation units of boiling type are in operation at Saransk thermal power plant No 2, Kazan thermal power plant No3, North-West thermal power plant, Omsk thermal power plant No 5, thermal power plant No 7 of Lenenergo,etc. Modular evaporation units are located at power units of 800 MWt of Permskaya SDPP and Surgut SDPP-1 and SDPP-2. At Kazan TPP No3 two flash type vaporizers IBM-50 of 50 t/h production each are installed for utilization of secondary steam of multi-stage evaporation unit and production of distilled water. Vaporizers are also applied in different technological schemes of industrial waste water processing.