P a r t   2

WATER PROTECTION FROM DISCHARGES

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

2.2.5. Experience of implementation of low waste water treatment systems

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More and more attention is paid worldwide to a complex solution of a waste water burning issue on a power plant scale. The approach is based on water circulation and recycling of natural water aimed at maximum possible reduction in water consumption and waste water volume.

Significant progress in this direction was achieved in the USA where legislation on the protection of natural resources is stricter in comparison with legislations of other countries and is constantly toughening. The system of state control over the water environment is established, operating since 1966. Purposeful training of experts specializing at water protection against pollution is carried out. Companies manufacturing waste water treatment equipment and other environmental equipment are quickly developing. The rate of return of these companies turns to be 1.5 ...2.0 times above the average country level [38]. As a result of this policy a number of thermal power plants with a limited and "zero" waste water discharge are currently in operation in the United States. "Zero" discharge is declared as a basic strategy in power plant designing [39]. The stated strategic issue is solved with consideration of the specific conditions.

Evaporating ponds are used to reduce the waste water discharges in areas with high insolation. In areas with insufficient insolation evaporation of waste water in vertical tube-type evaporators is recommended. As a result, up to 99% of impurities contained in waste water is removed and the distillate is produced, which is recycled. The thermal power plant San Juan (USA) "Public Service Co of New Mexico" has implemented a combined technology of mineralized waste water processing based a on membrane technology combined with evaporation (Fig. 2.7).

Power plant waste water is directed to the neutralization tank *1* where is processed with lime milk. From the neutralization tank waste water flows to the clarifier *2* and is treated with chemical reagents. The clarified water is collected in the pond *3* which also receives blow-off water of a circulating cooling system (CCS). Waste water from the pond *3* arrives to the preliminary water treatment *5*, and then is directed on the reverse osmosis unit (ROU) *6*. Filtrate of ROU after ion-exchange additional demineralization is used to compensate steam and condensate losses at thermal power plants. ROU brine is collected in the tank *7* and is additionally concentrated in evaporators *8*. Evaporator distillate is also directed for additional demineralization. Slurry is dehydrated on the slurry compressing unit *4* and is taken away.

Another example of the boiler make-up water treatment and waste water utilization at a "zero" discharge thermal power plant is a unit of the «Doswell Limited Partnership» (Ashland) company [39] (Fig. 2.8). Source water is primary demineralized on a six-stage reverse osmosis unit (ROU) *1*, degassed in the deaerator *2*, and is additionally demineralized at the chemical treatment plant *3*. Brine of ROU *1*, waste water of chemical demineralization plant *3* and boiler blow-off water after the mechanical filter *4* flow to the electrodialysis installation *5*, and then to the reverse osmosis unit *6*. The filtrate of ROU is also directed for degassing and chemical demineralization. Concentrate from the units *5* and *6* is additionally evaporated in the evaporator-crystallizer *7* up to solid salts appearance, which are dehydrated in press-filter *8* and are used for soil treatment.

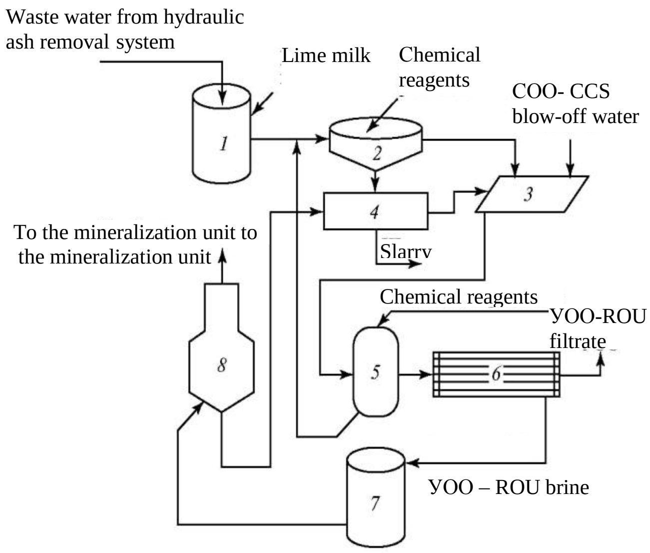

Fig. 2.7. Combined technology of mineralized water processing San Juan (USA), implemented by «Public Service Co. of New Mexico»

Water supply systems with limited or "zero" waste water discharges are implemented at several high capacity thermal power plants in the USA [40]. To ensure a reliable water supply a water pond is usually constructed at a power plant territory providing water storage sufficient for 10 day operation.

Water in a circulating cooling system (CCS) is in most cases clarified with coagulation or coagulation and lime treated depending on specific conditions. Different additives or softening of part of a circulating water are used to prevent scaling in CCS. CCS blow-off is used for compensation of water losses in flue gas desulphurization systems and hydraulic ash removal systems.

Boiler make-up water is prepared at a reverse osmosis unit combined with a chemical demineralization. Mineralized waste water is directed to the evaporation pond or the evaporation unit, where blow-off water of hydraulic ash removal system and other waste waters with increased mineralization are also forwarded.

Low mineralized water, including boiler blow-off water is collected in a special pond and is used in the power plant cycle. Rain water is collected separately and is utilized depending on its composition or is evaporated up to dry salts.

Evaporation units with steam compression providing regeneration of up to 90% of concentrated waste water are applied. Distillate produced with salt content of 15 g/m^3 is used, and slurry after mechanical dehydration is transported for utilization or storage in dumps.

To obtain a permission for the operation of the thermal power plant (HPP) Deerhaven (Florida, USA) water utilization scheme has been changed, that allowed significant reduction of the total amount of waste water. As a result CCS blow-off water, power plants drainage water, water treatment waste water, water from coal and waste dumps, after washing and preservation of main equipment and potable water preparation are directed to evaporators with steam compression. At that 90% of waste water is converted into distillate and is used to replenish the CCS. Evaporator concentrate is dried; the dry residue is directed for long-term storage to a power plant controlled sludge collector [41].

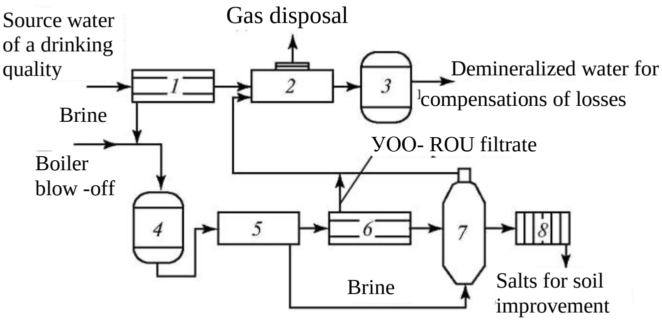

Fig. 2.8. Zero discharge water treatment plant designed by«Fluor Daniel Inc.» at the plant of «Doswell Limited Partnersship»

Certain experience is gained in our country in designing of low-waste water-management systems at thermal power plants. This principle is most fully implemented at Saransk heating thermal power plant (HTPP) [42].

Water from the Insar river and rain water are used at HTPP-2 as CCS make-up water. Blow-off water of this system is lime-treated, coagulated and clarified in a clarifier of VTI-160 type. Then water after advanced clarification on mechanical filters is treated at a two-stage sodium-cation exchange plant. Part of the softened water is used as a make-up water for a closed heating system, and the rest of it is mixed with a boiler blow-off water in the atmospheric type deaerator and is directed into a five-stage evaporation unit where is evaporated up to mineralization of 80 ... 100 g / kg. The evaporation unit is equipped with evaporators I-600 manufactured by boiler-turbine plant JSC "TKZ Krasniy Kotelshchik" and provides production of 100 m^3/h.

The distillate is used as a make-up water for drum boilers of 13.8 MPa pressure and blow-off water is mixed in a tank-reactor with conical bottom with a certain amount of waste water from regeneration of sodium cationic-exchangers. As a result of this mixing sediment of a complex composition appears. It contains carbonates, hydroxides, phosphates, silicate and organic compounds of calcium, magnesium, iron and some other compounds. After separation of the sediment and neutralization of the residual alkalinity by sulphuric acid, the solution is used for regeneration of the sodium-cationic-exchangers. Waste water of this process containing more than 30 mg/l of calcium is collected, and calcium sulfate dehydrate (gypsum) naturally precipitates from it. Part of the clarified solution is mixed with evaporator blow-off water in the process of preparation of the next portion of the regeneration solution using the above-described technology. Surplus clarified solution is directed to the crystallizer with a conical bottom, where is saturated with lime.

As a result of lime treatment all magnesium precipitates in the form of hydroxide and an additional amount of calcium precipitates as gypsum to a level close to the solubility of calcium hydroxide under these conditions, i.e. a lime solution virtually free from permanent hardness is produced. This solution together with lime milk is used for clarification of circulating cooling system blow-off water in a clarifier.

Thus, operation of the above system provides utilization of rain water from the territory of the HTPP-2 Saransk, blow-off water of circulating cooling system, of boilers and evaporators, waste water from regeneration of the sodium-cationic-exchangers. Only lime, coagulant and a small amount of sulfuric acid are used as reagents. The entire calcium and magnesium, as well as an equivalent amount of bicarbonate and sulfate ions contained in these waste waters and introduced with reagents are removed as sludge of two types - with a predominant content of calcium carbonate and gypsum, that simplifies their utilization [43].

As a result raw water consumption reduces and only compounds of sodium, received with natural water, are returned to the environment with leakages of a heating system, i.e., reduction of mass of contaminants in water occurs within a power plant. Based on the results of complex researches a unified low-waste technology including thermo-chemical demineralization of power plant waste water was developed. The schematic diagram of the technology is shown in Fig. 2.9. Such scheme is included into the design for construction of the second stage of water treatment at Saransk HTPP-2.

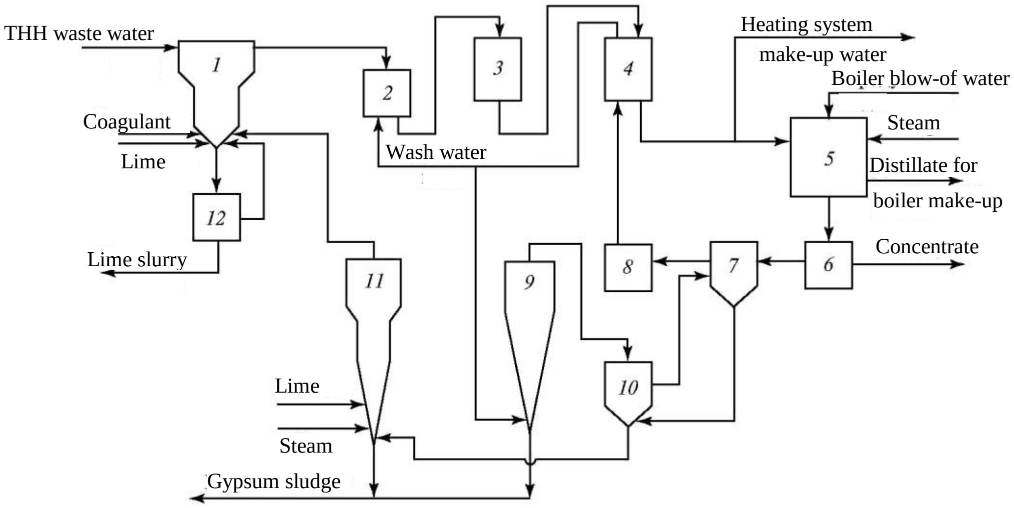

Fig. 2.9. Schematic diagram of low-waste unit of thermal-chemical demineralization of waster water at a thermal power plant: *1* — clarifier; *2* — clarified water tank; *3* — mechanical filter; *4* — Na-cation exchanger; *5* — Evaporation unit; *6* — concentrate tank; *7* — reactor-tank; *8* — tank for prepared regeneration solution; *9* — crystelliser; *10* — waste water stabilization tank; *11* —thermal chemical softener; *12* — tank for clarifier slurry collection

A provision is also made for coagulation and liming of CCS make-up water in clarifiers to reduce the amount of CCS blow-off water and prevent scaling.

Low-waste water treatment technology is implemented at one of the heating thermal power plants of "Samaraenergo". The principal diagram is shown in Fig. 2.10 [44, 45]. This heating thermal power plant produces 6000 m^3/h of make-up water for a heating system with an opened water supply and 260 m^3/h of demineralized boiler make-up water for boilers of 13.6 MPa pressure.

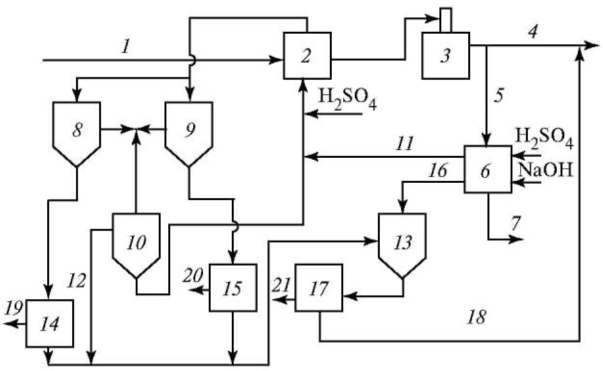

Fig. 2.10. Principal diagram of a water treatment plant with waste water utilization

Initial water *1* from a municipal water supply system is directed to the H-cationic-exchanger *2* and then to the decarbonizes *3*. The main flow of decarbonized water *4* is directed to the heating system, and the rest or it *5* to the chemical demineralization unit *6*. Demineralized water 7 is used as boiler make-up water.

Backwashing water and low-mineralized wash water of the ion-exchanger *2* regeneration process are collected in the sedimentation tank *8*. Waste water supersaturated with calcium sulfate is forwarded upward to the crystallizer *9*, containing earlier formed gypsum in a suspended state ($CaSO_4 \cdot 2H_2O$).

Clarified water from the units *8* and *9* is collected in the tank *10* and is used for backwash, regeneration and washing of filters *2*. For the regeneration of these filters acidic waste water *11* from the chemical demineralization plant *6* is used. Surplus clarified solution *12* from the tank *10* is directed into the reactor *13*. Sediments of the apparatus *8* and *9* are directed to the sludge compressing units *14* and *15*.

The filtrate of the sludge compressing unit along with flow *12* is directed to the reactor *13*, where the mixture is treated with exhausted alkaline solutions *16* of the chemical demineralization plant *6*. As a result, a sediment appears consisting mainly magnesium hydroxide. The sediment is dehydrated at the sludge compressing units *17*, and the clarified solution *18* is mixed with decarbonized water *4*, supplied to the heating system.

Sediments partially dehydrated at sludge compressing units *19-21* contain products of backwash of filter *2*, gypsum and magnesium hydroxide respectively and are suitable for useful application or long-term safe storage.

It should be noted that the average salt content of a heating system make-up water was 219 mg/kg, despite of the fact that waste water was discharged there, there at, salt content in the initial water of municipal water supply system was 338 mg/kg. Such result was achieved by H-cationic treating of the heating system make-up water. And volume of such water is substantially more than amount of boiler make-up water, which preparation causes introduction of most salts into the cycle.

An extensive complex of work on water consumption and waster water discharge was carried out at the Kazan HTPP-3. Initially water from the Volga river was used to prepare boiler make-up water by chemical demineralization after liming and coagulation, and the same water was used to prepare heating system make-up water using sodium cationic softening. Waste water from the filter regeneration after dilution with CCS blow-off water was discharged into the Volga river.

To reduce water and reagent consumption blow-off water of CCS was used as initial and Na-cationic exchange was substituted by acidation. Thus heat of CCS blow-off water was also utilized. However utilization of CCS blow-off aroused necessity to reduce and utilize water treatment waste water due to absence of water for its dilution aimed at achieving maximum concentration limit (MCL).

Attempts to solve the problem of waste water utilization at Kazan HTPP-3 have been made long ago. Back in the 80s of last century the first in country thermal-chemical desalination plant for processing of waste water was constructed. The design made a provision for: treatment of the neutralized waste water of chemical water treatment and sodium-cationic softening unit with soda and lime in clarifiers, deep two-stage sodium cationite softening of the clarified water and its evaporation in evaporators, acidification of evaporator blow-off water and its use for the regeneration of sodium-cationic-exchangers. For evaporation of softened waste water of chemical demineralization plant two multi-stage (six-stage) evaporation units were created with nominal production of 100 m^3/h with evaporators I-600 of JSC "TKZ “Krasniy Kotelshchik”

The design was developed at the time when there was lack of experience of utilization of the evaporator concentrate for filter regeneration. Subsequent researches and operation experience of thermal-chemical demineralization at Saransk HTPP-2 revealed that acidation of the blow-off water does not provide stable regeneration solution, resulting in pollution of ionite resins with sludge in the process of regeneration [46].

Another disadvantage of the design of a thermal-chemical desalination unit at Kazan HTPP-3 was a considerable soda consumption for precipitation of calcium in the clarifiers. The case is that that besides direct soda procurement costs, soda application leads to the introduction into a cycle of additional sodium ions. Their extraction from water as sodium sulfate or discharge with waste water causes more problems.

In connection with the above multi-stage evaporation unit was commissioned in 1996 which used softened blow-off water of CCS. In 2002-2003 two 16-stage flash type evaporators with production of distillate of 50 m^3/h developed by Ural VTI were put into operation at Kazan HTPP-3 [47]. Part of the softened water is demineralized at flash type evaporators and blow off water is mixed with another part of softened water and is evaporated at a multi-stage evaporation unit. Water to a multi-stage evaporation unit is supplied using a parallel scheme and steam is supplied consequently. As a result, the heat of the primary steam is firstly used in the six stages of the multi stage evaporation unit and then in 16 stages of a flash type evaporation unit, i.e. 22 times, yielding low unit heat consumption for thermal demineralization.

Commercial operation of evaporation units confirmed thermal demineralization efficiency for conditions of Kazan

HTPP-3. Evaporator distillate quality meets the requirements to boiler make-up water stated in technical operation rules for boilers with pressure of 14 MPa. Evaporation unit production is 320 m^3/h. The cost of the distillate turned to be 1.5 ... 2.0 times lower than of chemically treated water.

The improved scheme of water treatment plant of Kazan TPP-3 was developed by Moscow power engineering institute together JSC "VNIPI Energoprom" and is shown in Fig. 2.11. The design includes mainly technical decisions tested at the Saransk HTPP-2 [42].

directed to the tank *5*.

Acidic waste water of chemical demineralization plant is sent to the crystallizer-neutralizer *16*, where is neutralized with lime milk in a suspended layer of gypsum and after separation of the main part of the resulting sediment waste water stabilized by gypsum flows into the tank *13*.

Part of the solution together with sediments from tanks *11* and *12* is also directed to the tank *13*.

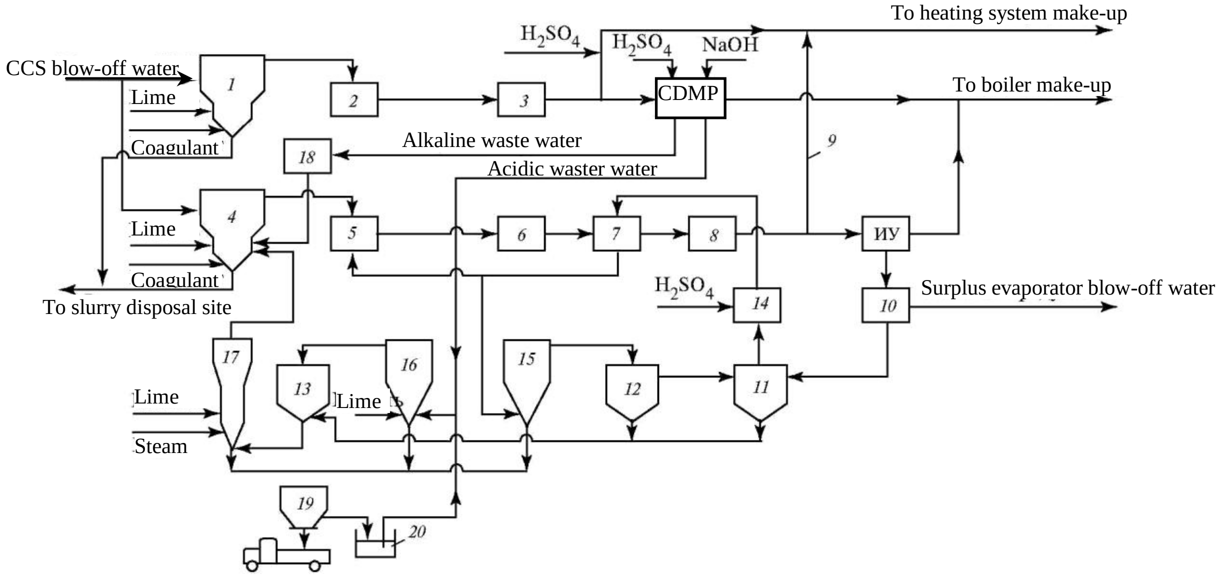

Fig. 2.11. Waste water utilization scheme at a thermal-demineralization complex at Kazan HTPP-3

The existing equipment (clarifiers *1*, tanks for cleared water *2* and mechanical filters *3*) is applied for lime treatment, coagulation and clarification of part of CCS blow-off water for further chemical demineralization and for heating system make-up water treatment. Existing chemical demineralization plant is used for preparation of the required volume of demineralized water.

Another part of CCS blow off water is also lime treated, coagulated and clarified (clarifiers *4*, clarified water tanks *5* and mechanical filters *6*) then is softened at sodium-cationic filters *7* and collected in the tank for chemically softened water 8.

The required volume of chemically softened water is directed to the evaporation unit and its surplus *9* is utilized for make-up of a heating system. The distillate of the evaporation unit is mixed with chemically demineralized water and is supplied for boiler feeding and concentrate having salt content of 80 ... 100 g/m^3, is collected in the tank *10*. The estimated amount of concentrate is pumped into the reactor tank *11*, where in a certain proportion is mixed with part of waste water from regeneration of sodium cationic-exchangers from the tank *12*. As a result of the interaction of these two flows sedimentation with the above described composition appears, which is pumped into the tank *13*. The clarified solution is collected in the tank *14* and after acidition and filtration is used for regeneration of the sodium-cationic-exchangers *7*.

Due to the fact that such regeneration solution contains sulphate ion in elevated concentrations, the exhaust regeneration solutions turn to be supersaturated with calcium sulfate. This solution and part of the wash water with a hardness of more than 30 mg-eqv/l are passed through the weighted gypsum layer in the crystallizer *15* of special design [48] for stabilization and collected in tank *12*. Less hard wash water is

After averaging the mixture from the tank *13*, together with the sediment comes to the thermal-chemical water softener *17*, where the suspended layer of gypsum is heated by mixing with steam up to 40 ... 60 ° C and is saturated with lime, providing almost complete separation of magnesium in the form of hydroxide and precipitation of the main part of calcium the form of gypsum [48]. At the output of the thermal-chemical softener calcium and hydrate-ion content is 40 ... 50 mg-eqv/l. To prevent carrying over of the smallest gypsum particles this alkaline solution is additionally clarified in the plate clarifier, located at the top of the unit *17*, and is used together with lime milk for water treatment in the clarifier *4*.

Alkaline waste water of chemical water demineralization is collected in the tank *18* and is evenly directed to the clarifier *4*. Backwash water from the mechanical and ion-exchange filters of a chemical demineralization unit and evaporation unit are collected (not shown in the scheme) and directed to the clarifiers *1* and *4*.

Lime sludge from clarifiers *1* and *4* is directed to the slurry tank with water return to the clarifier *4*. In future boiler blow-off water can be also directed there.

Sediments from of the units *15-17*, the main component of which is gypsum, come into the hopper *19* where the water is naturally filtered through a special drainage system to the sump *20* and through the crystallizer *16* is returned to the tank *13*. Gypsum with the residual moisture after drying in the bunker *19* makes 25 ... 30% and is transported for further processing. Studies carried out by specialized companies, showed that the composition of this gypsum corresponds to the best natural samples and can be widely used for various purposes like construction and agriculture.

Submission of softened water to the heating system reduces hardness of additional water, reducing acid consumption for its treatment, and in some cases allows to refuse from acidation. This increases the pH of the heating system water and its corrosion activity goes down.

The calculations showed that at operation of this scheme surplus evaporator blow-off water is produced in the amount of 0.8 m^3/h. This water can be used to regenerate sodium-cationic-exchangers at other plants or stored until the decision is made on its utilization. This concentrate contains mainly sodium, received with the raw water and injected with sodium hydroxide used for the regeneration ion-exchanges. In addition, it contains chlorides brought with initial water, as well as a small amount of sulfates carried with initial water, coagulant and sulfuric acid. The main part of sulphates (about 87%) is removed in the form of gypsum at waste water processing. Part of salts is taken away with additional water of the heating system.

It should be particularly noted that the total salt content in this surplus evaporator blow-off water is at 144.5 tons/year less than in the source water coming from the Volga river.

Reconstruction of water treatment at Kazan HTPP-3 using the above technology was performed by "VNIPIenergoprom" and showed that the existing equipment is basically used at its implementation. New equipment required was - units *15*, *16* and *17* (five tanks together with backup) for extraction of gypsum and a tank *10* for collection of evaporator blow-off water. The expenses associated with the described reconstruction, will be repaid within 3-5 years due to refusal from water use for waste water dilution to achieve maximum concentration limit.

Thus, optimization of the existing water treatment operation and its partial reconstruction will create a complex low-waste, resource saving water management system at Kazan HTPP-3, providing recycling of CCS and boiler blow-off water, waste water of water treatment with simultaneous reduction of reagent consumption and extraction of the considerable part of mineral components in the form suitable for useful application or long-term safe storage.

Many researches on creation of low-waste systems for treatment of heating system make-up water were carried out in Moscow State enterprise “Mosteploenergo” (now “MOEK) [49-51].

One of the options of reuse of waste water of Na-cationic exchanger regeneration is implemented at a number of district heating plants of Moscow. Schematic diagram of the unit is shown in Fig. 2.12.

Source water from a municipal water supply system is treated at the two-stage Na-cationic exchange system *2* and *3*, and after deaeration in the deaerator *4* treated water 5 is supplied as a make-up water to the closed heating system. Backwash water of the Na-cationic-exchanger *2* and *3* is collected in the tank *6*, clarified in the mechanical filter *7* and is collected in the tank *8*, where low-mineralized part of wash water *9* of filters *2* and *3* is also sent.

Regeneration waste water *10* of filters *2* and *3* with salt concentration more that 3 kg/m^3 is collected in the tank-crystallizer *1*, where is treated with lime (L) in an amount exceeding concentration of magnesium in this waste water by 1.3 times and then with soda (S). Soda amount should provide precipitation of the main part of calcium supplied to the tank *11* with waste water and introduced with lime.

The clarified solution *12* is passed through a mechanical filter *13*, saturated with sodium chloride up to a concentration of 85 ... 115 kg/m^3, and is used for regeneration of the filters *2* and *3*. Sediments *15* from the tank *11* are directed to the vacuum filters or press filters *16*. Partially dewatered sludge *17* is taken out by road.

Since the amount of mineralized regeneration waste water *18* always exceeds the amount of the regeneration solution *14* on the amount of wash water, surplus of this waste water *19* is discharged into municipal sewage system in order to provide flow balance. Waste water from the tank *8* is used for backwashing of filters *2* and *3*, and its surplus *20* is mixed with the initial water *1*.

The implementation of this technology has provided 55 ... 60% reduction of salt discharges into the sewage system.

For a complete waste water recycling a technology was developed shown in Fig. 2.13 [49, 50].

It differs from the cycle shown in Fig. 2.12 by using of electric-dialysis units *8* for concentrating of part of the waste water in order to bring their total volume to the volume of the regeneration solution. There at, a partially demineralized filtrate *18* of the electric dialysis unit *8* will be mixed with raw water reducing load on the Na-cationic-exchangers *2* and *3* with a corresponding decrease in the amount of waste water. The remaining elements of the scheme are the same as in Fig. 2.12.

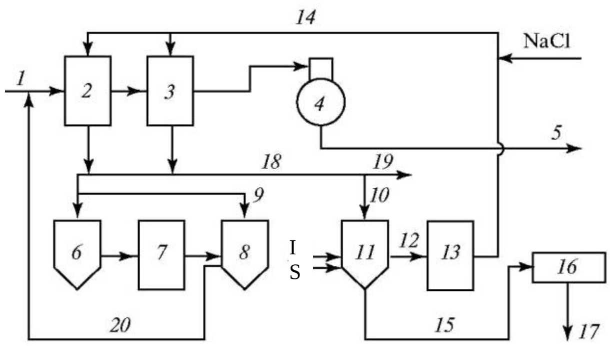

Fig. 2.12. Schematic diagram of water Na-cation exchange treatment with partial waste water utilization

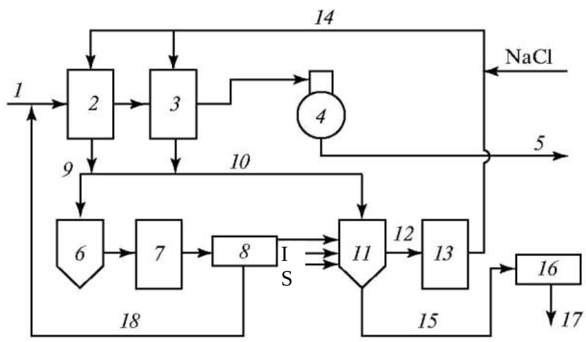

Fig. 2.13. Schematic diagram of water Na- cation exchange treatment with complete waste water utilization

Operation of such scheme can provide total elimination of discharges and sodium chloride consumption reduction to minimum.

Reverse osmosis units are at a commissioning stage at a number of plants of JSC "MOEC", designed to prepare make-up water for a heating system [51]. In future, this technology can be applied to prepare make-up water at low-waste power plants.

Technical-economical estimation of water treatment technologies with waste water recycling indicates that with recycling additional costs even now insignificantly differ from options with waste water dilution and discharge [52].

In the long term increase of raw water price and wastes discharge fee will stimulate creation of low-waste systems of industrial water management.

Thus, in our country a number of units providing low-waste and low-discharge water management at thermal power plants and heating plants was developed and operated. However, the extent of their implementation does not answer to the global problem of water protection from discharges of power engineering companies.

In some cases, use of organophosphorous antiscales (phosphonates) for water treatment is efficient. Their use for antiscaling treatment of water of circulating cooling systems began in the 70s. The first implementation of water correction treatment with a phosphonate OEDFK was held at the Ufimsky heating thermal power plant No4 by the scientific institute UralVTI. It was shown that the introduction a small amount of phosphonate (several milligrams per cubic decimeter) to a cooling water prevents the carbonate scaling in turbine condensers. Phosphonates dosing into the cooling water necessary to prevent scaling is several times less that acid amount for cooling water acidification and phosphate amount at cooling water phosphating. Methodical guidelines for use of OEDFK for this purpose are developed [53].

Currently phosphonate treatment of cooling water is applied at a large number of industrial enterprises, including Volgodonsk HTPP-2, Astrakhan HTPP-2 and other thermal power plants.

Application of phosphonates in heating systems began in the 90s. Application of phosphonates enables to refuse completely (or partially) from softening and decarbonization of make-up water of a heating system and operate using water with carbonate index (the product of calcium hardness and total alkalinity of water), significantly higher that standards established by rules for technical operation [37]. Under correct dosage of the selected phosphonate carbonate scaling in water-heating boilers and heating system heaters is practically excluded. The use of phosphonates leads to simplification of water treatment technologies, reduction of water own needs, significant reduction of chemical discharges used for regeneration of cationic-exchangers. According JSC "VTI", the economic effect of phosphonates application for correctional treatment of heating system make-up water makes from 5 to 10 rub/m^3.

Currently, this method of heating system water treatment is successfully used at many enterprises [54, 55], including the HTPP-24, of JSC "Mosenergo", Omsk HHPP-5, Volgodonsk HTPP-1, Toliatti HTPP-1, TPP VAZ (Togliatti), and other. Experts of JSC "VTI" have developed a technology of phosphonates application for heating systems at Omsk HTPP-6, Novogorkovsk HTPP, Sormovskay HTTP, Nizhniy Novgorod state district power plant.

Zinc-containing phosphonates are also effective inhibitors of corrosion of carbon steel in a deaerated heating system water. Applications of zinc complex OEDF for processing of highly aggressive water of a heating system of Rostov HTPP-2 significantly reduced the corrosion rate and iron content in a heating system water. According JSC "VTI", phosphonates not containing zinc (PAF-13A, IOMC-1) also possess protective properties in deaerated water, but they are less effective that OEDF-zink.

Phosphonates are manufactured by a number of domestic enterprises, foreign phosphonates are applies.

JSC "VTI" together with other organizations developed methodical guidelines on phosphonates application on the basis of the experience of their use [56]. The guidelines set rules for the application of phosphonates in heating systems, hot water systems, circulating cooling systems, steam boilers of low pressure, distillation and desalination plants and evaporators.