
Water-side Corrosion and Boiler Feedwater Issues

Prepared for the

**Romanian Energy and Electricity Authority
(RENEL)**

U.S. Agency for International Development

Contract No. EUR-0030-C-00-2055-00

Bechtel Corporation
San Francisco, California

November 1994



Contents

Section		Page
1	Introduction.....	1-1
	1.1 Background	1-1
	1.2 Report Organization.....	1-2
2	Summary, Conclusions, and Recommendations.....	2-1
	2.1 Modern Water Treatment Methods and Design	2-1
	2.1.1 Raw Water Treatment.....	2-1
	2.1.2 Chemical Softening Process.....	2-2
	2.1.3 Demineralization.....	2-2
	2.1.4 Condensate Treatment	2-3
	2.1.5 Design Considerations.....	2-3
	2.2 Water Treatment Problems at RENEL.....	2-3
	2.3 Steam System Layup during Shutdown.....	2-4
	2.4 Conclusions.....	2-5
	2.5 Recommendations	2-6
3	Basic Principles of Modern Water Treatment.....	3-1
	3.1 Makeup Water Treatment.....	3-1
	3.1.1 Raw Water Treatment.....	3-1
	3.1.2 Water Softening.....	3-3
	3.2 Condensate Treatment	3-9
	3.3 Design Considerations and Criteria.....	3-14
4	Water Treatment Problems in RENEL Power Plants	4-1
	4.1 Raw Water Supply.....	4-1
	4.2 Pretreatment Plant – Issues and Assessments.....	4-2

Section		Page
	4.3 Demineralizers – Issues and Assessments	4-9
5	Corrosion Protection during Shutdown	5-1
	5.1 Initial Cleaning.....	5-1
	5.2 Chemical Cleaning.....	5-2
	5.3 Layup Procedures.....	5-3
	5.4 Corrosion Protection during Startup.....	5-4

Bibliography

Appendix

- A Data Requirements and Discussion Topics – Water Quality Control and Treatment Investigations
- B RENEL Responses to Data Requirements and Topics
- C Water Quality Control and Treatment Investigations for RENEL – Letter report by Joseph Technology Corporation, Inc., Consultant

Illustrations

Figure		Page
3-1	Forced-Draft Aerator	3-4
3-2	Solids-Contact Clarifier.....	3-5
3-3	Gravity Filter.....	3-6
3-4	Vertical-Type Pressure Sand Filter.....	3-7
3-5	Hot-Process Phosphate Softening.....	3-8
3-6	Sodium Zeolite Softener.....	3-10
3-7	Ten Major Demineralizer Systems.....	3-11
3-8	Mixed-Bed Demineralizer.....	3-12
3-9	Regeneration of Mixed-Bed Demineralizer.....	3-13
3-10	Demineralizer and Pretreatment Flow Diagram.....	3-16
4-1	Static Settler Flow Sheet.....	4-3
4-2	Slurry Settler with Ejector Flow Sheet.....	4-4
4-3	VABAG Recirculating Settler	4-5
4-4	Recirculating Settler Flow Sheet	4-6
4-5	Recirculating Pump Settler Flow Sheet.....	4-7
4-6	Pretreatment Reagent	4-8

Tables

Table		Page
3-1	Analyses of Typical Surface and Groundwater in the United States (Parts per million - ppm).....	3-2
3-2	Recommended Boiler Feedwater Quality Limits.....	3-17
3-3	Recommended Water Quality Targets for Boiler Drum Pressure of 140 to 150 Bar with all Volatile Treatment.....	3-18
4-1	Impurities in Raw Water.....	4-1
4-2	Pretreatment Clarifier Types.....	4-2
4-3	Impurities in Water Entering the Demineralizer.....	4-10

Section 1

Introduction

This topical report has been prepared by the Bechtel Corporation to summarize the results of studies for the Romanian Energy and Electricity Authority (RENEL), conducted under contract with the United States Agency for International Development (USAID). The overall objective for the USAID support to RENEL is to improve the efficiency of the Romanian power generating sector. In response to specific requests by RENEL, studies were conducted in the following technical areas:

- Heavy fuel oil combustion and gas-side corrosion
- Boiler feedwater treatment and water quality control
- Ash handling in coal-fired power plants, and soils reclamation of full ash storage piles

Study results in each of these technical areas are presented in separate topical reports. This report contains the findings related to studies of boiler feedwater treatment and prevention of corrosion on the water side of boiler tubes.

Specific objectives of this study were to perform the following:

- Survey modern technologies for water treatment, such as clarification, softening, and demineralization
- Identify technologies for monitoring and control of water quality (colloidal silica, chlorine, sodium ions, and oxide reducers)
- Provide a preliminary assessment of RENEL's water treatment systems
- Identify modern methods for preserving equipment during shutdown

1.1 BACKGROUND

RENEL is experiencing persistent corrosion problems on internal surfaces exposed to steam and boiler water. These problems are prevalent in its thermal power plants and urban district heating plants. Components affected by corrosion include boiler tubes, economizer tubes, and the low-pressure sections of steam turbine. RENEL's own investigations revealed that these problems are caused by improper quality of the boiler feedwater and steam and by lack of proper methods for material protection during prolonged shutdown periods.

In most of the RENEL plants, makeup water and cooling water are supplied from surface sources. This water is heavily polluted with salts and organic matter. The water treatment process consist of:

- Pretreatment of coagulation and decarbonization with iron salts and hydrated lime

- Demineralization with anion cation filters and mixed bed units
- Water softening with sodium cationic filters
- Strong acid cationic filters and mixed bed filters for treating 50 to 100 percent of the condensate return

The quality of boiler feedwater is adversely affected by inadequate pretreatment, cooling water inleakage in the condensers, and low quality district heating condensate returns.

It has been reported that usage of reagents for regeneration and washing is 3 to 10 times higher than normal. This situation represents a significant increase in the operating costs and large quantities of chemical waste to be treated or discharged.

On the internal surfaces of boiler tubes, a tenacious crust of carbonate deposits have been observed. These deposits represent significant resistance to heat transfer and cause undesirable elevation of the tube metal temperatures. This condition, in turn, aggravates exposure to corrosion on the gas side.

There are several designs of water treatment equipment installed in RENEL power plants and district heating installations. In addition to domestic Romanian designs, there are also designs supplied from the former Soviet Bloc countries. Most of the treatment systems are manually controlled, and the laboratories are reported to lack modern analytical equipment.

Recognizing the urgent need for modernization of the water treatment systems, RENEL has indicated the need for the following:

- Information on modern technologies for water treatment, especially those that are able to remove colloidal substances
- Information on modern methods for controlling and monitoring the treatment plants
- Information of high performance chemicals for ion exchangers, inhibitors, and carrier substances
- Information on modern methods for preserving the steam system components during prolonged outages to minimize corrosive attacks

1.2 REPORT ORGANIZATION

The report on water treatment consists of five sections. In addition to this introductory section, this report contains the following:

- Section 2 summarizes the study findings, and presents the conclusions and recommendations derived from the investigations.
- Section 3 outlines the basic principles of modern water treatment provisions and standards for impurity content in boiler feedwater.
- Section 4 reviews and assesses the water treatment provisions in RENEL's power and district heating plants.
- Section 5 outlines the current layup practices to prevent corrosive attacks during prolonged shutdowns.

Section 2

Summary, Conclusions, and Recommendations

In many of its power plants and district heating boilers, RENEL is experiencing severe and widespread deposits and water-side corrosion. Such deleterious effects are normally the result of inadequate treatment of the raw water before it is used as makeup for the steam system water inventory. Corrosion is further aggravated if there is insufficient care exercised to remove any dissolved salts and oxygen from the condensate returning to the boiler.

Most of RENEL's plants obtain their water supply from surface sources, such as lakes or rivers. The incoming water is severely contaminated with mineral salts and organic matter. The existing water treatment systems are unable to remove these contaminants, and the resulting water quality is far below the desirable purity levels.

The water treatment provisions in RENEL's plants have the same basic steps as those used in modern Western plants, namely, pretreatment in clarifiers, demineralization, and condensate polishing. However, in RENEL's own assessment, the system is outdated and the equipment needs overhaul. A reliable automatic control system is needed to replace the current poorly instrumented and manually controlled operation. Some of the reagents are inappropriate for the impurities in the water. Observations by the Bechtel team, in the course of a visit to the Progressu plant, confirm this assessment.

Within the limited scope of this study, Bechtel has reviewed the water treatment recommendations of Western boiler manufacturers and their standards of feedwater purity.

2.1 MODERN WATER TREATMENT METHODS AND DESIGN

2.1.1 Raw Water Treatment

The raw water treatment has four major functions: aeration, coagulation, settling, and filtration.

Aeration serves the purpose of removing undesirable dissolved gases, such as carbon dioxide and hydrogen sulfide. It is accomplished in vessels with multiple trays, by bubbling air through the water. Obeying the law of partial pressures, the process is highly effective. If need be, the effectiveness can be further improved by raising the temperature, or increasing the contact surface area or the water residence time.

Coagulation helps to reduce coarse suspended solids, silt, turbidity, color and colloids. Adding coagulating chemicals, such as alum, sodium aluminate, copperas,

or ferrisul improves the performance. These chemicals form a floc that assists the coagulation. Temperature, pH, and thorough mixing of the chemicals are beneficial. To improve separation of colloids, the electric charge must be analyzed.

Settling and coagulation take place in the clarifier. The coagulated particles settle in quiescent regions of the clarifier and can be drained off. Any foam collected on the surface must also be removed.

Filtration is the final step in the pretreatment process. Its purpose is to remove any residual floc or particulate matter from the water leaving the clarifier. Both gravity and pressure filters are in use. The filters are of the graded bed type (fine sand, coarse sand, gravel or coarse anthracite). Diatomaceous earth and special precoat filters are used to eliminate any residual oil or color.

2.1.2 Chemical Softening Process

The function of this process is to eliminate dissolved salts of calcium and magnesium, both of which may cause deposits and scale in the boiler. Variations of the process includes lime-soda softening, which calls for addition of lime and soda ash or sodium carbonate. Hot phosphate softening uses a combination of sodium hydroxide and sodium phosphate to react with calcium and magnesium salts at about 100 centigrade. Zeolite softening uses sodium regenerated resins to accomplish replacement of the calcium and magnesium ions with sodium.

Zeolite softening can reduce the water hardness sufficiently for medium pressure boilers. The hot phosphate process will produce hardness needed for high-pressure boilers.

2.1.3 Demineralization

This process can remove a range of mineral salts with a combination of cation and anion beds. Cation hydrogen beds remove calcium, magnesium, and sodium. Bicarbonates, sulfates, chlorides and water soluble silica are removed in the anion beds. After depletion, these beds can be regenerated. The usual installations will have combinations of two to five anion and cation beds. There are also mixed-bed demineralizers where cation and anion beds are in the same vessel. Demineralization can produce water with quality equal to or better than that made with evaporation.

For proper operation, the water fed to the demineralizers must be free of turbidity and organic matter.

5

2.1.4 Condensate Treatment

Tolerance to impurities, particularly calcium and magnesium salts, in modern high-pressure steam systems is quite low if corrosion or deposits are to be limited. Coordinated phosphate treatment, using trisodium phosphate and disodium phosphate addition to the water, helps to minimize these salts.

To protect the magnetite layer or steel surfaces, which tend to prevent further corrosion, the water pH must be controlled between 8.6 and 9.4. This is accomplished by adding ammonia to the water. In addition to careful deaeration, the oxygen concentration is kept under control with the addition of hydrazine.

In dual purpose plants, where some of the steam is diverted for industrial or district heating, the returning condensate may contain undesirable impurities. In such installations, a condensate polishing station is installed. The polisher consists of deep bed cation demineralizers. The added benefit of these demineralizers is that they also remove any particulates from the water.

2.1.5 Design Considerations

The ultimate objective of the water treatment system is to ensure that the feedwater entering the boiler is free of detrimental constituents. The target values are shown in Table 3-2. The water treatment equipment and reagents must be specified to supply an adequate quantity of makeup water under the conditions of worst expected raw water quality and the maximum probable demand for makeup water. On-line and laboratory chemical analysis capability must be provided for timely and accurate detection of changes in the raw water and feedwater chemistry, together with automatic dosing of reagents.

2.2 WATER TREATMENT PROBLEMS AT RENEL

Information provided by RENEL indicates that the concentration of raw water impurities is well within the range experienced in the United States. With properly designed and operated water treatment plants, satisfactory makeup water quality should be attainable from the raw water available at the RENEL power plants.

Detailed analyses of problems at each plant will be required to determine the causes of poor performance of the treatment plants, and the appropriate remedies. The assessments below are based on information received during the data gathering visit to RENEL and the Progressu plant.

Many of the downstream operational problems in the treatment plant may be traced back to inadequate performance of the pretreatment plant. There are five different settler designs used in the plants. There are no data about any differences in the performance among these designs. However, it was reported that there is insufficient mixing of the reagents, and they are not able to respond to changes in raw water quality or demand level. There are no automatic controls for dosing of the reagents. The chemical softening process appears to be ineffective in removing the silica, including the colloidal form. Removal of organics is also deficient.

A properly designed clarifier should be equipped with separate chemical flash mixing, flocculation, sedimentation, and positive sludge removal. Properly designed and operated, these clarifiers could produce water with suspended solids content of 5 ppm. The polishing filters should have dual media (coal over fine sand) or multimedia beds. These could reduce turbidity to 1 ppm. If full softening takes place in the clarifier, calcium carbonate precipitation can be expected downstream unless the pH is lowered by acid addition. Unless oxidizing biocide is fed to the system, only about 50 percent reduction in organics can be expected.

With the existing pretreatment provisions, the water fed to the demineralizer has excessive amounts of organics and suspended solids, including colloidal silica. These impurities prevent proper functioning of the demineralizers and cause irreversible fouling of the resins. According to RENEL's observations, there are deficiencies in the demineralizer design, leading to uneven water distribution in the beds. Backwashing uses two to three times the normal amounts of chemicals. This may be at least partly due to cocurrent backwashing which is used because of inadequacies of the demineralizer internals design. The solids trapping devices are ineffective and have high-pressure drop. There is a belief that the resins used are not appropriate for the service. The protective polymer liners in the demineralizer vessels have puncture holes and are delaminating.

In addition to the above mentioned poor pretreatment, the problems in the demineralizer system can be traced to design deficiencies and the lack of adequate instrumentation and controls. These problems point up the need for a general redesign and refurbishing of the entire water treatment system.

2.3 STEAM SYSTEM LAYUP DURING SHUTDOWN

The internal surfaces of the steam system are susceptible to severe oxidation in the presence of moisture-laden air. The layup procedures are designed to prevent such corrosive damage. During hydro tests after construction or major repairs, the nondrainable portions of the system need to be filled with demineralized water



having 10 ppm of ammonia (for pH control) and 500 ppm of hydrazine to reduce the dissolved oxygen. Before initial startup the system is normally flushed and given a steam blow to remove scale from the surfaces. Chemical cleaning is accomplished with mild organic acids (chelates). The solvents may be circulated or allowed to stay in the system for some period of time. After cleaning, the surfaces are passivated. If startup is not scheduled immediately, the system is to be filled with demineralized water containing 10 ppm of ammonia and 200 ppm of hydrazine. Any free surfaces are to be covered with nitrogen under 0.3 bar positive pressure.

Layup procedures during shutdown vary with the expected shutdown duration and are also different during shutdowns depending on whether the system remains closed or must be opened up for repair.

For shutdowns of 4 days or less, without opening up of the system, the system is kept full of feedwater, maintaining the same ammonia and hydrazine concentration as during operation. A nitrogen blanket of 0.3 bar is to be established and maintained on the free surfaces and on the shell side of feedwater heaters. If part of the system must be opened for repair, this portion needs to be isolated and drained. The remainder of the system is kept full and under a nitrogen cap, as described above. Depending on the nature of repairs, it may be necessary to apply chemical cleaning on the repaired portion.

If the system is shut down longer than 4 days without repair work, it is to be filled with condensate quality water and capped with nitrogen as above. A water pH of 10 is to be maintained. The water must have 10 ppm of ammonia and 200 ppm of hydrazine. If there is a danger of freezing, the drainable portion may be emptied of water and filled with nitrogen. Heat may need to be applied to the nondrainable portion.

If the shutdown is longer than 4 days and involves repairs requiring partial draining, the portion to be repaired needs to be isolated and drained. The remainder of the system should be treated as above. After repairs and cleaning, the drained portion needs to be filled with demineralized water and capped with 0.3 bar nitrogen.

To provide corrosion protection during startup, it is essential to maintain pH control and to start deaeration using an auxiliary steam source.

2.4 CONCLUSIONS

Although limited in scope, the study provided an insight into modern Western water treatment methods and equipment. Methods for preventing corrosion

damage in the steam system components during shutdown have also been outlined. This study is only the preliminary step towards correcting the water treatment plant problems in RENEL's power plants. A plant-by-plant detailed study will be required to specifically identify the necessary upgrades.

The quality of the raw water received by RENEL's power and district heating plants is not worse than that of Western power plants. Since modern treatment plants can produce adequately pure makeup water for Western power plants, there is no reason why the same could not be accomplished in Romania with proper upgrading and modernization of the treatment plants.

Many of the problems with feedwater quality and subsequent steam-side scale and corrosion damage are caused by inadequate pretreatment. Correction of deficiencies in this section of the treatment plant should have high priority.

While the upgrading requires capital expenditures, significant economic benefits may be derived from improved plant availability and reduction of maintenance costs. The annual electricity production should increase and significant operating cost savings should result. The useful life of the plants will also be extended.

2.5 RECOMMENDATIONS

1. Based on a system-wide review of the problems associated with the water treatment plants, RENEL should conduct a detailed study on three of our representative plants to develop the specifications of modern water treatment plants which can produce adequate water quality for the power and district heating boilers. This study should be started with a series of carefully instrumented tests on the existing treatment plants.
2. The water treatment plant designs should be standardized around one or two basic designs. This standardization will result in economic benefits from quantity buying and the spare parts inventory.
3. Based on cost/benefit analyses, refurbishing of the treatment plants should be initiated at the earliest date when funds can be secured.

Section 3

Basic Principles of Modern Water Treatment

Treatment of boiler feedwater is a technology under continuous development and evolution since the 1880's. Numerous boiler explosions in that time period were traced back to boiler tube plugging with scale and sludge. These occurrences provided the incentive for removing impurities from the feedwater. The simple injection of soda ash directly into the boiler was an adequate method for the steam pressures and temperatures prevailing in that period.

Evolution of ever more efficient steam cycles at higher and higher steam pressures and temperatures and the desire to improve plant reliability led to increasingly more rigorous treatment techniques. Introduction of supercritical steam cycles accelerated the evolution of all volatile treatment (AVT) methods. These methods avoid the use of solid additives, where all the additives are carried along with the steam. AVT, with condensate polishing, provides the most modern techniques.

This section discusses the basic principles guiding the water treatment processes in modern western power plants.

3.1 MAKEUP WATER TREATMENT

In a power plant, any water losses in the steam cycle, such as steam and water leakage, process requirements, blowdown, sampling and venting, are replaced with treated raw water. Raw water is typically obtained from nearby rivers, water wells at the plant site, or occasionally from the community water supply. The purpose of treating the incoming raw water is to remove any solid or dissolved chemical species that could lead to deposits, sludges, and corrosion damage in the steam system components.

3.1.1 Raw Water Treatment

The chemical content of raw water varies widely with geographic location, upstream discharges into the source, and even seasonally. Table 3-1 shows the type and range of impurities found in typical surface and groundwater sources in the United States. The design of a water treatment system must be tailored to efficiently remove harmful contaminants from the raw water available at a given site.

The first stage of raw water treatment typically involves aeration, settling, coagulation, and filtering. These processes are discussed in the following paragraphs.

Aeration is used to remove undesirable dissolved gases, such as CO_2 and H_2S . The process involves bubbling air through the water. Because of the low partial pressure

Table 3-1
Analyses of Typical Surface and Groundwaters in the United States
(Parts per million - ppm)

Constituents	Rivers ⁽¹⁾	Lakes/Ponds ⁽²⁾	Wells ⁽²⁾
Silica (SiO ₂)	2.3 - 13	0.4 - 39	12 - 34
Iron (Fe)	0.03 - 0.12	0.05 - 0.15	0.0 - 2.1
Calcium (Ca)	1.7 - 5.3	3.4 - 79	7.2 - 72
Magnesium (Mg)	0.4 - 10	7 - 28	2.5 - 33
Sodium (Na)	1.4 - 3.5	6.4 - 28	138 - 147
Potassium (K)	4.0 - 4.7	0.6 - 1.0	0.4 - 1.7
Carbonate (CO ₃)	0.0 - 4	0	0
Bicarbonate (HCO ₃)	20 - 174	3 - 138	170 - 293
Sulfate (SO ₄)	1 - 300	4.4 - 17	8 - 200
Chloride (Cl)	7 - 79	2.6 - 6.5	8 - 195
Fluoride (F)	0 - 0.4	0.1 - 0.6	0.8 - 2.5
Nitrate (NO ₃)	0.2 - 4	0.2 - 0.4	0 - 1.1
Dissolved solids	42 - 661	23 - 171	392 - 1,380
Total hardness (as CaCO ₃)	35 - 315	34 - 171	28 - 316
Non-carbonate hardness	16 - 197	23 - 171	28 - 276
Specific conductance (mmho at 25°C)	56 - 1,040	30 - 263	661 - 867
pH	7 - 8.4	5.8 - 8.2	7.6 - 8

Notes:

1. Data represent annual averages. Maximum values may be 50 percent higher or lower.
2. River data are from six geographic locations, lake data are from three locations, and the well data are from three locations.

Source: Combustion – Fossil Power Systems
 Combustion Engineering Company, 1981

of these gases in the normal atmosphere, they will desorb from the water and leave with the vent. At the same time, the water becomes saturated with oxygen and nitrogen. Aeration is able to remove the undesirable gases completely. A modern forced air aerator is shown in Figure 3-1.

Coagulation reduces surface water contamination by adding coagulants, such as alum, sodium aluminate, copperas, or ferrisul. These agents form a floc which assists in coagulation of solids. The process is effective in removing coarse solids, silt, turbidity, color, and colloids. Removal of colloids requires a careful analysis of the impurities to establish their electrical charge, one of the principal reasons for remaining in a suspended state.

Settling is used to separate the majority of suspended solids, such as the products of coagulation, from the water. Coagulation and settling are processes carried out in clarifiers. Functional arrangement in a modern clarifier is shown in Figure 3-2.

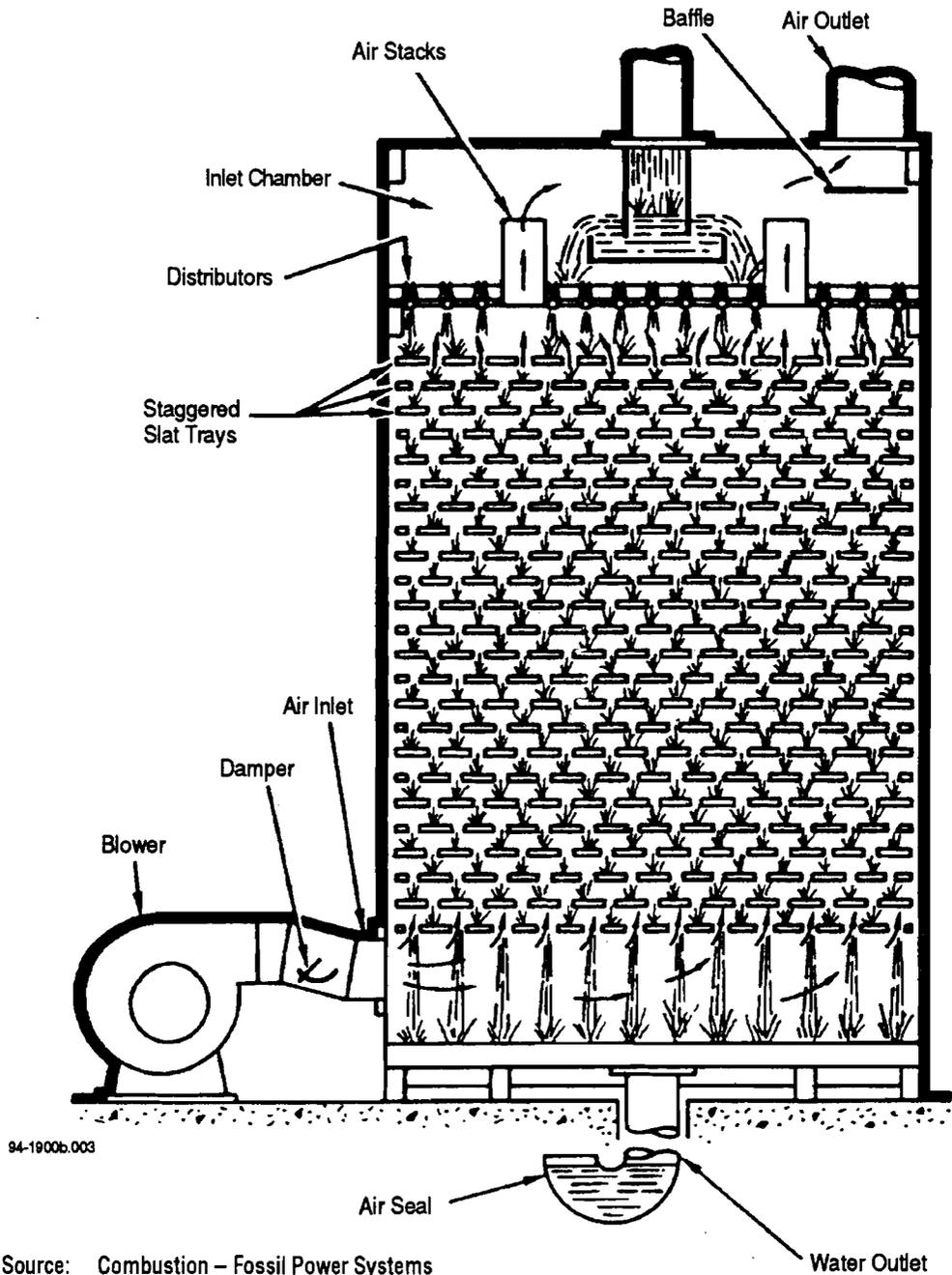
Filtration serves to remove any remaining floc or sludge components from the water. For filtration, the water is passed through a filter bed, consisting of graded gravel or anthracite. Diatomaceous earth or special precoat filters are used to remove oil or color from the water. Either gravity (Figure 3-3) or pressure (Figure 3-4) filters may be used for this purpose.

3.1.2 Water Softening

The presence of excessive hardness due to silica and silt in the water may cause scale deposits in the steam system. There are chemical processes that can effectively reduce such constituents. Processes that are frequently used are described below.

Lime-soda softening is a process that is used to precipitate calcium bicarbonate as calcium carbonate and magnesium salts as magnesium hydroxide. Both reaction products have very low solubility in water. Reagents used in the process are lime and soda ash (sodium carbonate). This process can reduce the hardness to 33 parts per million (ppm).

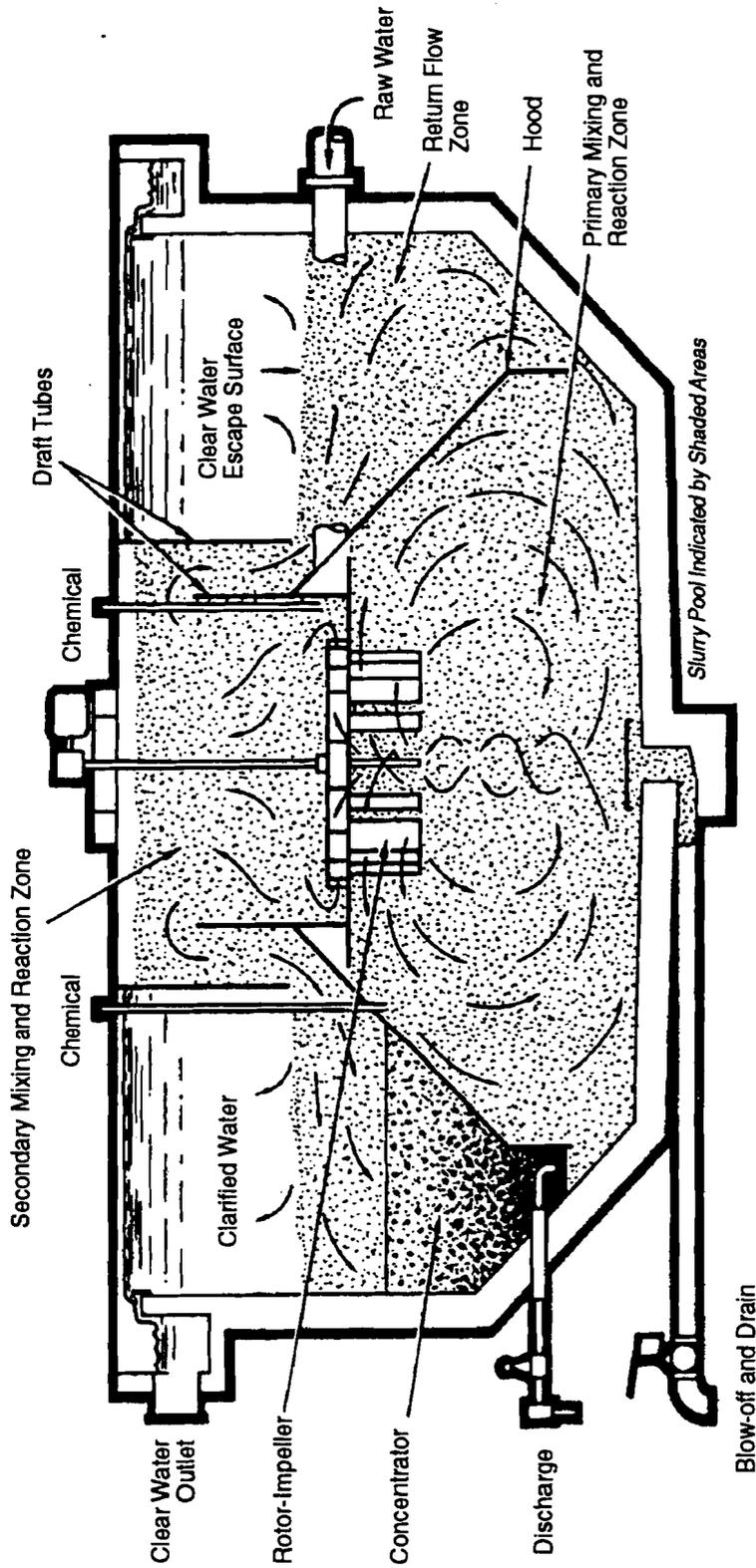
Hot-process phosphate softening uses phosphate salt (for example, sodium phosphate) to react with calcium and magnesium salts. The process takes place at temperatures of 100°C. The reactions can be controlled to produce essentially zero hardness. The process precipitates calcium hardness in the form of tricalcium phosphate and the magnesium as magnesium hydroxide. With hardness below 60 ppm, adequate softness can be achieved in a single stage. Higher hardness values require two-stage treatment. This process is particularly suitable for turbid waters with low hardness and alkalinity. A typical configuration of the hot phosphate softener is shown in Figure 3-5.



Source: Combustion – Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-1 Forced-Draft Aerator

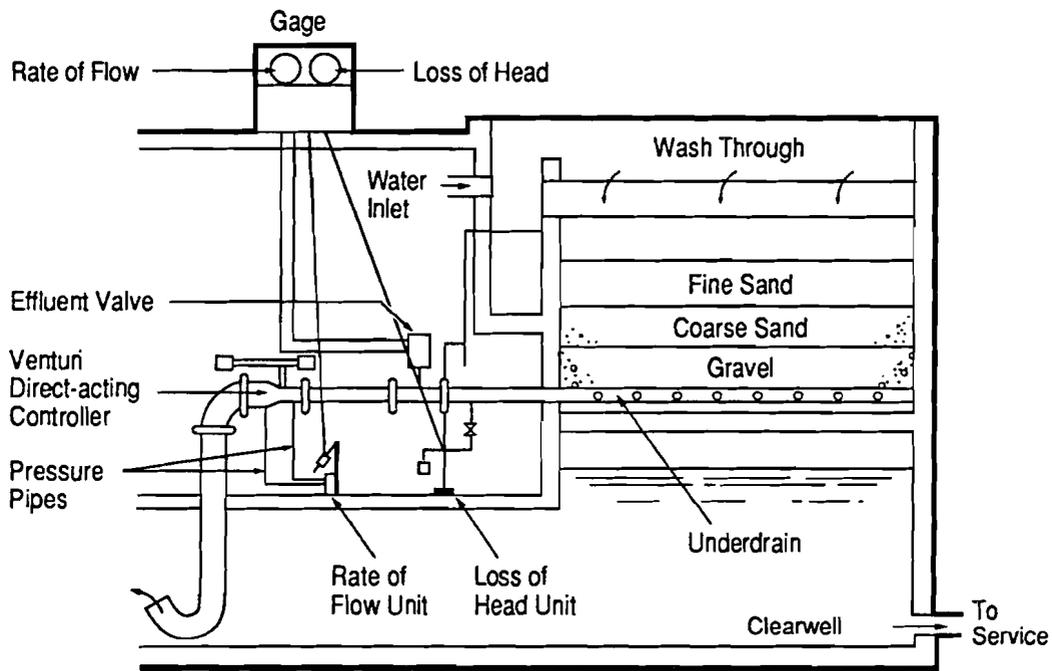
13



94-1900b.004

Source: Combustion - Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-2 Solids-Contact Clarifier



94-1900b.016

Source: Combustion - Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-3 Gravity Filter

15

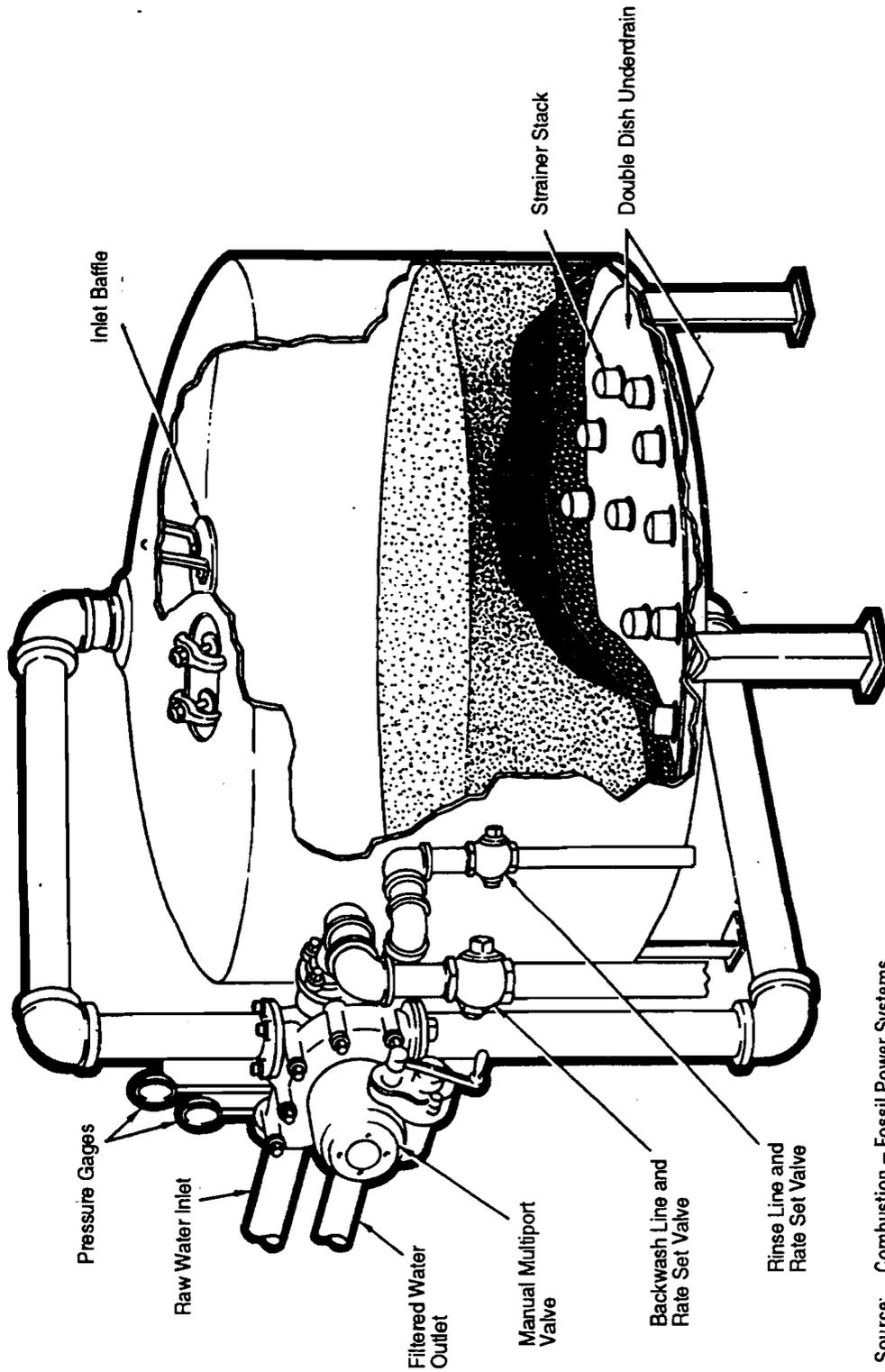
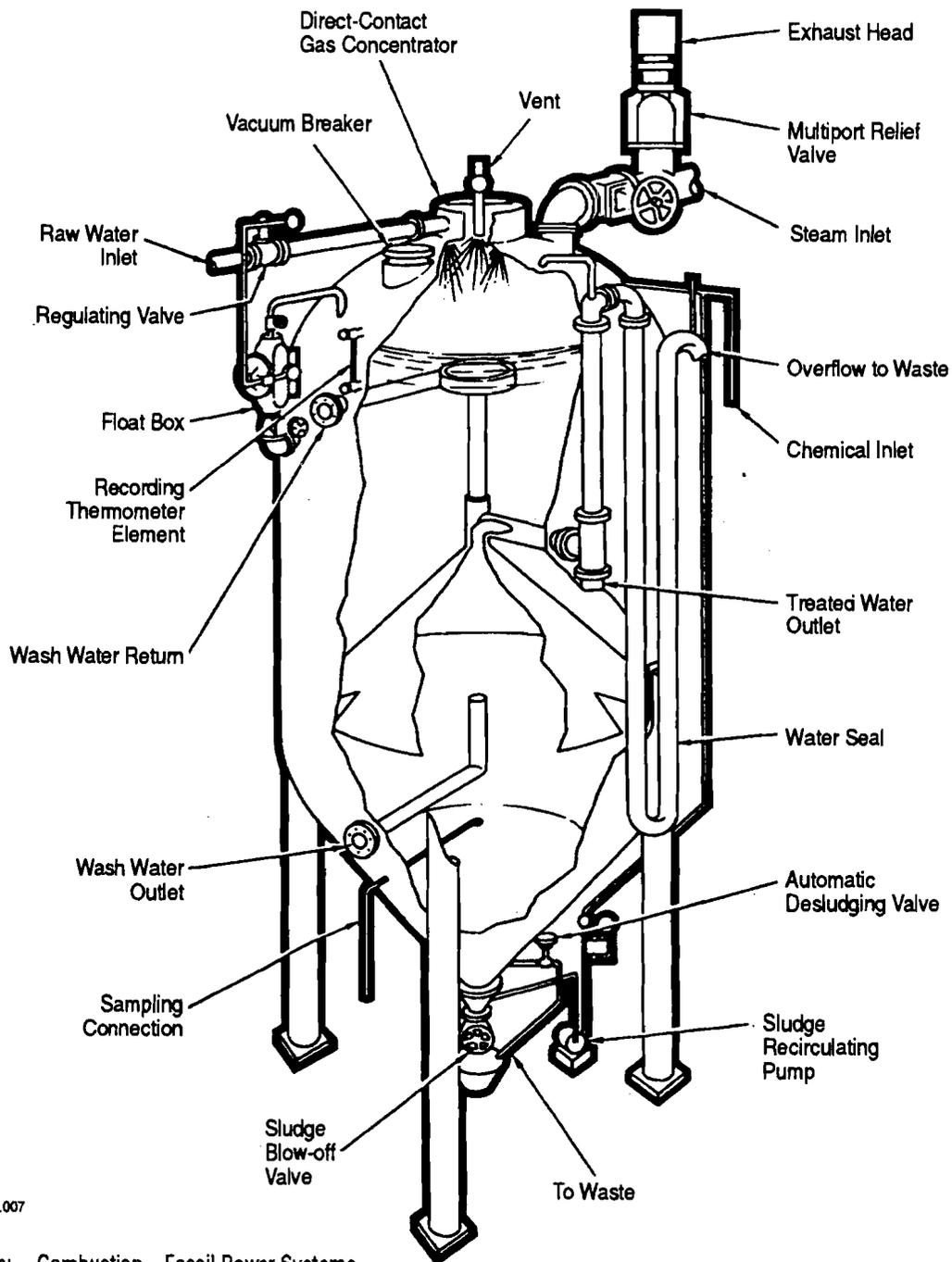


Figure 3-4 Vertical-Type Pressure Sand Filter

Source: Combustion – Fossil Power Systems
Combustion Engineering Company, 1981

94-1900b.005



94-1900b.007

Source: Combustion – Fossil Power Systems
 Combustion Engineering Company, 1981

Figure 3-5 Hot-Process Phosphate Softening

Zeolite softening uses natural or artificial compounds with the capability to exchange ions with materials contacting them. Such compounds include natural green sand, sulfonated coal, and phenolic or polystyrene resins. In the process, hard water is passed down through a bed of zeolite. In the bed, the calcium and magnesium ions are exchanged for sodium. A sodium zeolite softener is shown in Figure 3-6. After depletion, these beds can be regenerated by flowing sodium salt solution through them. Treatment with salt solution and acids can reduce alkalinity and hardness in water containing a high concentration of carbonates. Zeolites can produce adequate water quality for industrial boilers. Hot lime-zeolite can produce adequate water for medium-pressure boilers.

The process is not suitable for highly turbid waters or those with high carbon dioxide content. Silica is not removed by zeolites.

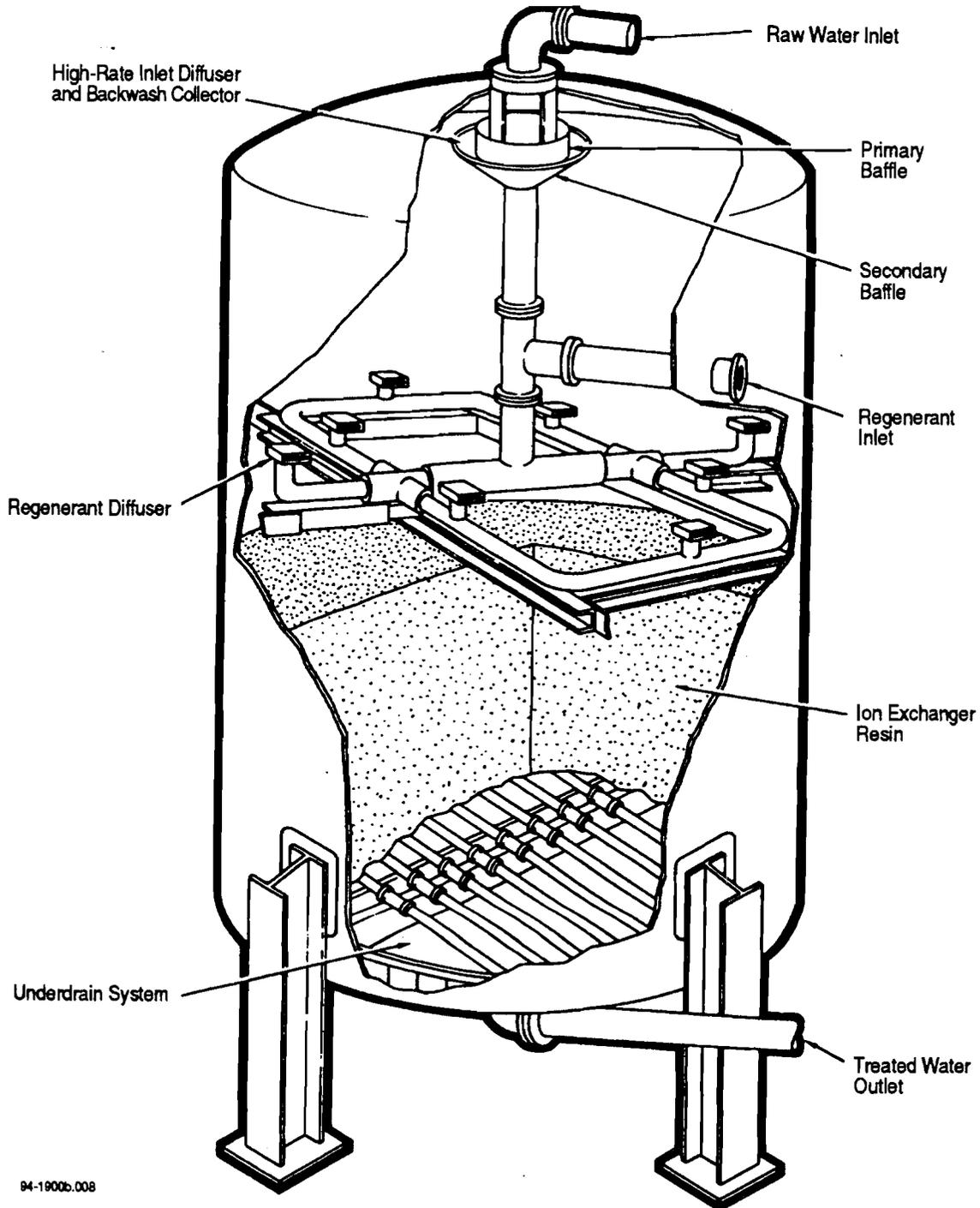
Demineralization uses ion exchange processes to remove mineral salts. Calcium, magnesium and sodium are removed in hydrogen cation exchangers. Anions, such as bicarbonates, sulfates, chlorides and soluble silica are removed in the anion exchangers. Synthetic resins are used in the exchange beds. Resins with a wide range of properties are commercially available. Sulfonic, carboxylic, and phenolic hydroxyl compounds are used in cation exchangers. Amino or quarternary nitrogen is used in the anion exchangers. Demineralizers can produce water quality comparable or better than evaporation processes.

Anion and cation exchangers can be arranged and grouped in a variety of combinations (Figure 3-7). Mixed-bed demineralizers can accomplish both anion and cation exchange in a single unit. Figure 3-8 is a schematic showing the mixed-bed demineralizer. The regeneration scheme of these types of demineralizers is shown in Figure 3-9.

For proper and effective operation, the water fed to the demineralizers must be free of turbidity and organic matter. These substances tend to foul and blind the resins and reduce their effectiveness.

3.2 CONDENSATE TREATMENT

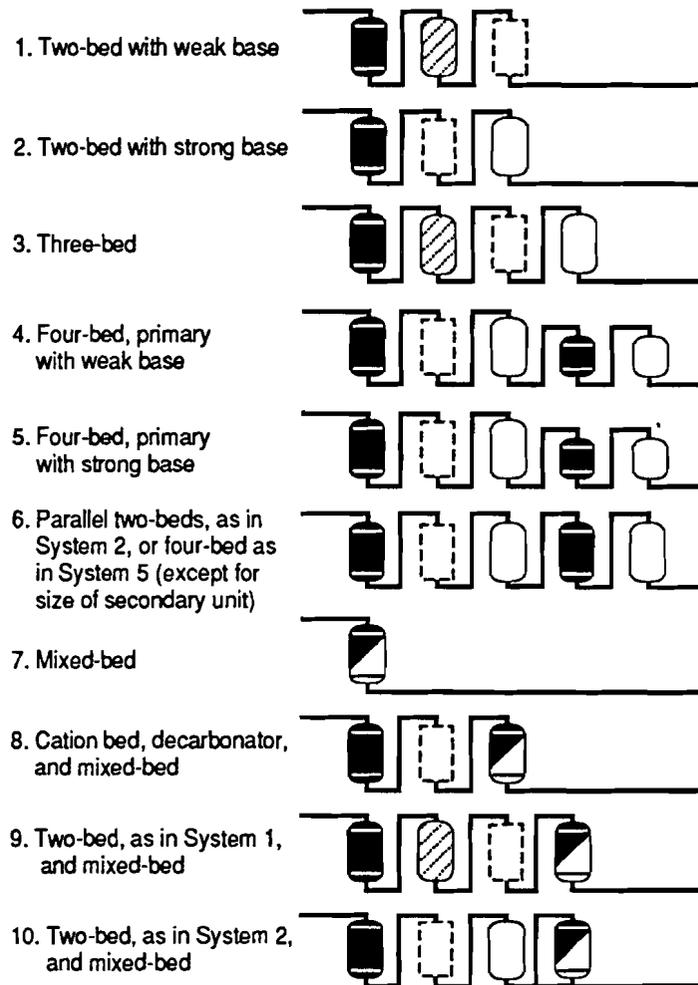
Since high water quality is critical for extended trouble-free operation of the boilers, there is a need for internal treatment of the boiler feedwater, particularly in modern high-pressure plants. One method to keep the feedwater free of calcium and magnesium salts is to treat the feedwater with phosphates, such as trisodium phosphate, disodium hydrogen phosphate, sodium metaphosphate, or sodium



94-1900b.008

Source: Combustion – Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-6 Sodium Zeolite Softener



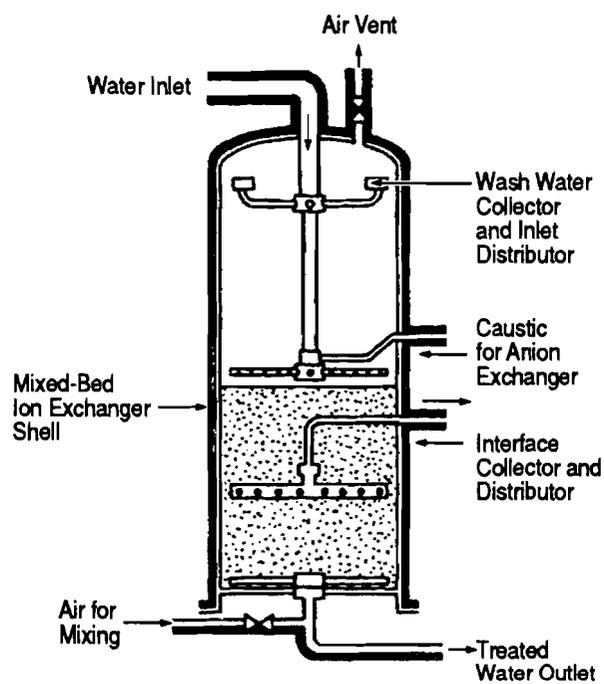
The secondary units in Systems 4 and 5, which are used only for polishing, may be smaller than the primary, as indicated.

- Strong acid cation exchanger
- Strong base anion exchanger
- Weak base anion exchanger
- Mixed-bed
- Decarbonator or vacuum deaerator

94-1900b.001

Source: Combustion – Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-7 Ten Major Demineralizer Systems

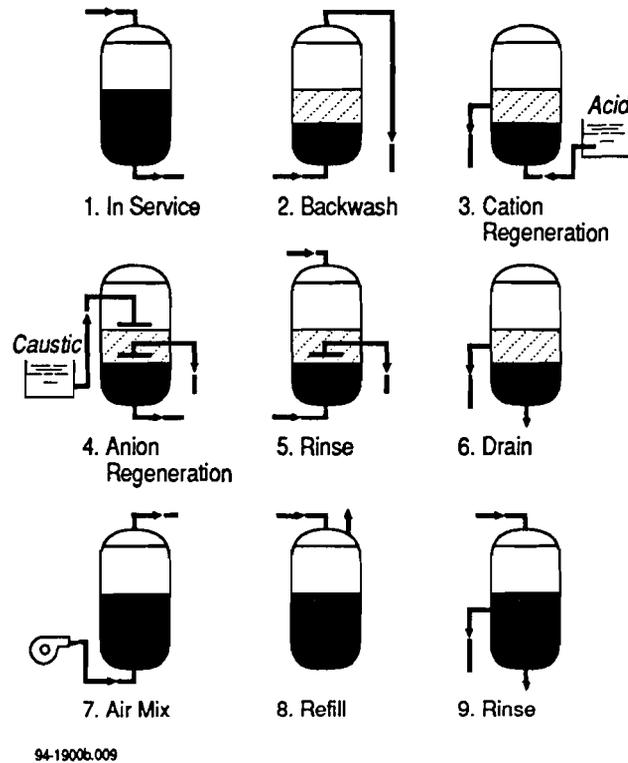


94-1900b.002

* Houses mix of cation and anion exchange resins. Air for mix enters through bottom distributor.

Source: Combustion – Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-8 Mixed-Bed Demineralizer*



* Initial backwash to end of rinse and return to service takes 2 to 3 hours.

Source: Combustion - Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-9 Regeneration of Mixed-Bed Demineralizer*

22

pyrophosphate. These agents convert the calcium and magnesium salts to their respective phosphates which are readily dispersed and removed with the blowdown.

Steel, used in boiler pressure parts, develops a protective layer of magnetite in contact with water. The objective of internal water treatment is to prevent any chemically induced damage to this protective layer. Researchers have found that the magnetite layer is sensitive to dissolution at pH values below 5 and above 13. Minimum corrosion occurs at pH values between 9 and 11. An effective way to establish the right pH is by means of the so-called coordinated phosphate treatment. The preferred way is to add a combination of trisodium phosphate and disodium phosphate. This combination is less sensitive to errors in the chemical dosing.

Some boiler manufacturers recommend use of "volatile treatment" which involves addition of volatile amines, such as ammonia. This additive maintains pH control in boilers operating at pressures above 135 atmospheres. Hydrazine or suitable substitutes are added for oxygen control. This treatment avoids the addition of any solids and with it the carryover of volatile solids. This treatment is not desirable with any hardness in the water or impurities introduced with condenser leakage.

The presence of excessive oxygen in the feedwater can lead to pitting corrosion. Mechanical deaeration and the use of hydrazine are necessary to keep oxygen concentrations below 5 parts per billion (ppb). A major problem is keeping the oxygen concentration under control during startup, before the deaerator reaches operating pressure. Admission of auxiliary steam at 1.2 to 1.3 atmospheres to the deaerator during startup helps to maintain oxygen control during this period.

In plants where part of the steam is used for industrial or district heat supply, the returning condensate has undesirable contaminants. This condensate is treated in a separate polisher. This polisher consists of deep bed demineralizers with cation resin. These beds have the added advantage of serving as particulate filters. The beds may be designed with resin regeneration or they may use disposable cartridge resins.

3.3 DESIGN CONSIDERATIONS AND CRITERIA

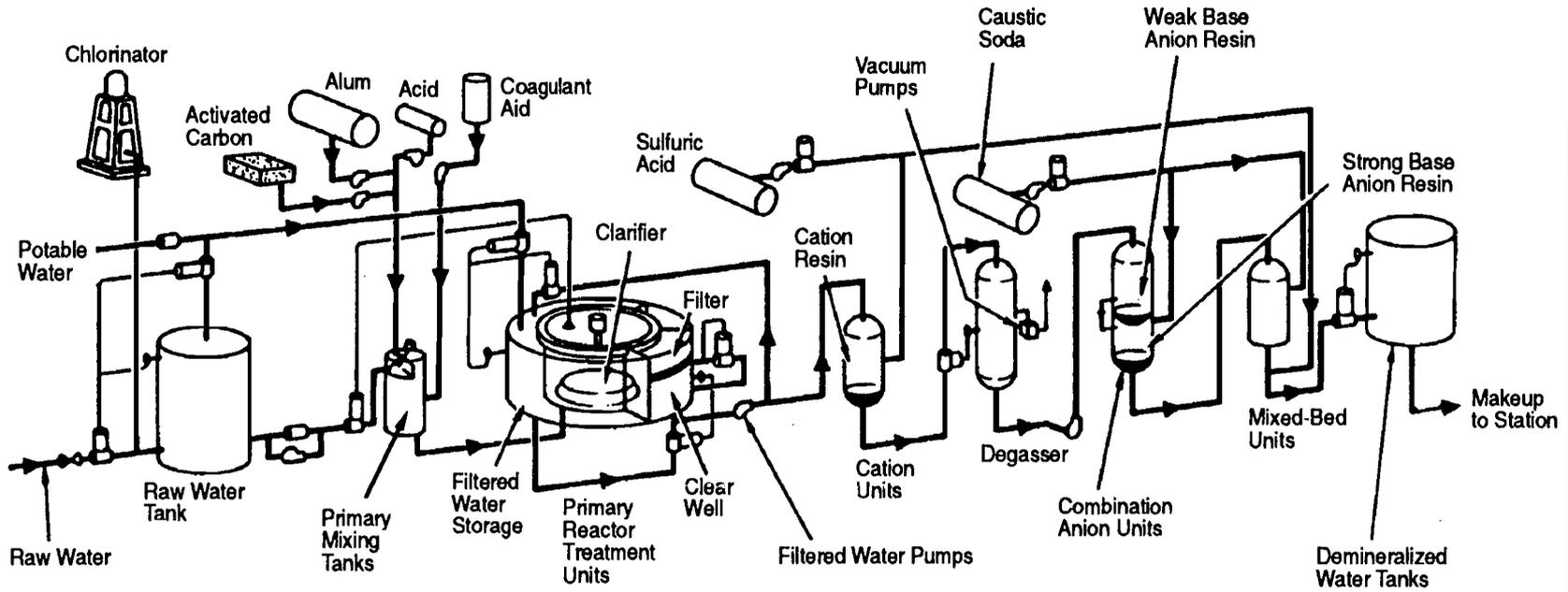
Because of harmful chemicals in the boiler feedwater, the steam system hardware is subject to severe corrosion and scale formation. The water treatment system configuration and the preferred additives are governed by certain factors, including the following:

- Impurity species and concentrations in the incoming raw water; possible variation of these factors because of the different seasons or for other reasons
- Boiler drum pressure and temperature
- Metals and alloys used in the pressure parts
- Probability of impurities entering the steam system during normal operating modes (for example, cooling water leakage into the condensate or condition of condensate returned from industrial or district heating users)
- Expected maximum demand for makeup water (rate of makeup and maximum short-term totals)

In new power plants, the water treatment system is designed as a system. The makeup and feedwater treatment sections are designed to ensure that the feedwater entering the boiler has the desired purity. A typical system arrangement is shown in Figure 3-10. Recommended maximum impurity concentration for drum-type boilers is shown in Table 3-2. A more detailed listing of target values for 140 to 150 bar drum-type boilers is given in Table 3-3. The values in Table 3-3 are for normal operation; they may be exceeded for short periods of time during startup and abnormal operations.

It should be recognized that proper operation of the treatment system requires the use of modern analytical instrumentation and reliable means for controlling the rate of reagent additions.

The water treatment system capacity must be conservatively selected. The major demand for makeup water is for replacement for boiler blowdown. With satisfactory operation of the treatment system, the blowdown rate may be as much as 3 to 5 percent of the feedwater flow. Other in-plant uses, such as closed-loop cooling and increased blowdown during startup and restart, add further demand.



94-1900b.010

Source: Combustion - Fossil Power Systems
Combustion Engineering Company, 1981

Figure 3-10 Demineralizer and Pretreatment Flow Diagram

25

Table 3-2
Recommended Boiler Feedwater Quality Limits

Quality Parameter	Boiler Drum Pressure			
	10 - 40	40 - 68	68 - 136	above 136
Total solids (ppm)	–	–	0.15	0.05
Iron (ppm)	0.1	0.05	0.01	0.01
Copper (ppm)	0.05	0.03	0.005	0.002
Oxygen (ppm)	0.007	0.007	0.007	0.007
pH	8.0 - 9.5	8.0 - 9.5	8.5 - 9.5	8.8 - 9.5*
Total hardness (as CaCO ₃) (ppm)	0	0	0	0
Total organics	0	0	0	0

Notes:

* Limit with steel feedwater heaters: 9.2 - 9.5; with copper alloy heaters: 8.8 - 9.2

Source: STEAM, ITS GENERATION AND USE; Babcock and Wilcox Co., 1992

Table 3-3
Recommended Water Quality Targets for Boiler Drum Pressures
of 140 to 150 Bar with all Volatile Treatment

Makeup Water from Mixed-Bed Demineralizer		
Parameter	Unit	Target Value (equal to or less than)
Sodium	ppb	3
Chloride	ppb	3
Sulfate	ppb	3
Silica	ppb	10
Total organic carbon	ppb	300
Specific conductivity	mmho/25°C	0.1
Condensate Discharge		
Parameter	Unit	Target Value (equal to or less than)
Sodium		6 (with polisher)
		3 (without polisher)
Oxygen	ppb	20
Total organic carbon	ppb	200
Cation conductivity	mmho/25°C	0.3 (with polisher)
		0.3 (without polisher)
Condensate from Polisher		
Parameter	Unit	Target Value (equal to or less than)
Sodium	ppb	3
Silica	ppb	0.1
Cation conductivity	mmho/25°C	0.02

Table 3-3 (Cont'd)

Deaerator Inlet		
Parameter	Unit	Target Value (equal to or less than)
Oxygen	ppb	20
Hydrazine	ppb	>20 or >3 * O ₂
Deaerator Outlet		
Parameter	Unit	Target Value (equal to or less than)
Oxygen	ppb	7
Feedwater Inlet		
Parameter	Unit	Target Value (equal to or less than)
Oxygen	ppb	5
Iron	ppb	10
Copper	ppb	2
Ammonia		consistent with all pH values
Cation conductivity	mmho/25°C	0.2
pH - all steel construction		9.0 - 9.6
- mixed steel/copper alloy construction		8.8 - 9.2
Steam		
Parameter	Unit	Target Value (equal to or less than)
Sodium	ppb	3
Silica	ppb	10
Chloride	ppb	3
Sulfate	ppb	3
Total organic carbon	ppb	100
Cation conductivity	ppb	0.15

Section 4

Water Treatment Problems in RENEL Power Plants

Excessive corrosion damage in RENEL power plants and district heating system boilers have been observed for some time. Corrosion and scale deposits have impaired the efficiency and reliability of these plants. The cause of these problems was traced back to the poor quality of makeup waters supplied to the boilers, and to contamination caused by cross leakage in the district heating unit heat exchangers.

Discussions in this section are based on data received from RENEL staff and a visit to the Progressu combined power and heat plant in Bucharest (Appendices A and B). The information gathered during the site visit was reviewed by Joseph Technology Corporation, Inc. Their assessment is contained in Appendix C. In addition, also used is information received in the course of a previously completed district heating plant study performed by Bechtel under a U.S. Trade and Development Agency contract.

4.1 RAW WATER SUPPLY

Most of the plants receive water from rivers and/or lakes. The incoming water contains significant amounts of contaminants and suspended solids. The concentration of the impurities varies widely from one water source to another and also seasonally. Table 4-1 indicates the range of concentrations:

**Table 4-1
Impurities in Raw Water**

Impurities	Concentrations
Alkalinity"m"	1.8 - 5.5 mval/l
Total hardness	3.5 - 7.5 mval/l
Calcium (+2 ion)	2.0 - 5.0 mval/l
Organics as KMnO ₄	20 - 120 mg/l
Total silica	6 - 20 mg/l
Suspended solids	30 - 250* mg/l

* Peaks during flooding may reach 1500 mg/l.

The above concentrations are well within the range experienced in the United States as evident from a comparison with Table 3-1.

4.2 PRETREATMENT PLANT – ISSUES AND ASSESSMENTS

Issues

RENEL lists 83 pretreatment plants. There are five types of units as indicated in Table 4-2. This table also identifies figure numbers for each of the clarifier types. Most of the plants have provisions for adding powdered lime, ferrous sulfate, or ferric chloride, and coagulating additives.

**Table 4-2
Pretreatment Clarifier Types**

Settler Type	Capacity (cm/h)	No. of Units	Figure No.
Static-type	100 - 200	20	4-1
Slurry recirculating with ejector	200 - 250	22	4-2
VABAG recirculating	300	2	4-3
ISPE slurry recirculating with ejector and scraping bridge	500-750	16	4-4
ISLGC with slurry recirculating pump and stirrer	620-1000	23	4-5

The additive feed system is shown in Figure 4-6. There is no indication that any deaeration process is used to remove carbon dioxide or hydrogen sulfide. There are final filters of horizontal or vertical tank type, using 0.6 - 1.2 mm quartz sand beds.

The RENEL staff reports that it is not able to achieve satisfactory operation of the system. Most of the problems seem to be related to deficiencies in the settler design. There is apparently inadequate mixing of reagents, the plant cannot respond to changes in raw water quality and flow rate changes, and the slurry bed and drain provisions are inadequate. There is no automatic control to adjust the reagent addition rates to the raw water quality and throughput. There are no provisions to maintain the settler at constant temperature.

As a result, the quality of the clarified water is not good enough for efficient operation of the demineralizers down stream. Colloidal silica is not removed and the decarbonation reaction is not completed.

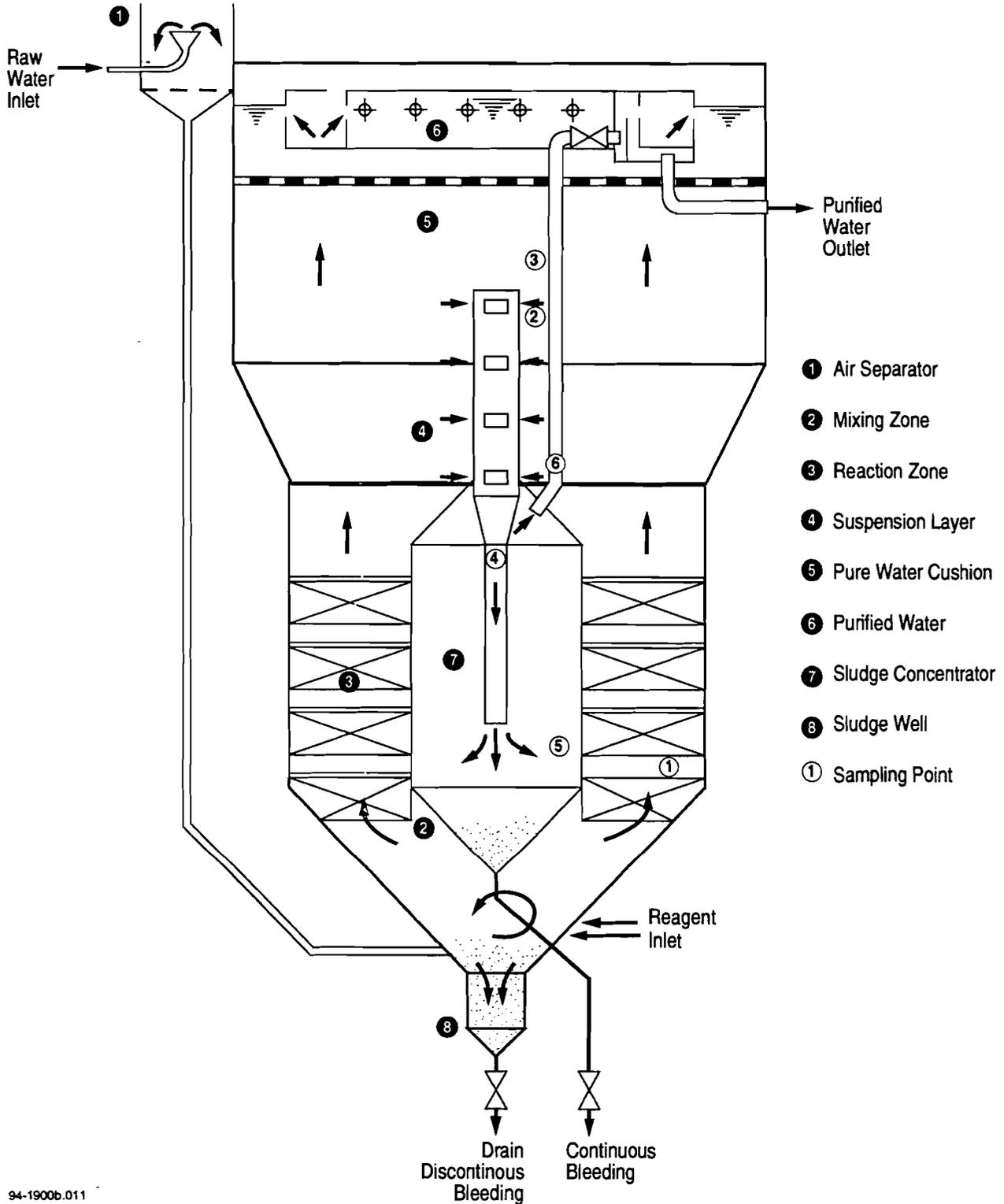
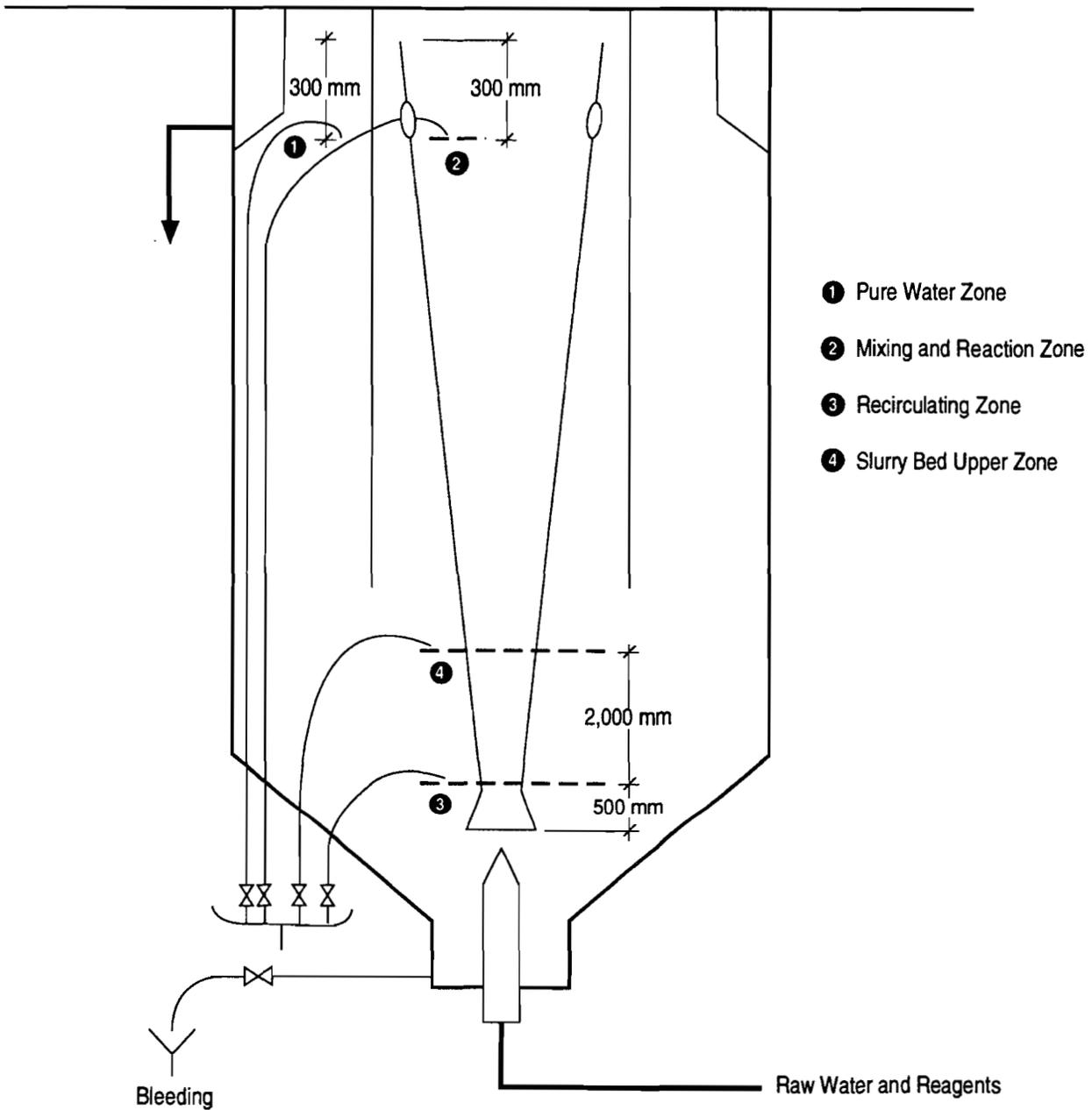


Figure 4-1 Static Settler Flow Sheet

94-1900b.011

31



94-1900b.012

Figure 4-2 Slurry Settler with Ejector Flow Sheet

32

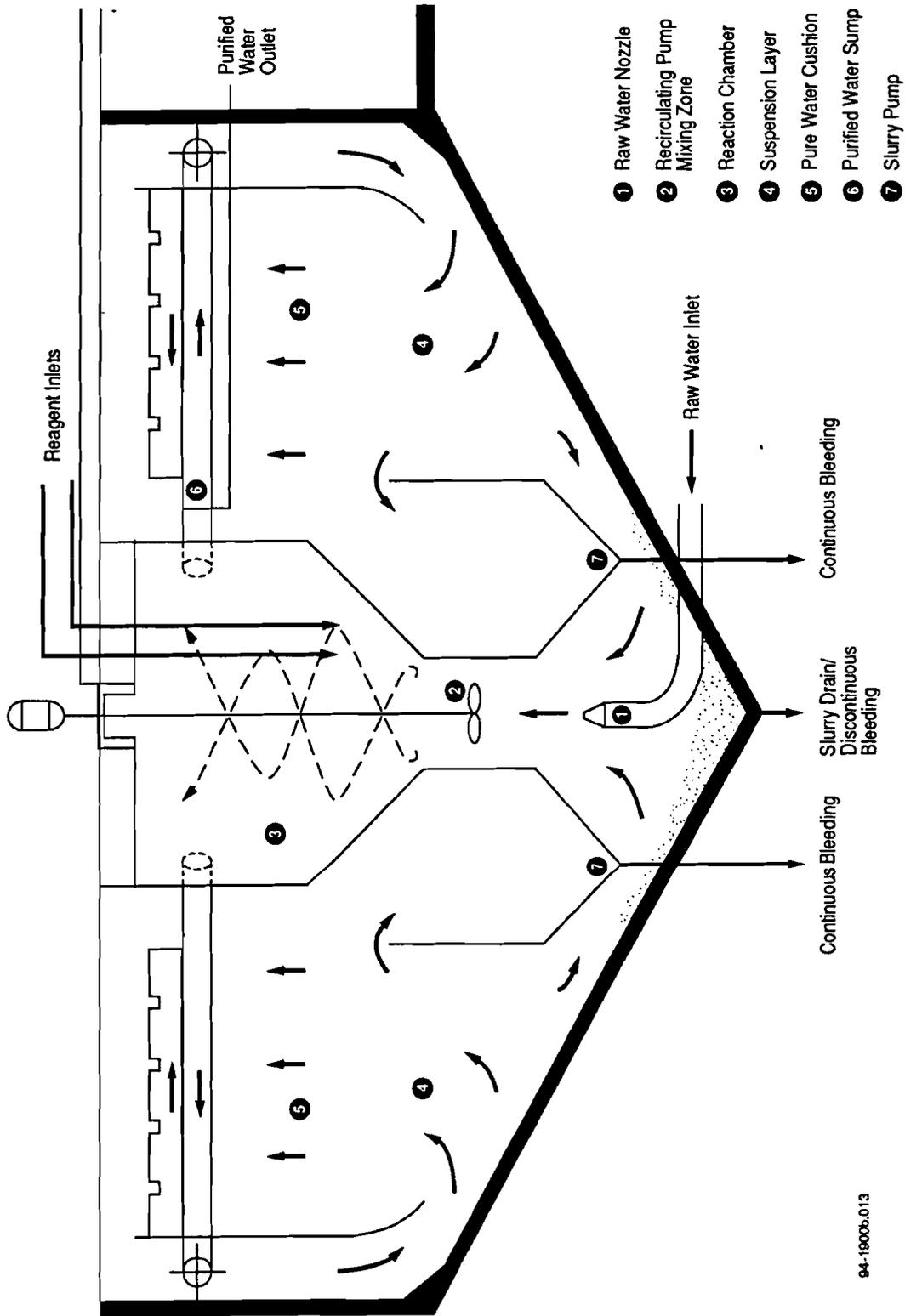
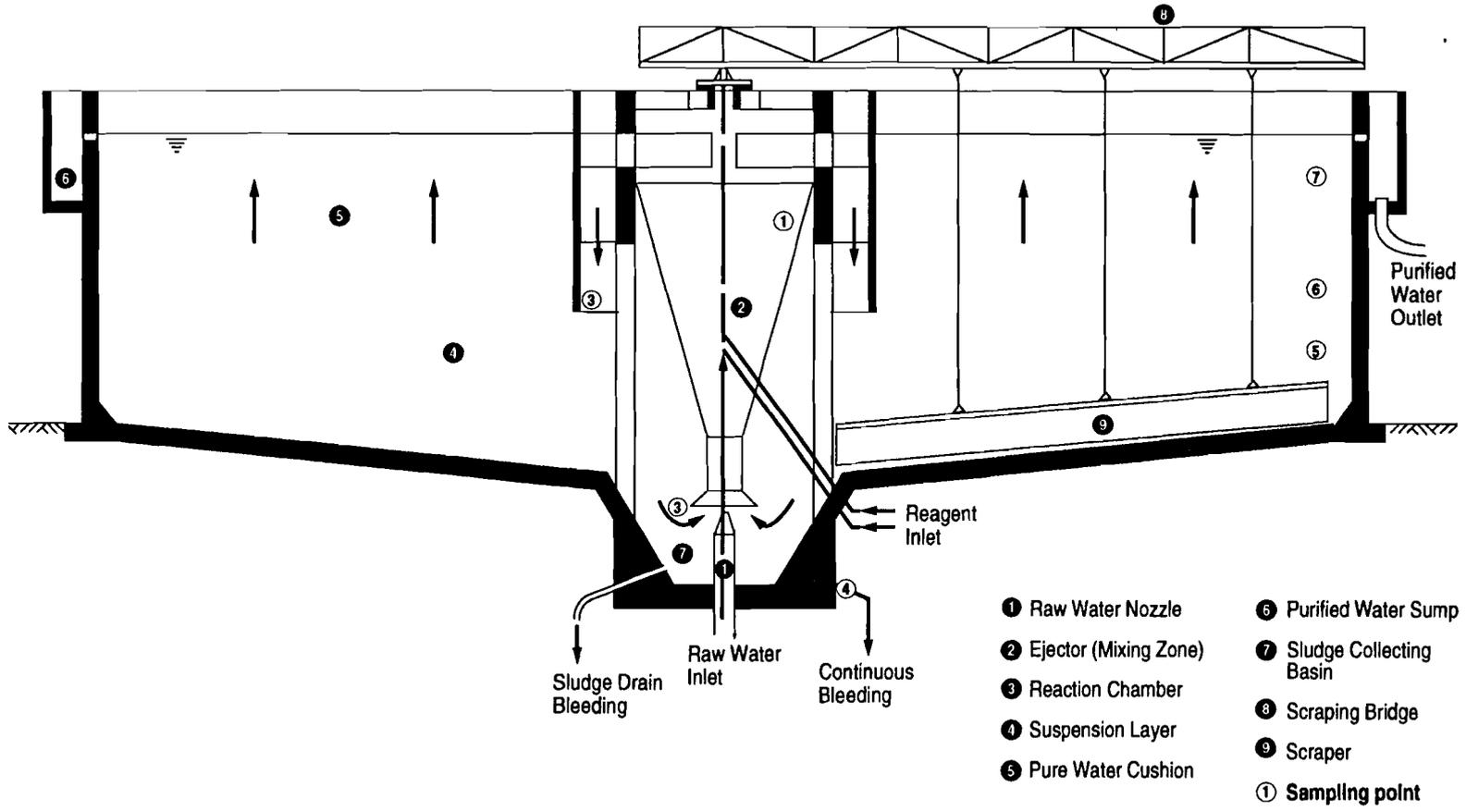


Figure 4-3 VABAG Recirculating Settler

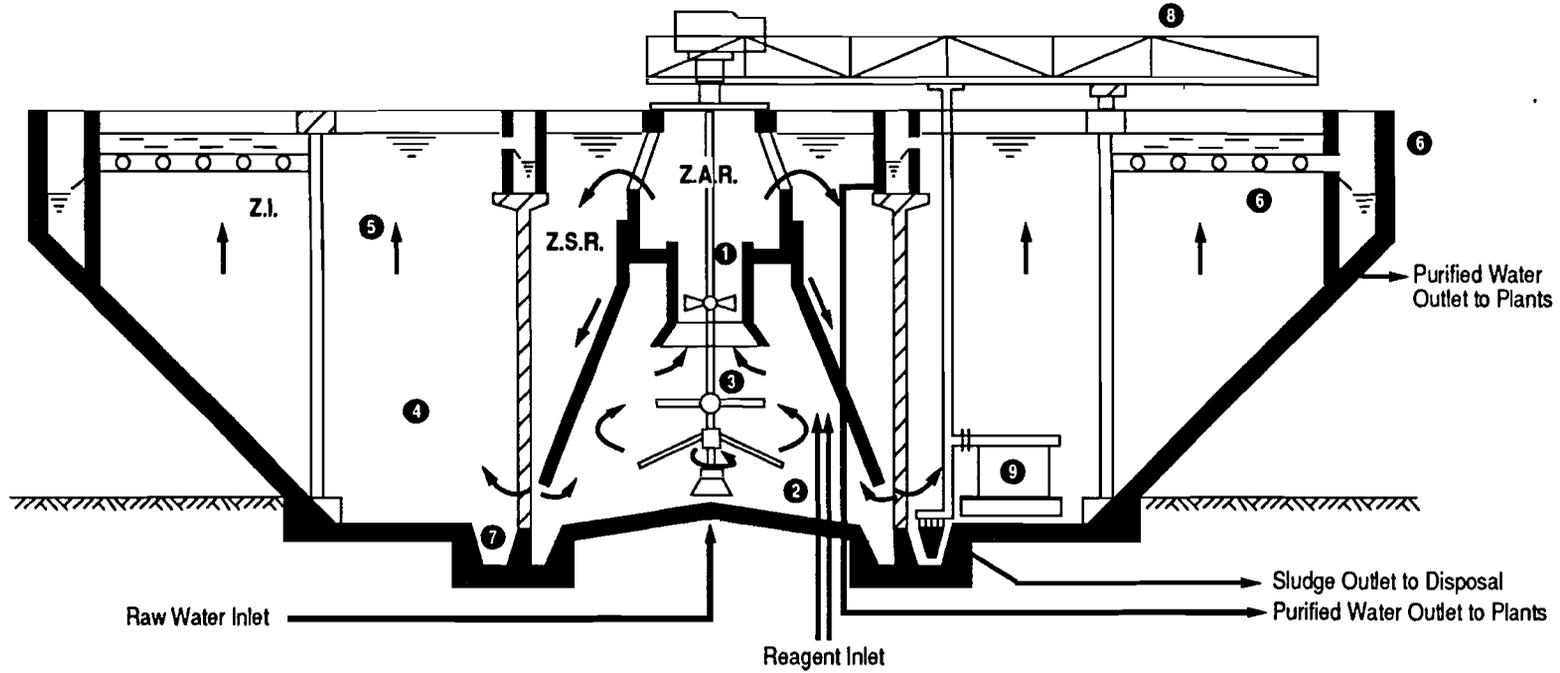
94-19006-013



94-1900b.014

Figure 4-4 Recirculating Settler Flow Sheet

24



- ① Reaction Mixing Chamber
- ② Stirrer
- ③ Recirculating Pump
- ④ Suspension Layer
- ⑤ Pure Water Layer
- ⑥ Pure Water Collecting
- ⑦ Sludge Collecting Trough
- ⑧ Scraping Bridge
- ⑨ Scraper

1900b.015

Figure 4-5 Recirculating Pump Settler Flow Sheet

ms

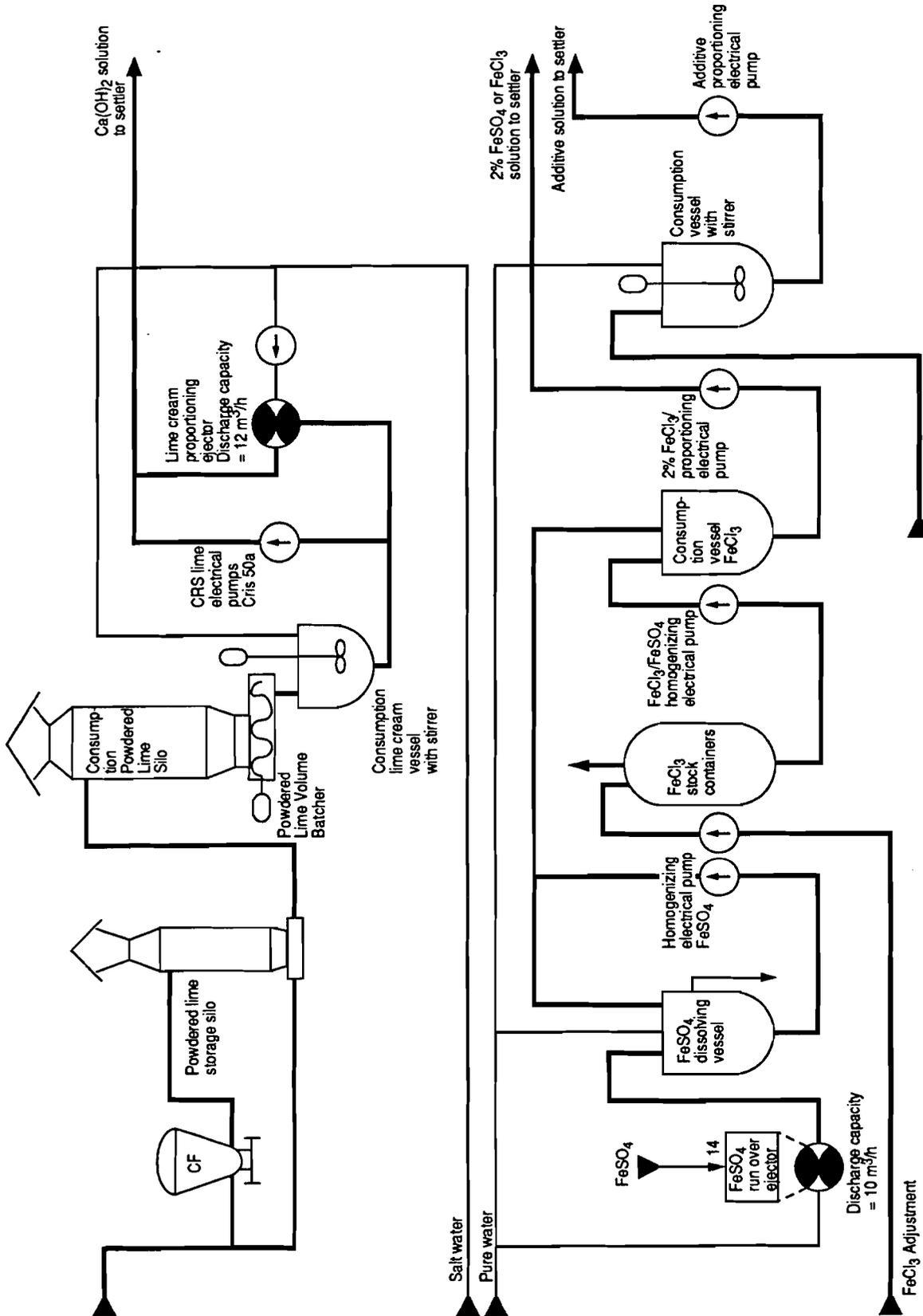


Figure 4-6 Pretreatment Reagent

94-19006.017

36

Assessment

Although more detailed evaluation will be required, the information on hand points out the need for redesigning the flow arrangements to promote more rapid reagent mixing and improve the slurry settling. There is also a clear need for automatic control of the reagent dosing system. This includes automatic sensing devices at the raw water inlet and the product outlet.

A properly designed pretreatment clarifier should include separate chemical flash mixing, flocculation, sedimentation, and positive sludge removal (separate scraper drive and sludge blowoff mechanism). Such a clarifier, properly operated, should produce water with suspended solids content in the range of 5 ppm.

Polishing filters should have dual media (coal over fine sand) or multimedia arrangement. Adequate backwashing, possibly supported by an air scout, should be incorporated. With this kind of filter properly operated, the turbidity should be reduced to less than 1 ppm.

In such a pretreatment system, the colloidal silica is also effectively removed. Insoluble colloidal silica will pass through the demineralizer resins and end up in the boiler drum. At the drum pressure and temperature, the colloidal silica becomes water soluble and will add to the soluble silica content.

To prevent postprecipitation of calcium carbonate, it is necessary to lower the water pH by direct acid feed.

Finally, it may be desirable to feed an oxidizing biocide to the clarifier to further reduce organic matter. Experience shows that without biocide only about 50 percent reduction could be expected in pretreatment.

4.3 DEMINERALIZERS – ISSUES AND ASSESSMENTS

Issues

The capacity of power plant demineralizing stations ranges from 100 cm/h to 2,000 cm/h. The largest number has capacities in the range of 200 cm/h to 1,000 cm/h. These stations have two to five demineralizers in series. They are generally equipped with strong acid cation exchangers and weak and strong basic anion exchangers. Only two stations have weak acid exchangers. About 64 percent of the stations use four demineralizers in series. About 35 percent of the demineralizer stations have a final mixed bed demineralizer with internal regeneration.

Approximately 90 percent of the water fed to the demineralizer stations comes from the pretreatment plant. Because of the substandard performance of these plants, the demineralizers receive water that has high organic matter and suspended solids content, including colloidal silica and alkalinity. The range of impurity content in the water received from the pretreatment plant is shown in Table 4-3. These impurities prevent the proper functioning of the demineralizer station. They also damage the resins and impede regeneration.

Table 4-3
Impurities in Water Entering the Demineralizer

Impurities	Concentrations
Alkalinity "m"	0.7 - 1.7 mval/l
Alkalinity "p"	0.0 - 0.5 mval/l
Total hardness	2.0 - 7.5 mval/l
Ca (2+ion)	2.0 - 6.0 mvath
Total salinity	2.0 - 13.0 mval/l
Total silicon as SiO ₂	4.0 - 16.0 mg/l
Colloidal SiO ₂	0.0 - 0.5 mg/l
Suspended solids	1 - 50 mg/l
Organics as KMnO ₄	10 - 60 mg/l

According to RENEL reports, the internal water distribution in the demineralizers is not uniform, leading to uneven depletion of the beds. Drainage in the mixed bed demineralizers, using double flow is inadequate. The devices for trapping solids at the filter outlet have high-pressure drops and poor capture efficiency. Apparently, the resins used in the ion exchange beds are not appropriate for the required service.

There is insufficient instrumentation and controls in the demineralization stations, requiring labor intensive manual operation of controls. There are frequent breakdowns of equipment such as diaphragm valves. The pumps used to move the regenerating liquids (dilute HCl) are suffering frequent breakdowns. The internal elastomer liners of the exchangers are prone to delamination and puncture.

The flow direction in the exchangers is the same during both operation and regeneration. This leads to high consumption of the regenerating agents and results

in less than satisfactory regeneration and high levels of sodium and silicon ions in the product water. Cocurrent flows were selected when the countercurrent distributors of the regenerating agents did not function properly.

Assessment

Problems in the demineralizers are attributable to three distinct causes:

- Poor quality of water received from the pretreatment plant
- Deficiencies in the design of the equipment, including the use of unsuitable resins
- Lack of adequate instrumentation and controls

The deficiencies in the pretreatment plant were discussed in Section 4.2. Poor quality of the pretreated water hinders the effective performance of the resin beds. Organic matters cause irreversible blinding of the resins and reduce the effectiveness of the beds. The high silica content is not reduced by the demineralizers and will pass through to the steam system. Improvements in the pretreatment system should have high priority in any efforts to correct the water treatment plant.

The reported equipment failures and operational malfunctions indicate the need for major refurbishing of the demineralizer plant. This refurbishing should include specification of modern hardware and experience-proven design for the demineralizer internals (such as the water and reagent distribution provisions). Refurbishing should also include specification of resins that promise more effective performance. The present cocurrent backwash system not only uses excessive amounts of regeneration agents, but is also leading to rapid deterioration of the bed material.

An important part of the refurbishing should be the incorporation of a modern instrumentation and control system. On-line analytical capability is essential for rapid responses to changing water feed quality or demand for makeup.

Section 5

Corrosion Protection during Shutdown

The steam power system will be shut down for repairs or during periods of slack demand, such as the summer period when the district heating demand can be satisfied with steam from the power boiler. During this period, the internal (steam side) surfaces will need to be protected from corrosion.

Layup procedures, in preparation for shutdown, vary according to the type of boiler (natural circulation, forced circulation, or once through) and the expected duration of shutdown. If some part of the steam system needs to be drained for repairs, additional measures must be taken. The original equipment manufacturer usually provides instructions for layup procedures. The layup procedures described below are for drum-type boilers.

5.1 INITIAL CLEANING

After major repair work on the pressure boundary, the boilers and steam cycle components must be hydro tested. New boilers must also be hydro tested. For this process, the drainable portion of the system may be filled with clean filtered water. Nondrainable superheater and reheater sections, however, must use demineralized water with ammonia (about 10 ppm) added for pH control and hydrazine for oxygen control (about 500 ppm). In the United States, the American Society of Mechanical Engineers (ASME) has developed specific procedures and requirements for the conduct of hydro tests.

A thorough chemical cleaning is usually deferred until after the boiler has operated at power for some time. Experience shows that this delay will ultimately result in a cleaner boiler.

The next step is a chemical boilout. The system is first flushed with special strainers installed to capture any debris remaining after the construction work. This step is followed by phosphate flushing of the feedwater system. To remove any remaining grease, oil, and paints, the system is given a caustic and phosphate chemical boilout.

Removal of loose scale is accomplished with high velocity air or steam blow, steam blow being the more frequently used option. The high steam velocity and mild thermal shock during this process were found to be quite effective for scale removal. The steam blow is a two-step process. In the first step, the superheater, main steam piping, and the cold return piping are cleaned. (This requires a temporary crossover pipe to connect the main steam pipe with the cold return line.) The second step includes the main steam piping, the superheater, reheater, and the hot and cold reheat piping. The steam is then discharged to the atmosphere through temporary piping. In both steps, steam blow is repeated until the special targets installed in the

system remain clean. The special filters are usually retained in the system until after short periods of initial, low power operation.

5.2 CHEMICAL CLEANING

Even with effective water treatment, the internal surfaces of the boiler tube headers and the drum tend to accumulate deposits. These deposits may form a tenacious layer or may be of a loose, porous character. Even a thin scale (1 or 2 mm thick) creates a significant resistance to heat flow, resulting in an undesirable increase in tube metal temperature. If not removed, these deposits could eventually lead to tube pluggage.

Periodic chemical cleaning helps to keep these undesirable effects under control. The need for chemical cleaning may be determined on the basis of deposit weight per unit area of the tube. For measurement purposes, a segment of the boiler tube is cut out and the deposit is scraped off until shiny metal is visible. In boilers operating below 70 bar, cleaning should be scheduled if the scale weight is greater than 200 to 400 grams per square meter. From 70 to 140 bar, the limiting weight is 125 to 200 grams per square meter. Above 140 bars, cleaning should be scheduled if the weight reaches 100 to 125 grams per square meters.

An alternative, nondestructive, means of monitoring the scale buildup is to install chordal thermocouples. These installations have thermocouples mounted on the inside and outside surfaces of a boiler tube. The difference between the two indicated temperature provides indication of the local heat flux. In addition, as the scale thickness increases, the tube wall temperatures increase. A comparison with thermocouples installed on the adiabatic side of the tube (the side facing the insulation) gives a good indication of the scale growth. Even if the absolute measurements are inaccurate, observation of changes with time may be used as indicators of scale buildup.

The cleaning itself may be accomplished by circulating the solvent (in this case, usually some chelates) in the system, or allowing the static solvent to dissolve the scale (hydrochloric acid is most frequently used). This latter option is called "soaking." With both types, an inhibitor is added to limit the attack on the steel. After the treatment, the solvent is drained and the system is flushed with clean water to remove any remaining particulates and traces of the solvent. After flushing, the surfaces are passivated.

Since chemical cleaning removes some of the metal, it should not be used frequently. The entire process requires careful advance planning and careful monitoring while in progress. Advice from the original equipment manufacturer is most important.

5.3 LAYUP PROCEDURES

Because of the severe corrosion effects of moist air, and the fact that thorough drying of the steam system internals is nearly impossible, exclusion of air is a major reason for careful layup procedures. These procedures vary according to the expected length of the shutdown period and the need for exposing parts of the system for repairs.

1. Layup after Hydro Testing

If several days pass before startup or restart, the superheaters should be filled with clean water to overflow. The entire system needs to be purged and filled with nitrogen to a positive pressure of 0.3 bar.

2. Layup after Chemical Cleaning

The system is to be filled with demineralized or condensate quality water. This water should contain 10 ppm of ammonia and 200 ppm of hydrazine, thoroughly mixed. The steam drum and the shell side of the feedwater heaters are to be capped with nitrogen at a positive pressure of 0.3 bar.

3. Layup for 4 Days or Less – No Partial Drainage Required

The system must be kept filled with condensate. Ammonia and hydrazine concentration must be maintained at the same levels as was used during normal operation. A nitrogen cap of 0.3 bar is to be established and maintained. A 0.3 bar nitrogen pressure on the shell side of feedwater heaters must also be established and maintained.

4. Layup for 4 Days or Less – Part of the System Drained for Repair

The water should be drained only from the part of the system that requires repair. The remainder of the system should be isolated and capped with nitrogen to 0.3 bar. A nitrogen blanket (0.3 bar) is to be maintained on the steam drum and on the superheater. Also, the feedwater heater shell sides are to be capped with nitrogen at 0.3 pressure.

Depending on the nature of repairs, it may be desirable to perform chemical cleaning of the opened section before returning it to service.

5. Layup for More than 4 Days – No Part of the System Drained

The system must be filled with condensate quality water. The superheaters and reheaters are to be filled with condensate quality water containing ammonia concentration of 10 ppm and hydrazine concentration of 200 ppm, thoroughly mixed. The water should have a pH of 10. Ammonia and hydrazine are to be added to raise the concentrations to the same levels in the water walls, reheaters, and the tube side of feedwater heaters. The undrainable parts of the system should be filled from the outlet end. The free surfaces (in the superheaters, feedwater heater shell side and drum) should be capped with nitrogen to 0.3 bar pressure.

If freezing were to be a problem, the drainable portions of the system may be drained and filled with nitrogen to the previously indicated pressure. It may be necessary to apply heating to prevent freezing in the nondrainable portions.

6. Layup for More than 4 Days – Part of the System Drained for Repairs

Again, the system should be kept filled with condensate quality water, except the portion that needs to be drained for repairs. The layup procedures, except for the drained part, are similar to those specified above for long-term outages.

After repairs, the drained portion of the system should be cleaned and filled with condensate quality water, containing 10 ppm ammonia and 200 ppm hydrazine. A 0.3 bar nitrogen cap is to be established and maintained.

5.4 CORROSION PROTECTION DURING STARTUP

Unless appropriate steps are taken, serious corrosion may take place during startup. The key requirements are to:

- Maintain adequate pH control
- Provide deaeration

To ensure deaeration and to supply the necessary steam for the turbine seals, steam may be obtained from other units that are in operation or from an auxiliary boiler.

Following a shutdown of more than 4 days' duration, the boiler needs to be flushed to waste at approximately 25 percent of flow as the first step of startup. The process

should be continued for about 8 hours, or until the suspended solids concentrations is decreased to 3 ppm. The pH must be kept under control.

As the second step, the deaerator should be pressurized to a positive 1 bar, and the condenser should be evacuated. Using the condensate pump, circulate water in the preboiler section of the system at about 25 percent of full flow to clean up this section. The deaerator storage tank should be blown down, if necessary, to prevent recontamination of the feedwater. The control limits for this step are as follows:

■ Total suspended solids	200 ppm (maximum)
■ Oxygen	10 ppm
■ Hydrazine	20 ppm
■ pH (at high-pressure heater outlet)	
for system with copper alloys	8.6 - 9.2
copper-free system	9.2 - 9.4

At the third step, the feedwater recirculation valve is closed, and the boiler is fired up to go through the regular startup procedure. Load should not be raised above 30 percent until all water system chemistry parameters have reached the specified nominal values.

BIBLIOGRAPHY

Bibliography

- Betz Handbook of Industrial Water Conditioning*, 8th Ed. Betz Laboratories, Inc. Trevese, PA, 1980
- The NALCO Water Handbook*, 2nd Edition, McGraw-Hill Book Co. New York 1988.
- Drew Principles of Industry Water Treatment*, 3rd Ed., Drew Chemical, Boonton, New Jersey, 1979
- Water and Steam in the Power Cycle – Purity and Quality, Leak Detection and Measurement*, ASME Performance Test Code 19.1, American Society of Mechanical Engineers.
- Consensus of Current Practices for Layup of Industrial and Utility Boilers*, American Society of Mechanical Engineers, New York, 1985.
- Steam, Its Generation and Use*, 40th Ed. Babcock & Wilcox Company, Barberton, OH 1992.
- Combustion Fossil Power Systems*, Combustion Engineering, Inc., 1982, 3rd Edition.
- Cohen, P. editor, *The ASME Handbook of Water Technology in Thermal Power Systems*, American Society of Mechanical Engineers, 1989.
- Elliott, T. C. and the editors of Power Magazine, *Standard Handbook of Power Plant Engineering*, McGraw-Hill Publishing Co., New York, 1989.
- Fisher, S. A., *Ion Exchange, Part III – Resin Analysis*, Power Magazine, October 1982.
- Jonas, O., and Dooley, B., "International Water Treatment Practices and Experiences," *Proceedings of the 51st Annual Meeting, International Water Conference - Pittsburgh, PA*, 1990.
- Leferre, L. J. *Ion Exchange, Part I – System Design and Operation*. Power Magazine, August 1982.
- Puri, V. K., *Pretreatment of Water for Cooling and Steam Generating Systems*, 21st Annual Liberty Bell Corrosion Course, Philadelphia, PA, 1983.
- Selby, K.A., *Ion Exchange, Part II – Operation and Supervision*, Power Magazine, October 1982.

APPENDIX A

Data Requirements and Division Topics –
Water Quality Control and
Treatment Investigations

WATER QUALITY CONTROL AND TREATMENT INVESTIGATIONS

- A list of water chemistry monitoring points and methods of chemical control and measurement accuracy for the power plant condensate-feedwater train and for the secondary district water loop.
- A list and composition of materials presently used in the power plant and district heating plants (hot water peaking boilers, condensers, feedwater heaters, district heating heat exchangers, etc.).
- Specific details of methods used for chemistry control.
- Representative chemical analysis of the condensate/feedwater, power plant and district heating make-up.
- Detailed information about the deaeration / degasification methods and concentrations of oxygen, carbon dioxide and PH of the water after the deaerator. Sources of steam for deaeration, and deaerator pressure. Where is the district heating make-up water introduced? If it is introduced into the power plant condenser, please provide a schematic diagram of the condenser or the condenser drawing. Where are the drains from the district heat exchangers introduced?
- Chemical analysis, particularly iron and copper oxide concentrations in the supply and return lines of the district heating system at the power plants.
- Deposit rates and chemical composition of scale at the hot water peaking boilers.
- Operational modes of the hot water peaking boilers (maximum temperatures, recirculation, etc).
- Presence of corrosion coupons in the condensate / feedwater and district heating trains and information on corrosion rates and types of corrosion.
- Source of make-up and chemical composition of organics introduced with make-up and concentration of organics in the condensate / feedwater train.
- Existing shutdown and lay-up procedures for the power plant turbine, boilers, hot water peaking boilers, balance-of-plant and district heating equipment.

APPENDIX B

RENEL Responses to Data Requirements and Topics

WATER QUALITY CONTROL AND TREATMENT INVESTIGATIONS

* A list of water chemistry monitoring points and methods of chemical control and measurement accuracy for the power plant condensate-feedwater train and for secondary district water loop.

1. List of water chemistry monitoring points and methods of chemical control and measurement accuracy for condensate and feedwater in thermal power plants (IPP).

Measurement point	Drum boiler with natural circulation	Once-through boilers
Condensate	- After condensate electrical pump [CEP]	- After CEP, stage 1 - After polishing system.
Feedwater	- After deaerator, 6 ata. - On feed pump discharge at ECC inlet.	- After deaerator, 6 ata - On FP discharge at ECC inlet.

Chemical control methods are described under point A., and the same is true for the accuracy of such methods.

2. Listing of water chemistry monitoring points for the district heating loop.

- Monitoring points: Hot water boilers (HwB) feedwater
Mains water - district heating return

Details about chemical control methods and their accuracy are given under point 4.

* A list and composition of materials presently used in the power plant and district heating plants (low water heating boilers, condensers, feedwater heaters, district heating heat-exchangers, etc)

CONDENSERS

Imported from: Laiton amirante a l'arsenic 70/29/1
Alloy - C44300

Composition

Cu : 70-73%
 Sn : 0.5 - 1.2%
 Pb max. : 0.07%
 As : 0.02 - 0.1%
 Zn : balance
 As per ASTM B111-78

Sn: 0.9-1.3%

As(Sb) or P=0.002-0.06% as per
Pb = 0.07% STAS 95/87

Fe = 0.07%

Zn = balance

BOILERS AND HEAT EXCHANGERS

- CuZn20 (Cu= 70-81%, Pb = 0.05%, Fe = 0.1%, Mn = 0.05%,
Al = 0.02%, Sn = 0.05%, Zn = balance)
or CuZn39Pb2, CuZn39AlPb, CuZn 37
- OLT 37 K II (C_{max} = 0.17%, Mn = 0.4 - 0.9%,
Si = 0.15 - 0.35%, P_{max} = 0.04%,
 S_{max} = 0.04%, Al= 0.02 - 0.045 %)

BOILER PIPING

-Hot water boilers, vaporisers

OLT 45 K III (C_{max} = 0.23%, Mn = 0.4 - 1.2%, Si=0.15 -0.38
 P_{max} = 0.01%, S_{max} =0.01%, Al= 0.02- 0.045 %

-Vaporiser and economiser

16Mo 3 (C= 0.12 -0.2%, Mn =0.5-0.8%, Si= 0.15 - 0.35%,
Mo = 0.25 - 0.4%, P_{max} = 0.035%, S_{max} = 0.035%
Al = 0.01 - 0.03%)

Connecting piping and superheaters:

14 CrMo 10 (C = 0.1 - 0.18%, Mn = 0.4 - 0.7%, Si= 0.15 - 0.35%,
Cr= 0.7 - 1.1%, Mo = 0.4 - 0.55%, P_{max} = 0.035%,
 S_{max} = 0.035%, Al= 0.015-0.045%)

10 CrMo 10(C_{max} = 0.15%, Mn = 0.4 - 0.7%, Si = 0.15 - 0.5%,
Cr = 2.0 - 2.5%, Mo = 0.9 - 1.1%, P_{max} = 0.04%,
 S_{max} = 0.04%)

12CrMoV 3 (C_{max} = 0.08 - 0.15%, Mn = 0.4 - 0.7 %,
Si = 0.15 - 0.35%, Cr = 0.9 - 1.2%, Mo =0.25 - 0.4%
V = 0.15 - 0.3%, P_{max} = 0.03. S_{max} = 0.03%)

X20CrMo V 12.1 (DIN) (C = 0.17 - 0.27%, Si \leq 0.5 %,
Mn \leq 1%, P_{max} = 0.03%, S_{min} = 0.03%,
Cr = 10 - 12.5%, Mo = 0.8 - 1.2 %,
Ni = 0.3 - 0.8%, V = 0.25 - 0.35 %)

14Mo V63 (DIN) (C= 0.18%, Si = 0.35%, Mn = 0.7%,
P = 0.035%. Cr = 12.5%. Mo = 1.2%. V=0.32%)

Foreign types of steels (equivalent)

OLT 35 K = TS5 (ISO), St. 1o(GOST), St.35.8(DIN), Grade A(ASM)
TU 37-C (ANFOR), 11353 (CSN)

OLT 45 K = TS9H (ISO), St 2o(GOST), St.45.8 (DIN), Grade B
(ASTM), TU 48 - C (ANFOR), 11453 (CSN)

16 Mo 3 = TS 26(ISO), 15Mo3(DIN), 15o2o(CSN),

14CrMo 1o= TS 32(ISO), 15HM (GOST), 13CrMo44 (DIN),
P 12(ASM), 15.121(CSN)

12CrMoV3 = 12 HLMF (GOST)

1oCrMolo = TS 34 (ISO), 1oCrMo9.1o(DIN), 1oCD9 - 1o

Other import sorts of steel used for boiler piping and ducts.

- headers, superheaters: 12o21 (CSN)

- economiser, heat exchangers 12o22 (CSN)

- economiser, shields, header screens 1511o (CSN)

- headers, superheaters, connecting pipes 15111(CSN);1512B(CSN)

- superheaters: 15225 (CSN)

15123 (CSN)

17134 (CSN)

17341 (CSN)

* Specific details of methods used for chemistry control.

Chlorine determination

- titration method with mercuric nitrate in the presence of diphenyl carbazine
- application range: 10±250 mg Cl⁻/l
0.2 ± 25 mg Cl⁻/l

Silica determination

- indirect method by determining the total silica and the ionic one, while making the difference [subtraction] colloidal silica is determined.
- photometer method
- method accuracy: ± 0.001 mg SiO₂/l

Iron determination

- photometer method
- method accuracy: ± 0.001ppm

Turbidity determination

- phormazine suspension standard method

Dissolved oxygen determination

- winkler method, modified with manganous hydroxide which absorbs completely the existing oxygen.
- method accuracy: 0.06 ppm for O₂ contents of 0.06±1ppm
0.006 ppm for O₂ contents of 0.008±0.06ppm

Ammonia Ion Determination

- photometer method
- method accuracy: 2%

Copper Determination

- photometer method with diethyldithiosulfocarbamic (CUPRAL) for those copper contents ranging between 0.001±0.05ppm. Accuracy of method: 0.0025ppm.
- ionometer method with copper electrode for copper contents ranging between: 0.003±0.1mg/l.

Sodium and potassium determination

- use of combined industrial glass electrodes is recommended
- measurement accuracy: ± 0.05ppm

Oxidation potential determination

- the oxidation potential is determined by consumption of permanganate
- organic substances are oxidised with a titrated solution of potassium permanganate.

Hydrazine determination

- volumetric method for hydrazine contents bet. 0.4-8ppm. Accuracy of the method: 0.01 ppm
- photometer method for hydrazine contents ranging between 0.02-0.4ppm. Method accuracy: 0.01 ppm.

* Representative chemical analysis of the condensate/feedwater, power plant and district heating make-up. (point A)

Condensate	Feedwater	District heating make-up
Adjusted conductivity 0.03-0.05µs/cm	Dissolved O ₂ 0.02-0.02mg/l	Appearance : limpid
SiO ₂ : 0.02-0.03mg/l	Hydrazine excess: 0.03±0.06mg/l	Oils : nil
Cu: 0.003±0.005mg/l	SiO ₂ 0.02-0.04mg/l	Free CO ₂ : nil
Hardness: nil	Fe: 0.02±0.03mg/l	Total hardness: 0.05±0.1 meq/l
Fe: 0.02 - 0.03 mg/l	Cu: 0.003±0.006mg/l	pH: 7.5±9.5
	Adjusted conductivity 0.03-2.45µs/cm	Dissolved O ₂ : max. 0.1mg/l Fe _{max} -

*Detailed information about deaeration/degasification methods and concentrations of oxygen, carbon dioxide and pH of water after the deaerator. Where is the district heating make-up water introduced? If it is introduced into the plant condenser, please provide a schematic diagram of the condenser or the condenser drawing. Where are the drains from the district heat exchangers introduced?

- O₂ concentration at degasifiers for district heating: 0.1±0.2mg/l
- boiler water pH: - about 6.5 (1.2 ata) when NH₃ is not dosed into the demineralized water?
- about 6.5 (1.2 ata) when NH₃ is dosed.
- pH at 1.2 ata degasifiers from district heating:

4 9.9.5 when soft water is produced out of the pre-treated water.

4 7.9.6 when softened water is produced out of non-pre-treated water.

- Steam sources: power steam boilers (reduction-cooling station and turbine extractions) and industrial steam boilers.

- District-heating thermal agent can be introduced in the turbine boilers (base or peak), hot water boilers or condenser bundles. The condensate from the district heating heat exchangers is introduced in the drainage tank.

* Chemical analysis, particularly iron and copper oxide concentration in the supply and return lines of the district heating system at the power plants.

QUALITY VALUES	M.U.	LIMIT VALUES	
		Hot water boiler feedwater	Mains water (return)
Appearance		limpid	limpid
Max. oils	mg/l	nil	nil
Max. suspended matters	mg/l	nil	5
Free CO ₂	mg/l	nil	nil
Total hardness	mg/l	0.05-0.1	0.05-0.15
pH		7.5-7.9	7.9-9.5
Max. dissolved O ₂	mg/l	0.1	0.1
Max. Fe	mg/l	-	0.5

If the temperature of the heating water from the mains is higher than 140°C, the contents of the dissolved oxygen will be maintained at values lower than 0.05 mg/l for both: aggregated supply water (hot water boiler or peaking boiler) and water from the mains.

* Deposit rates and chemical composition of scale of the peaking boilers.

No deposits exist.

* Operational modes of the hot water peaking boilers (maximum temperatures, recirculation, etc.).

Peaking boilers parameters

55

- max. temperature: 110°C
- max. pressure: - steam: 2.5 ata
- water: 20 ata
- capacity: 60 tcal/h

* Presence of corrosion coupons in the condensate/feedwater and district heating trains and information on corrosion rates and types of corrosion.

Corrosion coupons: O_2 , CO_2 , organic matters derived from the heavy polluted waters and from the returned industrial condensate as well as from the condenser raw water ingress.

Types of corrosion:

- uniform corrosion due to organic matters decomposition.
- cavity corrosion due to the presence of oxygen, especially at economiser.
- corrosion due to brittleness caused by hydrogen existence.
- cracking corrosion.

* Source of make-up and chemical composition of organics introduced with make-up and concentration of organics in the condensate/feedwater train.

Organics introduced into the make-up water derive from the returned condensate and, they are generally, organics of an industrial nature: chlorinated products, phenols. Due to the fact that many of the organics are not involved in the permanganate consumption, sometimes the norm of 2mg/l is not observed. There also occur problems with the boiler, due to the nature of organics when the limit value of 2mg/l is not obtained.

Concentration of the organics vary within the range of 1-10mg, $MMCO_2/l$

* Existing shutdown and lay-up procedures for the power plant turbine, boilers, hot water peaking boilers, balance-of-plant and district heating equipment.

District heating boilers made of steel, HP/LP preheaters (steel piping).

- the method uses solution of sodium nitrite and borax.

Hot water boilers

- the method uses $Ca(OH)_2$ solution; its concentration is between 0.8 - 1.4 g/l
- this method is used for both: clean carbon-steel areas and areas with oxide-corrosion.

Steam turbines

- dry conservation method with not or dry air.
- wet conservation method: layer coating of all turbine internals with a passivating preserving agent, as for example: DICHAN.

Steam condensers, district heating boilers with piping made of brass, LP preheaters with brass piping.

- distinct procedures: - water line with TRIA-M solution of 1% concentration.
- steam line: not air drying.

Water pumps

- method consists of drying the inside areas of the water pumps and introduction of a hygroscopic agent of SILICA GEL type.

Steam boilers

- the method uses sodium nitrite and sodium tetraborate alkaline solution.

Thermal degasification

- the inner areas of the degasifier is air dried and then a conservation agent is introduced; as for example DICHAN (dicyclohexylamine).

BEST AVAILABLE COPY

57

FEEDWATER CHEMICAL VALUES

Standard Limits as per ISCIR code, C18/86

Nr	Characteristics	Forced Circulation Boilers	Natural Circulation Boilers
1.	Physical Properties	Limpid, colourless free of slurry	Limpid, colourless, free of slurry
2.	Total hardness	Undetectable	Undetectable
3.	pH	8.5 ± 1	8.5 ± 1
4.	Hydrazine excess, mg/l	min. 0.05	0.05 ± 0.1
5.	Conductivity, us/cm	max. 0.3	max. 0.5
6.	Total silica, mg/l	max. 0.02	max. 0.025
7.	Iron, mg/l	max. 0.02	max. 0.02
8.	Na + K, mg/l	max. 0.01	non-standardized
9.	O ₂	0.02	0.02
10.	Copper, mg/l	max. 0.03	max. 0.03

FEEDWATER CHEMICAL VALUES

Real values achieved during operation
at LUDUS power plant

Nr	Characteristics	Forced Circulation Boilers	Natural Circulation Boilers
1.	Physical Properties	Limpid, colourless free of slurry	Limpid, colourless, free of slurry
2.	Total hardness	Undetectable	Undetectable
3.	pH	8.8 ÷ 9.2	8.5 ÷ 9.0
4.	Hydrazine excess, mg/l	0.05 ÷ 0.07	0.06 ÷ 0.01
5.	Conductivity, μ s/cm)	0.2 ÷ 0.3	0.3 ÷ 0.6
6.	Total silica, mg/l)	0.015 ÷ 0.022	0.015 ÷ 0.022
7.	Iron, mg/l	0.01 ÷ 0.02	0.02 ÷ 0.025
8.	Na + K , mg/l	No measurement done. non-standardized	
9.	O ₂	0.02 ÷ 0.025	0.02 ÷ 0.03
10.	Copper , mg/l	0.02 ÷ 0.04	0.03 ÷ 0.04

APPENDIX C

Water Quality Control and Treatment Investigations
for RENEL – Letter report by Joseph Technology
Corporation, Inc., Consultant



JOSEPH TECHNOLOGY CORPORATION, INC.

Phone: (201) 673-0629

188 Broadway, Woodcliff Lake, New Jersey 07675

Fax: (201) 673-8060

January 20, 1994

Mr. Roger F. Griffin
Project Director
Bechtel
PO Box 193965
San Francisco, CA 94119-3965

Subject: **US AID contract EUR-0030-C-00-2055-00**
Regional Energy Efficiency Project
Electric Power Systems Components
Technical Services Subcontract 21978-TSC-5
Water Quality Control and Treatment Investigations for RENEL

Dear Roger:

After obtaining the information from Mr. J.H. Westik on the RENEL water chemistry, we are pleased to provide you with our recommendations on the subject project.

1. Cycle Chemistry Control

Power Plant

Based on Western water quality target values for 2030 psig (140 bar) and 2175 (150 bar) drum units with all-volatile treatment (A.V.T.), the following operational values are recommended:

A. Make-up Water From Mixed Bed

Parameter	Target Value
Sodium, ppb	≤ 3
Chloride, ppb	≤ 3
Sulfate, ppb	≤ 3
Silica, ppb	≤ 10
Specific Conductivity, mmho/25°C	≤ 0.1
Total Organic Carbon, ppb	≤ 300

It is apparent that problems with both the existing pre-treatment and make-up demineralizer equipment prevent this quality make-up to be achieved. This will be discussed later in greater detail.

B. Condensate Being Discharged

Parameter	Target Value
Sodium, ppb	≤ 6 (with polisher) ≤ 3 (without polisher)
Cation conductivity, mmho/25°C	≤ 0.3 (with polisher) ≤ 0.2 (without polisher)
Total organic carbon, ppb	≤ 200
Oxygen, ppb	≤ 20

C. Condensate Polisher Effluent

Parameter	Target Value
Sodium, ppb	≤ 3
Cation conductivity, mmho/25°C	≤ .02
Silica, ppb	≤ .10

D. Deaerator Inlet

Parameter	Target Value
Oxygen, ppb	≤ 20
Hydrazine, ppb	≥ 3 x O ₂ or ≥ 20

E. Deaerator Outlet

Parameter	Target Value
Oxygen, ppb	≤ 7

F. Feedwater Inlet

Parameter	Target Value
pH	9.0 - 9.6 (All Ferrous Metallurgy) 8.8 - 9.2 (Mixed Fe-Cu Metallurgy)
Ammonia	Consistent with all pH values
Cation conductivity, mmho/25°C	≤ 0.2
Iron, ppb	≤ 10
Copper, ppb	≤ 2
Oxygen, ppb	≤ 5

G. Steam

Parameter	Target Value
Sodium, ppb	≤ 3
Cation conductivity, mmho/25°C	≤ 0.15
Silica, ppb	≤ 10
Chloride, ppb	≤ 3
Sulfate, ppb	≤ 3
Total organic carbon, ppb	≤ 100

It should be noted that exclusions to the above target values can be tolerated during start-up or other abnormal operations for a reasonable period of time.

It should be further noted that the representative chemical analyses of power plant condensate and feedwater stated in the "Water Quality Control and Treatment Investigations" far exceed the above Western water quality target values which could result in the increased water-side corrosion in the RENEL steam plants.

District Heating

A. District Heating Makeup

Sodium zeolite softening is the usual treatment method producing effluent hardness in the 1-2 mg/l range for district heating makeup based on Western water quality standards. Higher hardness values in the makeup can result in calcium carbonate scale on heat exchange tubes depending on the final water chemistry characteristics of the heated makeup. Also should a tube leak develop between the condensate (which is returned to the power plant condenser as partial makeup) and the district heating hot water, hardness would be a more objectionable and limiting cation than sodium.

B. District Heating Hot Water Quality

To minimize corrosion of the hot water transfer tube surfaces oxygen, carbon dioxide and organic matter should be kept to a minimum while the pH remains elevated.

Oxygen Levels

It may be desirable to remove the 0.1 to 0.2 mg/l oxygen levels from the district heating degasifiers further by feeding an additional oxygen scavenger to further reduce corrosion.

Carbon Dioxide/pH Levels

Carbon dioxide can be reduced while increasing the pH by means of neutralizing amines such as ammonia, morpholine or cyclohexylamine. A pH range of 8.3 to 9.0 is normally sufficient for this purpose. With ammonia dosing, however, the pH should not exceed 9.0 with mixed ferric - copper metallurgy.

Organic Matter

Organic matter should also be reduced to a minimum since organics can plate out on heat exchange surfaces and cause under surface corrosion.

2. Pretreatment

Proper pretreatment usually includes a separate clarifier and associated chemical feed with polishing filters. The pretreatment clarifier should feature separate chemical flash mixing, flocculation, sedimentation and positive sludge removal (i.e. with a separate scraper drive and sludge blowoff mechanism). Such a clarifier system when properly designed and operated can produce effluent suspended solids in the range of 5 N.T.U. turbidity.

Polishing filters should feature dual media (i.e. coal over fine sand) or multi media, proper backwashing distribution and collection possibly supported by an air scout depending on the nature of the clarifier residual carry over. When a filter is properly designed and operated it can further reduce the clarifier effluent carry over in the range of 0.2 N.T.U. turbidity.

It should be noted that when the suspended solids are removed in a properly designed pretreatment system that the colloidal silica will also be effectively removed. Insoluble colloidal silica will pass through ion exchanger makeup demineralizer resins unexchanged and finally to the cycle drum. In the high temperature and pressure environment of the drum the colloidal silica will solubilize and add to the overall silica soluble drum levels.

Also in regard to the pretreatment system, when full softening takes place in the clarifier, post precipitation of calcium carbonate can be anticipated downstream of the clarifier unless the pH is corrected downward by direct acid feed.

Finally in regard to the pretreatment system, it may be desirable to feed an oxidizing biocide (i.e. chlorine) for further reduction of organic matter. Unless an oxidizing biocide is fed only a 50% reduction in organics can be anticipated as confirmed by plant data.

3. Makeup Demineralizer

It is reported that the existing makeup demineralizer is subject to resin clogging, irreversible resin fouling and low regeneration efficiency. All of the above problems can directly attributed to inadequate or improper pretreatment and high influent organics.

A. Pretreatment

The pretreatment must be revised, upgraded or replaced to assure proper operation. A direct study would be required before detailed recommendations could be presented.

B. Organics

Organics must be removed to low levels to avoid irreversible resin fouling. This can be partially accomplished by proper pretreatment (i.e. adding the organic scavenger previously discussed.) Activated carbon units will no doubt also be required to further reduce objectionable organics which cause this fouling. Activated carbon units would also remove any residual chlorine if this chemical is used as part of the pretreatment to further reduce organics.

4. Additional Systems

A. Boiler Tube Deposits

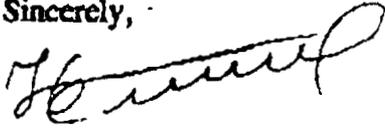
A complete chemical analysis and relative composition of the boiler tube deposits is still suggested.

B. Condensate Polishing System

Refer to the JTC 11/3/93 letter, item 4. for the additional information requested.

If you have any questions, please do not hesitate to call me.

Sincerely,

A handwritten signature in cursive script, appearing to read "I Olikar".

Dr. I Olikar, P.E.
Principal

IO:gb

cc: Joseph H. Westik