IPS

ENGINEERING STANDARD

FOR

PROCESS DESIGN OF WATER SYSTEMS

CONTENTS :   PAGE No.

APPENDICES:

0. INTRODUCTION

"Process Design of Utility Systems for OGP Process ", are broad and contain subject of paramount importance. Therefore a group of IPS Standards are prepared to cover the subject. The process engineering standards of this group includes the following Standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-310	"Process Design of Water Systems"
IPS-E-PR-330	"Process Design of Production and Distribution of Compressed Air Systems"
IPS-E-PR-340	"Process Design of Fuel Systems"
IPS-E-PR-460	"Process Design of Flare and Blowdown Systems"
IPS-E-SF-120,140, 160, 180, 200, 220, 380, and G-SF-240	"Fire Fighting Systems"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF WATER SYSTEMS"

1. SCOPE

This Engineering Standard Specification specifies the minimum requirements for the process design and selection of various water supply systems, used in OGP Industries, and consist of the following four systems:

Section 6:	Water Treatment System.
Section 7:	Raw Water and Plant Water System.
Section 8:	Cooling Water Distribution and Return System.
—	Fire Water Distribution and Storage Facilities (see IPS-E-SF-220).

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant:

IPS   (IRANIAN PETROLEUM STANDARDS)

IPS-E-SF-120,140, 160, 180, 200, 220, 380 and G-SF-240	"Fire Fighting Systems"
IPS-E-SF-220	"Fire Water Distribution and Storage Facilities"
IPS-E-PR-360	"Process Design of Liquid & Gas Transfer & Storage"
IPS-E-PR-440	"Process Design of Piping Systems" (Process Piping & Pipeline Sizing)
IPS-E-PR-491	"Process Requirements of Refinery Non-Licensed Units, Part IV, Chemical Injection Systems"
IPS-E-PR-750	"Process Design of Compressors"
IPS-E-PR-771	"Process of Requirements of Heat Exchanging Equipment"
IPS-E-PR-790	"Process Design of Cooling Towers"
IPS-E-PR-895	"Process Design of Solid-Liquid Separators"
IPS-C-ME-110	"Large Welded Low Pressure Storage Tanks"

USPHS (US PUBLIC HEALTH SERVICE)

—	"Drinking Water Standards", No. 956, 1962

DEGREMONT

—	"Water Treatment Handbook", 5th. Ed., ISBN 2.85014.004X, 1979

DCC   (DREW CHEMICAL CORPORATION)

—	"Principles of Industrial Water Treatment", Library of Congress, Catalog Card Number 77-76610, 1st. Ed., 1977

AWWA   (AMERICAN WATER WORKS ASSOCIATION, INC)

   —   "Water Treatment Plant Design", 1971
   Manual M21,   "Ground Water", Latest Edition

API   (AMERICAN PETROLEUM INSTITUTE)

   —   "API Glossary of Terms Used in Petroleum Refining", 2nd., Ed., 1962

GPSA   (GAS PROCESSORS SUPPLIERS ASSOCIATION)

   —   "Engineering Data Book", Section 18, 1987

DIN   (DEUTSCHES INSTITUT FUR NORMUNG eV)

   Standard DIN 19633 "Ion Exchange Resins for Water Treatment", 1990

3. DEFINITIONS AND TERMINOLOGY

For the preparation of the following definitions, "API Glossary of Terms Used in Petroleum Refining", and DCC, "Principles of Industrial Water Treatment", have been used.

3.1 Alkalinity

The acid neutralizing capacity of a water. It is usually expressed as "M" alkalinity (the methyl/orange endpoint at a pH$\approx$4.3) and "P" alkalinity (the phenolphthalein endpoint at a pH$\approx$8.3). Several ions contribute to alkalinity, but it is generally due to bicarbonate $(HCO)^{-1}$, carbonate $(CO_3)^{-2}$ and hydroxyl $(OH)^{-1}$ ions.

3.2 Break-Point Chlorination

The addition of chlorine to water to the point where free available residual chlorine increases in proportion to the incremental dose of chlorine being added. At this point all of the ammonia has been oxidized.

3.3 Coagulation

The precipitation from solution or suspension of fine particles which tend to unite in clots or curds.

3.4 Backwash

That part of the operating cycle of an ion-exchange process wherein a reverse upward flow of water expands the bed, effecting such physical changes as loosening the bed to counteract compacting, stirring up and washing off light insoluble contaminants to clean the bed, or separating a mixed bed into its components to prepare it for regeneration.

3.5 Boiler Water

A term construed to mean a representative sample of the circulating boiler water, after the generated steam has been separated, and before the incoming feed water or added chemical becomes mixed with it, so that its composition is affected.

3.6 Brackish Water

Water having a dissolved matter content in the range of approximately 1,000 to 30,000 mg/L.

3.7 Breakthrough

The first appearance in the solution flowing from an ion-exchange Unit of unadsorbed ions similar to those which are depleting the activity of the resin bed. Breakthrough is an indication that regeneration of the resin is necessary.

3.8 Brine

Water having more than approximately 30,000 mg/L of dissolved matter.

3.9 Drift

Water lost from a water-cooling tower as liquid droplets entrained in the exhaust air, units: kg per hour or percent of circulating water flow.

3.10 Feedwater

The water supplied to a boiler to make-up for losses.

3.11 Floc

Any small, tufted, or flakelike mass of matter floating in a solution, e.g., as produced by precipitation.

3.12 Fresh Water

Water having less than approximately 1,000 mg/L of dissolved matter.

3.13 Hardness

A characteristic of water generally accepted to represent the total concentration of calcium and magnesium ions.

3.14 Ion-Exchange

A chemical process involving the reversible interchange of ions between a solution and a particular solid material (ion-exchanger), such as an ion-exchange resin consisting of matrix of insoluble material interspersed with fixed ions of opposite charge.

3.15 Resin

A polymer of unsaturated hydrocarbons from petroleum processing, e.g., in the cracking of petroleum oils, propane deasphalting, clay treatment of thermally cracked naphthas. Chief uses include:

- rubber and plastics;
- impregnants;
- surface coatings.

3.16 Raw Water

Untreated water.

3.17 Regenerant

The solution used to restore the activity of an ion exchanger. Acids are employed to restore a cation exchanger to its hydrogen form; brine solutions may be used to convert the cation exchanger to the sodium form. The anion exchanger may be regenerated by treatment with an alkaline solution.

3.18 Rinse

The operation which follows regeneration; a flushing out of excess regenerant solution.

3.19 Ryznar Stability Index

An empirical method for predicting scaling tendencies of water based on a study of operating results with water of various saturation indices.

$$\textbf{Stability Index} = 2pH_S - pH \qquad\qquad\qquad\qquad \textbf{(Eq. 1)}$$

Where:

pH_S **= Langelier's Saturation pH.**

This index is often used in combination with the Langelier Index to improve the accuracy in predicting the scaling or corrosion tendencies of a water. The following chart illustrates how to use this index:

RYZNAR STABILITY INDEX	TENDENCY OF WATER
4.0 - 5.0 5.0 - 6.0 6.0 - 7.0	Heavy Scale Light Scale Little Scale or Corrosion
7.0 - 7.5 7.5 - 9.0 9.0 and higher	Corrosion Significant Heavy Corrosion Corrosion Intolerable

3.20 Synthetic Resin

Amorphous, organic, semisolid or solid material drived from certain petroleum oils among other sources; approximating natural resin in many qualities and used for similar purposes.

3.21 Langelier's Index

A technique of predicting whether water will tend to dissolve or precipitate calcium carbonate. If the water precipitates calcium carbonate, scale formation may result. If the water dissolves calcium carbonate, it has a corrosive tendency. To calculate Langelier's Index, the actual pH value of the water and Langelier's saturation pH value (pH_S) are needed. Langelier's saturation pH value is determined by the relationship between the calcium hardness, the total alkalinity, the total solids concentration and the temperature of the water. Langelier's Index is then determined from the expression pH-pH_S. Fig. 1 is a chart used for determining Langelier's Index. The interpretation of the results obtained are shown below:

pH - pH_S	Tendency of Water
Positive Value	Scale Forming
Negative Value	Corrosive
Zero	Neither Scale Forming Nor Corrosive

Also note that the presence of dissolved oxygen in the water may cause water with a "Zero" Langelier's Index to be corrosive rather than "neutral".

Caution must be observed in employing Langelier's Index for controlling corrosion or deposit formation, since there are factors that may make its application inappropriate. These include temperature differences within a system, changing operating conditions, or the presence of chemical treatment in the water.

3.22   Blowdown

Blowdown is the continuous or intermittent removal of some of the water in the boiler or cooling water system to reduce concentration of dissolved and/or suspended solids.

3.23   Recirculation Rate

The flow of cooling water being pumped through the entire plant cooling loop.

3.24   Bed Expansion

The effect produced during backwashing; the resin particles becomes separated and rise in the column. The expansion of the bed due to the increase in the space between resin particles may be controlled by regulating backwash flow.

3.25   Chlorine Residual

The amount of available chlorine present in water at any specified period, subsequent to the addition of chlorine.

3.26   Chlorine Requirement

The amount of chlorine, expressed in mg/kg, required to achieve under specified conditions the objectives of chlorination.
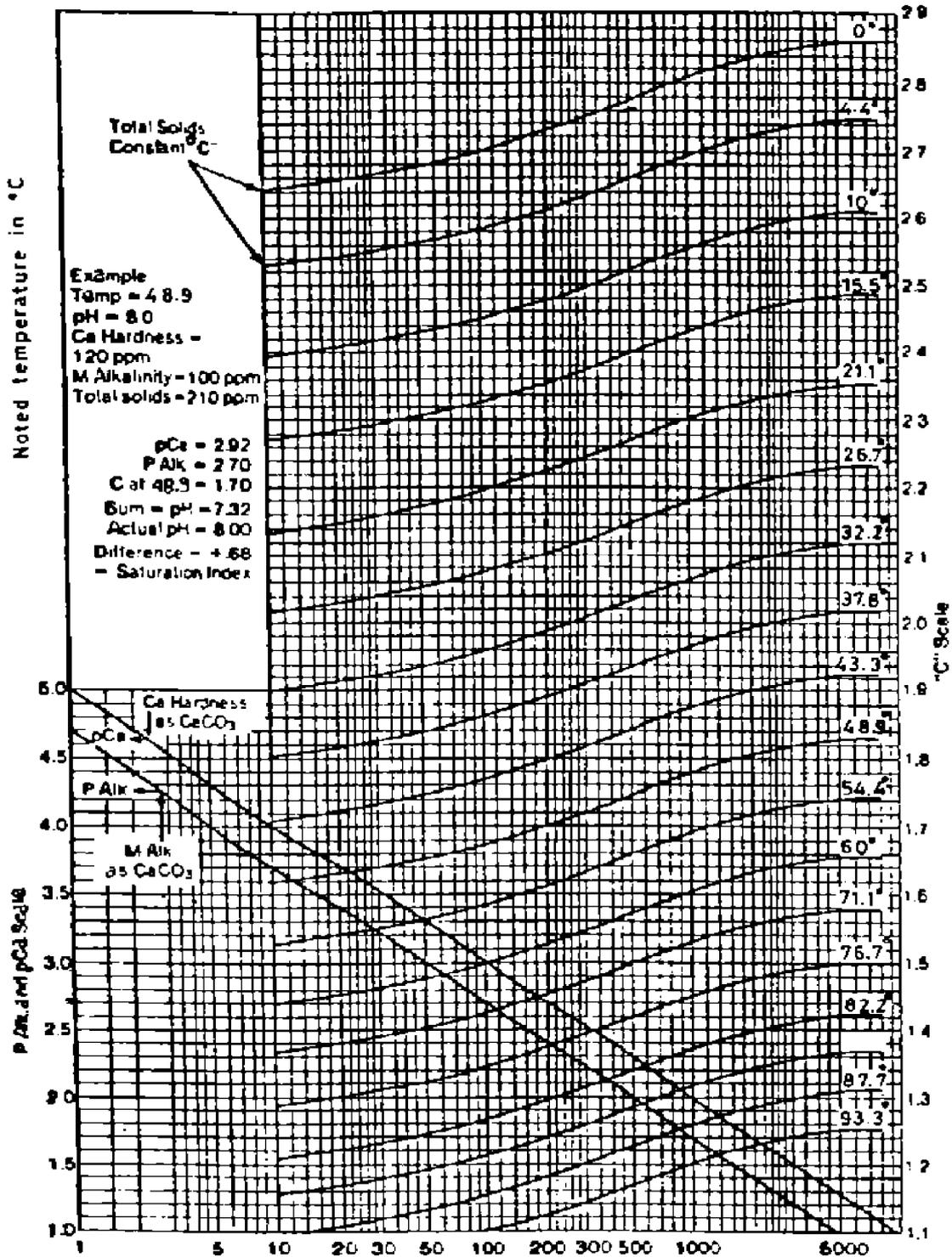
LANGELIER SATURATION INDEX
Fig. 1

4. SYMBOLS AND ABBREVIATIONS

A	Surface area of the settling basin, in (m²).
ABMA	American Boiler Manufacturers' Association.
API	American Petroleum Institute.
ASME	American Society of Mechanical Engineers.
AWWA	American Water Works Association.
C	Exchange capacity of the resins expressed in (French degrees/L per liter of consolidated resins).
DIN	Deutsches Institute Fur Normung eV.
DWS	Drinking Water Standards.
Eq	Equation.
GPSA	Gas Processors Suppliers Association.
IPS	Iranian Petroleum Standards.
MCL	Maximum Contaminant Level.
MPN	Maximum Possible Numbers.
OGP	Oil, Gas, and Petrochemical.
pH_s	Langlier Saturation pH.
ppm_m	parts per million by mass, in (mg/kg).
Q	Inflow rate, in (m³/h).
Rev	Revision.
SAF	Total concentration of salts of strong acids, in [French degrees $(SO_4^{-2} + Cl^{-1} + NO_3^{-1})$].
sp gr	Specific Gravity (Relative Density).
TAC	Complete Alkalinity Titration.
TCO_2	Content of carbon dioxide in the water after passing through the cation exchanger, in (French degrees).
$TSiO_2$	Silica content (1 French degree = 12 mg/L SiO_2 based on Table E.1).
USPHS	United States Public Health Service.
V	Volume of water to be supplied in (m³).
v	Velocity of settling, in (m/h).
V_a	Volume of anion resin.
V_c	Volume of cation resin.
V_L	Rise rate, in (m/h).
V_p	Downward velocity, in (m/h).

5. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

6. WATER TREATMENT SYSTEM

6.1 General

Water treating requirements for refinery and/or plant services depend upon:

    1) the quality of the source of make-up water;
    2) the manner in which the water is used;
    3) environmental regulations; and
    4) site climatic conditions governing wastewater disposal.

These factors should be considered in selecting the overall plant process and utility systems.

6.1.1 Source water types

6.1.1.1 Source or make up water is normally either ground or surface water, neither of which is ever chemically pure.

6.1.1.2 Ground waters contain dissolved inorganic impurities which come from the rock and sand strata through which the water passed.

6.1.1.3 Surface waters often contain silt particles in suspension (suspended solids) and dissolved organic impurities (dissolved solids).

6.1.1.4 Table 1 lists some of the common properties or characteristics and the normal constituents of water, together with corresponding associated operating difficulties and potential methods of water treatment.

TABLE 1 - COMMON CHARACTERISTICS AND IMPURITIES IN WATER

CONSTITUENT	CHEMICAL FORMULA	DIFFICULTIES CAUSED	MEANS OF TREATMENT
Turbidity	None, usually expressed in Jackson Turbidity Units	Imparts unsightly appearance to water; deposits in water lines, process equipment, boilers, etc.; interferes with most process uses	Coagulation, settling and filtration
Color	None	Decaying organic material and metallic ions causing color may cause foaming in boilers; hinders precipitation methods such as iron removal, hot phosphate softening, can stain product in process use	Coagulation, filtration, chlorination, adsorption by activated carbon
Hardness	Calcium, magnesium, banum and strontium salts expressed as $CaCO_3$	Chief source of scale in heat exchange equipment, boilers, pipelines, etc.; forms curds with soap; interferes with dyeing, etc.	Softening, distillation, internal boiler water treatment, surface active agents, reverse osmosis, electrodialysis
Alkalinity	Bicarbonate (HCO_3^{-1}), Carbonate (CO_3^{-2}), and hydroxyl (OH^{-1}), expressed as $CaCO_3$	Foaming and carryover of solids with steam; embrittlement of boilers steel; bicarbonate and carbonate produce CO_2 in steam, a source of corrosion	Lime and lime-soda softening acid treatment, hydrogen zeolite softening, demineralization, dealkalization by anion exchange, distillation, degasifying
Free Mineral Acid	H_2SO_4, HCl, etc. expressed as $CaCO_3$, titrated to methyl orange end-point	Corrosion	Neutralization with alkalies
Carbon Dioxide	CO_2	Corrosion in water lines and particularly steam and condensate lines	Aeration, deaeration, neutralization with alkalies, filming and neutralizing amines
pH	Hydrogen ion concentration defined as: $pH = \log \dfrac{1}{(H^{+1})}$	pH varies according to acidic or alkaline solids in water; most natural waters have a pH of 6.0-8.0	pH can be increased by alkalies and decreased by acids
Sulfate	$(SO_4)^{-2}$	Adds to solids content of water, but, in itself is not usually significant; combines with calcium to form calcium sulfate scale	Demineralization, distillation, reverse osmosis, electrodialysis
Chloride	Cl^{-1}	Adds to solids content and increases corrosive character of water	Demineralization, distillation, reverse osmosis, electrodialysis
Nitrate	$(NO_3)^{-1}$	Adds to solids content, but is not usually significant industrially; useful for control of boiler metal embrittlement	Demineralization, distillation, reverse osmosis, electrodialysis
Fluoride	F^{-1}	Not usually significant industrially	Adsorption with magnesium hydroxide, calcium phosphate, or bone black, Alum coagulation, reverse osmosis electrodialysis
Silica	SiO_2	Scale in boilers and cooling water systems; insoluble turbine blade deposits due to silica vaporization	Hot process removal with magnesium salts adsorption by highly basic anion exchange resins, in conjunction with demineralization, distillation
Iron	Fe^{+2} (ferrous) Fe^{+3} (ferric)	Discolors water on precipitation; source of deposits in water lines, boilers, etc.; interferes with dyeing, tanning paper mfr. etc.	Aeration, coagulation and filtration, lime softening cation exchange, contact filtration, surface active agents for ion retention
Manganese	Mn^{+2}	same as iron	same as iron

(to be continued)

TABLE 1 - (continued)

CONSTITUENT	CHEMICAL FORMULA	DIFFICULTIES CAUSED	MEANS OF TREATMENT
Oil	Expressed as oil or chloroform extractable matter, ppm_m	Scale, sludge and foaming in boilers; impedes heat exchange; undesirable in most processes	Baffle separators, strainers coagulation and filtration, diatomaceous earth filtration
Oxygen	O_2	Corrosion of water lines, heat exchange equipment, boilers, return lines, etc.	Deaeration, sodium sulfite, corrosion inhibitors, hydrazine or suitable substitutes
Hydrogen Sulfide	H_2S	Cause of "rotton egg" odor; corrosion	Aeration, chlonnation, highly basic anion exchange
Ammonia	NH_3	Corrosion of copper and zinc alloys by formation of complex soluble ion	Cation exchange with hydrogen zeolite, chlorination, deaeration, mixed-bed demineralization
Conductivity	Expressed as micromohos, specific conductance	Conductivity is the result of ionizable solids in solution; high conductivity can increase the corrosive characteristics of a water	Any process which decreases dissolved solids content will decrease conductivity; examples are demineralization, lime softening
Dissolved Solids	None	"Dissolved solids" is measure of total amount of dissolved matter, determined by evaporation; high concentrations of dissolved solids are objectionable because of process interference and as a cause of foaming in boilers.	Various softening process, such as lime softening and cation exchange by hydrogen zeolite, will reduce dissolved solids, demineralization; distillation; reverse osmosis electrodialysis
Suspended Solids	None	"Suspended Solids" is the measure of undissolved matter, determined gravimetrically; suspended solids plug lines, cause deposits in heat exchange equipment, boilers, etc.	Subsidence, filtration, usually preceded by coagulation and settling
Total Solids	None	"Total Solids" is the sum of dissolved and suspended solids, determined gravimetrically	See "Dissolved Solids" and "Suspended Solids"

6.1.2 Quality of source waters

6.1.2.1 Type of water treatment depends on the quality of the source water and the quality desired in the finished water.

6.1.2.2 Adequate information on the source water is thus a prerequisite for design. This includes analysis of the water and where the supply is non-uniform, the ranges of the various characteristics. Typical water analysis calculation is given in Appendix A.

6.1.2.3 The quality of many sources will change little over the lifetime of treatment plant except for the seasonal changes that should be anticipated in advance. Other sources can be expected to deteriorate substantially as a result of an increase in wastes. A reasonably accurate prediction of such changes in quality is difficult to make.

6.1.2.4 In some instances, it is best arrived at by judgment based on past trends in quality, a survey of the source, and evaluation of future developments relating to the supply.

6.1.2.5 Ground water sources tend to be uniform in quality, to contain greater amount of dissolved substances, to be free of turbidity, and to be low in color.

6.1.2.6 Surface water supplies receive greater exposure to wastes, including accidental spills of the variety of substances.

6.1.2.7 Generalizations like the above, although useful, are not a substitute for the definitive information required for plant design.

6.1.2.8 To provide adequate protection against pollution, special studies in the design of intakes should have to be made to indicate the most favorable locations for obtaining water.

6.1.2.9 In connection with deep reservoirs, multiple intakes offer flexibility in selecting water from various depths, thus overcoming poorer water quality resulting from seasonal changes.

6.1.2.10 For ground water sources, the location and depths of wells should be considered in order to avoid pollution and secure water of favorable quality.

6.1.3 Typical raw water specifications

As a typical guidance the raw water specifications of three refineries are presented in Tables B.1, B.2 and B.3 of Appendix B, for ground water, surface water and sea water.

6.1.4 Preliminary water treatment

Regardless of the final use of source water and any subsequent treatment, it is often advisable to carry out general treatment close to the intake or well. The purpose is to protect the distribution system itself and at the same time to provide initial or sufficient treatment for some of the main uses of water.

6.1.4.1 In case of surface water, general protection should be provided against clogging and deposits.

6.1.4.1.1 The obstruction or clogging of apertures and pipes by foreign matter can be avoided by screening or straining through a suitable mesh. The protection used is either a bar screen, in which the gap between the bars can be as narrow as 2 mm, or a drum or belt filter, with a mesh of over 250 micrometers (μm).

6.1.4.1.2 According to the requirements of the equipment and the amount of pollution (slime) in the water a 250 μm filter may be used on an open system, or microstraining down to 50 μm may be necessary in certain specific cases. In some cases, rapid filteration through silicous sand may be necessary after screening and will eliminate suspended matter down to a few micrometers. Where there are large amount of suspended matter, grit removal and/or some degree of settling should be provided.

6.1.4.2 In case of ground water the main risks are abrasion by sand or corrosion.

6.1.4.2.1 For abrasion the pumps should be suitably designed, and the protection, which concerns only the parts of the system downstream the pumps, will take the form of very rapid filteration through sand, straining under pressure of use of hydrocyclones, if the grit is of the right grain size.

6.1.4.2.2 Corrosion frequently occurs on systems carrying underground water and leads to the formation of tuberculi-form concretions, which must not be confused with scale. This corrosivity is often caused by the lack of oxygen. The best method, therefore, of preventing corrosion is by oxygenation and filteration processes that have the dual advantage of removing the grit and any iron present, and of feeding into the water the minimum amount of oxygen needed for system to protect itself.

6.1.5 Treatment process selection

6.1.5.1 The quality of the source, giving due consideration to variations and possible future changes, the quality goals for the finished water, and cost, shall form the basis for selecting a treatment process.

6.1.5.2 Often various types and combination of treatment Units would be used to achieve the performance desired (see Table 1). Determination of the most suitable plan should be on a comparative cost study which includes an evaluation of the merits and liabilities of each proposal.

6.1.5.3 The experience acquired through treatment of the same or similar source shall provide an excellent guide in selecting a plan.

6.1.5.4 Where experience is lacking or where there is the desire for a different degree of performance, special studies should be indicated. Tests conducted in the laboratory, in existing plants, or in pilot plants should then be employed to obtain information for design purposes.

6.1.6 Plant sizing and layout

For plant sizing and layout the following considerations should be followed:

a) Coordination of plant elements to provide for efficient production of a high quality effluent. Major considerations in treatment plant design include, frequency of basin cleaning, length of filter runs, and effluent quality.

b) Economic but durable construction.

c) Simplification of equipment and operations.

d) Centralization of operations and control.

e) Chemical feed lines as short and direct as reasonably possible.

f) Simplified chemical handling and feeding.

g) Essential instrumentation only.

h) Appropriate use of automation.

6.1.7 Potable water quality

In refineries and/or plants water system the minimum specification required for potable water should be as per local authority of municipal water supply, and is recommended to be based on establishment water system performance goals potable water standard specifications as presented in Appendix C.

6.1.8 Boiler water quality criteria

6.1.8.1 Boiler water chemistry

There are four types of impurities of concern in water to be used for the generation of steam:

a) Scale-forming solids which are usually the salts of calcium and magnesium along with boiler corrosion products. Silica, manganese and iron, can also form scale.

b) The much more soluble sodium salts which do not normally form scale, but can concentrate under scale deposits to enhance corrosion or in the boiler water to increase carryover due to boiler water foaming.

c) Dissolved gases, such as oxygen and carbon dioxide, which can cause corrosion.

d) Silica, which can volatilize with the steam in sufficient concentrations to deposit in steam turbines.

6.1.8.2 Boiler blowdown

Blowdown should be employed to maintain boiler water dissolved solids at an appropriate level of concentration. At equilibrium the quantities of dissolved solids removed by blowdown exactly equals those introduced with the feedwater plus any injected chemicals.

6.1.8.3 ABMA and ASME standard

The American Boiler Manufacturers' Association (ABMA) and the American Society of Mechanical Engineers (ASME) have developed suggested limits for boiler water composition which depend upon the type of boiler and the boiler operating pressure. These control limits for boiler water solids are based on one or more of the following factors:

6.1.8.3.1 Sludge and total suspended solids

These result from the precipitation in the boiler of feedwater hardness constituents due to heat and to interaction of treatment chemicals, and from corrosion products in the feedwater. They can contribute to boiler tube deposits and enhance foaming characteristics, leading to increased carryover.

6.1.8.3.2 Total dissolved solids

These consist of all salts naturally present in the feedwater, of soluble silica, and of any chemical treatment added. Dissolved solids do not normally contribute to scale formation but excessively high concentrations can cause foaming and carryover or can enhance "underdeposit" boiler tube corrosion.

6.1.8.3.3 Silica

This may be the blowdown controlling factor in softened water containing high silica. High boiler water silica content can result in silica vaporization with the steam, and under certain circumstances, silicaous scale. This is illustrated by silica solubility data in Fig. 2. Silica content of boiler water is not as critical for steam systems without steam turbines.

6.1.8.3.4 Iron

Occasionally in high pressure boilers where the iron content is high in relation to total solids, blowdown may be based upon controlling iron concentrations, high concentrations of suspended iron in boiler water can produce serious boiler deposit problems and are often indications of potentially serious corrosion in the steam/steam condensate systems.

6.1.8.3.5 While there are other considerations (such as corrosive or deposit forming tendencies) in establishing limits for boiler water composition, the ABMA recommendations as per Table 2 clearly indicate that boiler feedwater purity becomes more important as operating pressures increases.

6.1.9 Common deposits formed in water systems

The deposits may be classified generally as scale, sludge, corrosion products, and biological deposits. The more common types of deposits are shown in Table D.1 of Appendix D.
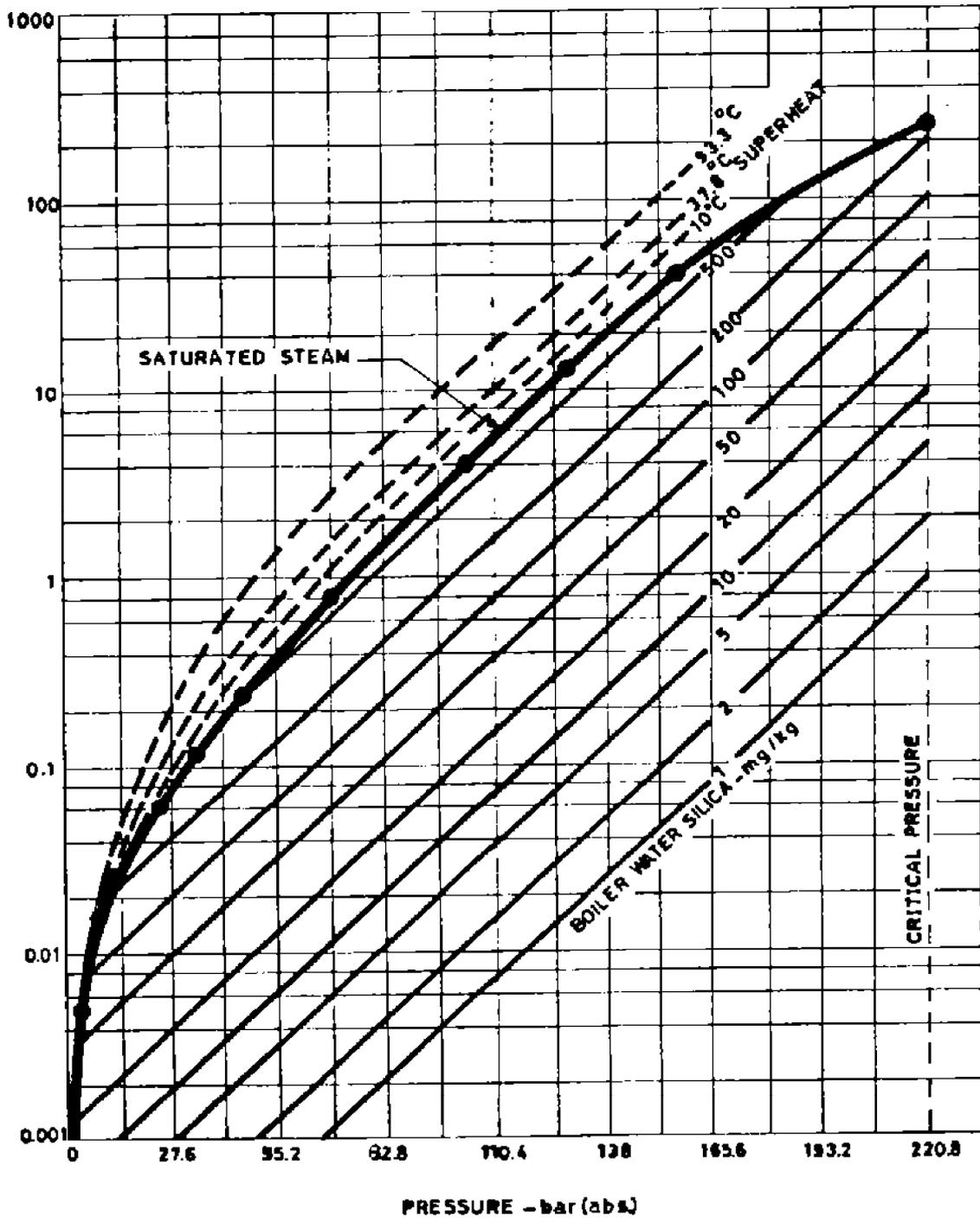
Note:

Reference is made to GPSA, Section 18.

RELATIONSHIP BETWEEN BOILER PRESSURE, BOILER WATER SILICA
CONTENT AND SILICA SOLUBILITY IN STEAM
Fig. 2

TABLE 2 - RECOMMENDED BOILER WATER LIMITS AND ASSOCIATED STEAM PURITY AT STEADY STATE FULL LOAD OPERATION DRUM TYPE BOILERS*

Drum Pressure bar (ga)	Range Total Dissolved Solids Boiler Water mg/kg (max)	Range Total Alkalinity mg/kg (max)	Suspended Solids Boiler Water mg/kg (max)	Range Total Dissolved Solids Steam mg/kg (max Expected Valued)
0.20 - 69	700 - 3500	140 - 700	15	0.2-1.0
20.76 - 31.03	600 - 3000	120 - 600	10	0.2-1.0
31.10 - 41.38	500 - 2500	100 - 500	8	0.2-1.0
41.45 - 51.72	400 - 2000	80 - 400	6	0.2-1.0
51.79 - 62.07	300 - 1500	60 - 300	4	0.2-1.0
62.14 - 68.96	250 - 1250	50 - 250	2	0.2-1.0

* Reference is made to GPSA, Section 18.

6.2 Types of Processes-Design

6.2.1 Coagulation & flocculation

6.2.1.1 General information

6.2.1.1.1 In water treatment, coagulation is defined as a process by which colloidal particles are destabilized, and is achieved mainly by neutralizing their electric charge. The product used for this neutralizing is called a coagulant.

6.2.1.1.2 Flocculation is the massing together of discharged particles as they are brought into contact with one another by stirring. This leads the formation of flakes or floc. Certain products, called flocculating agents, may promote the formation of floc.

6.2.1.1.3 Separation of the floc from the water can be achieved by filteration alone or by settling.

6.2.1.1.4 Coagulation and flocculation are frequently used in the treatment of potable water and preparation of process water used by industry.

6.2.1.1.5 Certain dissolved substances can also be adsorbed into the floc (organic matter, various pollutants, etc.).

6.2.1.2 Main coagulants

6.2.1.2.1 The most widely used coagulants are based on aluminum or iron salts. In certain cases, synthetic products, such as cation polyelectrolytes, can be used.

6.2.1.2.2 Cation polyelectrolytes are generally used in combination with metal salt, greatly reducing the salt dosage which would have been necessary. Sometimes no salts at all are necessary, and this greatly reduces the volume of sludge produced.

6.2.1.3 pH value for coagulation and dosage

6.2.1.3.1 For any water, there is an optimum pH value, where good flocculation occurs in the shortest time with the least amount of chemical.

6.2.1.3.2 For actual application of coagulating agents, the dosage and optimum pH range should be determined by coagulation control or a jar test.

6.2.1.4 Choice of coagulant

Coagulant should be chosen after the raw water examination in laboratory by means of flocculation test, while considering following factors:

a) Nature and quantity of the raw water.
b) Variations in the quality of the raw water (daily or seasonal especially with regard to temperature).
c) Quality requirements and use of the treated water.
d) Nature of the treatment after coagulation, (filter coagulation, settling).
e) Degree of purity of reagents, particularly in the case of potable water.

6.2.2 Sedimentation

a) The process by which suspended or coagulated material separates from water by gravity is called sedimentation.

b) Sedimentation alone, is an effective means of water treatment but is made more effective by coagulation.

c) Presedimentation basins or sand traps are sometimes used when waters to be treated contain large amounts of heavy suspended solids. This decreases the amount of sediment which accumulates in the sedimentation basin as a result of the coagulation and sedimentation process.

d) If water is to be filtered in the course of treatment, coagulation and sedimentation will reduce the load on filters.

6.2.2.1 Type of sedimentation tanks

a) The effectiveness of a sedimentation tank depends on the settling characteristics of the suspended solids that are to be removed and on the hydraulic characteristics of the settling tank.

b) The hydraulic characteristics of a settling tank depend on both the geometry of the tank and the flow through the tank.

c) Most sedimentation tanks used in water purification today are of the horizontal-flow type.

d) Horizontal-flow tanks may be either rectangular or circular in plan. Circular, horizontal-flow tanks may be either center feed with radial flow, peripheral feed with radial flow, or peripheral feed with spiral flow.

e) Fig. 3 shows the flow patterns in horizontal-flow type of sedimentation tanks.
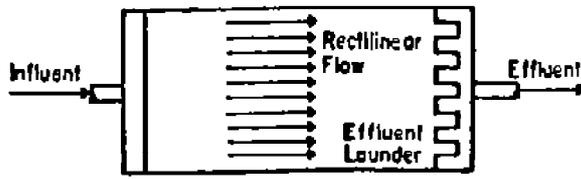
a) Rectangular settling tank, rectilinear flow
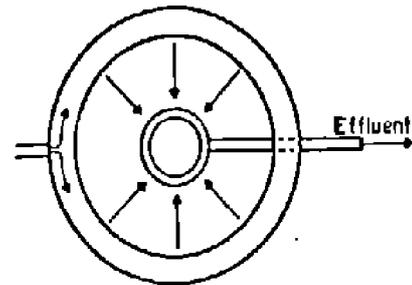
d) Peripheral-feed settling tank, radial flow
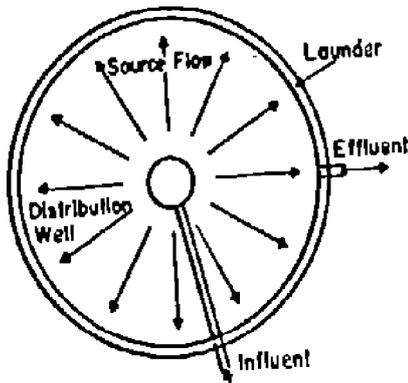
b) Center-feed settling tank, source flow
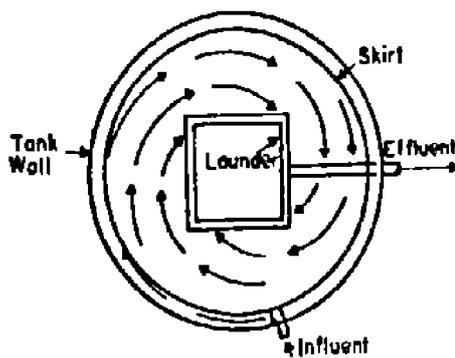
c) Peripheral-feed settling tank, spiral flow
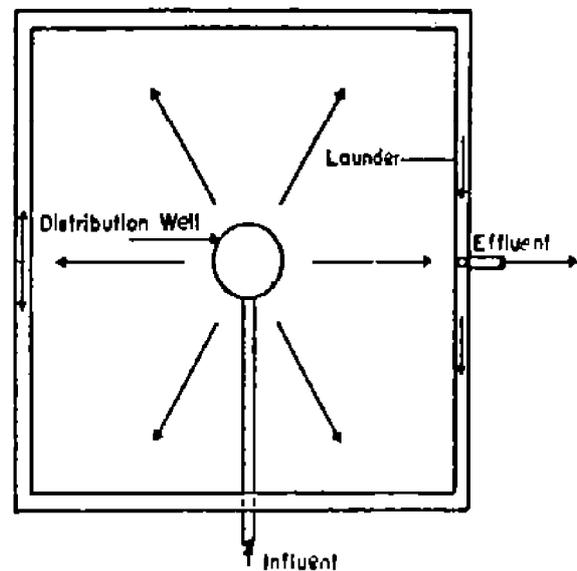
e) Square settling tank, radial flow

FLOW PATTERNS IN SEDIMENTATION TANKS *
Fig. 3

* Of the circular tanks, the one with center feed and radial flow, 2(b), is the only one commonly used today.

f) In horizontal-flow tank design, the aim should be to achieve as nearly as possible the ideal condition of equal velocity for all points lying on each vertical line in the settling zone (The ideal basin condition). This, in effect would be complete separation of the four zone of the tank.

g) The sedimentation basins should be equipped with mechanical equipment for continuous removal of settled solids.

6.2.2.2 Practical sedimentation basin

1) The situation in practical sedimentation basins is modified because of the relative density (specific gravity) and shape of the particles, coagulation of particles, concentration of particles, and movement of water through the settling tank.

2) The relative density of suspended matter may vary from 2.65 for sand to 1.03 for flocculated particles or organic matter and mud containing 95% water.

3) Floc particles resulting from coagulation with aluminum compounds have a relative density of about 1.18, and those obtained using ferrous sulfate as a coagulant have a relative density of 1.34. These values can be increased by clay or silt or decreased by organic matter. However most of the particles in a settling basin settle at velocities within Stock's law.

4) Because of the difference in shape, size and relative density of particles, there is a wide range of settling velocities. This results in some subsiding particles overtaking others, thus increasing the natural tendency of suspended matter to flocculate.

6.2.2.3 Factors influencing the design of sedimentation basins

1) Sedimentation basins are often designed on the basis of existing installations which are handling the same type of water. Experience and judgment of the engineer are also instrumental in the design. However, there are some important points, other than structure, which should be considered in the design of a basin.

2) The basin should be large enough to insure an adequate supply of treated water during periods of peak load.

3) The characteristics and type of water treatment also affect the design of the basin. Such things as the nature of the suspended material and the amount and type of coagulant needed, if any, should also be considered.

4) The influence of temperature is also important, since the viscosity of the water is less on a warm summer day than in cold weather.

5) The number of basins depends upon the amount of water and the effect of shutting a basin down. It is desirable to have more than one basin to provide for alternate shutdown of individual basins for cleaning or repairs.

6) Basins vary in shape-square, rectangular and round. However, regardless of shape, most basins have slopping bottoms to faciliate the removal of deposited sludge.

7) Sedimentation basins are equipped with inlets in order to distribute the water uniformly among the basins and uniformly over the cross section of each basin. Inlet and outlets should be designed to avoid short circuiting through the basin.

6.2.2.4 Hydraulic properties of sedimentation basin

a) Surface area or surface overflow rate

1) The surface area of the tank is one of the most important factors that influences sedimentation. For any particular rate of inflow the surface area provided determines the tank overflow rate, $v = Q/A$ (Eq. 2), (see Table 3). If there were such a thing as an ideal tank, the tank overflow rate could be made equal to the settling velocity of the particles that the tank was designed to remove.

2) Because no ideal tank exist, it is customary to reduce the tank overflow rate and to increase the detention time over those indicated by theoretical analysis. It is recommended to apply a correction factor 1 to 1.25 to both values when settling a discrete solid.

3) For the sedimentation of flocculent particles from dilute suspensions, the settling velocity will generally be decreased by a factor of 1.25 to 1.75.

4) The net effect of these corrections is to provide the range of settling velocities for different applications summarized in Table 3.

5) The higher settling velocities or tank overflow rates would be used for warmer water; the lower settling velocities for cold waters.

6) The settling velocity used in the settling tank design overflow rate is one of the major factors determining tank efficiency.

TABLE 3 - TYPICAL SEDIMENTATION TANK OVERFLOW RATES

TYPE OF WATER	TREATMENT	OVERFLOW RATE $m^3/m^2.h$
Surface Water	Alum Floc	0.61 - 0.93
Surface or Ground Water	Lime Softening	0.93 - 1.54
	Clarification in Upflow-Units	2.44 - 4.52 1.83 - 2.44 (Cold Water) 2.44 - 3.66 (Warm Water)
	Softening in Upflow-Units	1.83 - 6.11 to 3.06 (Surface) to 4.40 (Well)

b) Depth

1) The theoretical detention time is equal to the volume of the tank divided by the flow rate (see Eq. 1). Hence, if A and Q are constant, the theoretical detention time is directly proportional to the tank depth.

2) As the performance of the tank depends on the flocculation of the suspended solids, and the degree of flocculation depends on the detention time, the tank performance in removal of flocculent particles will depend on its depth.

3) The efficiency of removal, however, is not linearly related to the detention time. For example, if 80 percent of the suspended solids were removed with a detention time of 2 h, a detention time of 3 hour might remove only 90 percent.

4) The raw water entering a sedimentation tank will have a greater density than the water in the tank, as it will contain more suspended solids. The heavier influent water will tend to form density currents and move toward the bottom of the tank, where it can interfere with the sedimentation process. Density currents are more apt to occur in deep tanks.

5) Sedimentation basins are commonly designed to remove solids resulting from chemical coagulation of surface water and limesoda as softening of surface and ground waters. In a properly designed basin, a detention time of from 2-4 h is usually sufficient to prepare the water for subsequent filteration. When the water is to be used without filteration, longer detention time (up to 12 h) may be provided.

c) Velocity through basin

The velocity of flow through settling basin will not be uniform over the cross section perpendicular to the flow even though the inlets and outlets are designed for uniform distribution. The velocity will not be stable because of density currents, and the operation of the sludge removal mechanism. In order to minimize these disturbances, the velocity through a sedimentation tank should be kept between 0.0026 and 0.015 m/s.

d) Inlet and outlet conditions

1) The inlet to a sedimentation tank should be designed to distribute the water uniformly between basins and uniformly over the full cross section of the tank.

2) The inlet is more effective than the outlet in controlling density and internal currents, and tank performance is effected more by inlet than by outlet conditions.

3) The best inlet is one that allows the water to enter the settling tank without the use of pipe lines or channels.

4) The head loss in preamble baffle ports or basin inlet ports should be relatively large compared to the kinetic energy of the water moving past the permeable ports. This is required to assure equal distribution of flow between tanks and between inlet ports.

5) As flocculent solids will frequently be involved, the velocities in the influent channels must be kept low, usually between 0.15 and 0.60 m/s, to prevent break up of the floc. Similar low velocities are required through the inlet ports to reduce the danger of inertial currents interfering with sedimentation.

6) It has been found that relatively minor changes in an inlet can completely change the hydraulic performance of a settling tank.

7) The main purpose of the inlet is to provide a smooth transition from the relatively high velocities in the influent pipe to the very low uniform velocity distribution desired in the settling zone, in such a way that interference with the settling process is minimal.

8) The purpose of the outlet is the same except that the transition is from the settling zone to the effluent pipe.

9) The water level in settling basins is usually controlled at the outlet. This control, however may be set by means other than the outlet weir, as for example, by a succeeding Unit.

10) It may be desirable to encourage deliberate flunctuation of water level in the settling basins to make use of the storage in them, or to break up ice.

11) Basin outlets are often of the V-notch weir type, and these are quite often provided with means for vertical adjustment to aid in control of overflow. The V-notches help in keeping a uniform flow over the weir at low water levels.

12) The effect of weir rates, cubic meters per hour per meter of weir, on sedimentation, is not well known, but weir rates are usually limited to commonly accepted values (see Table 4).

13) Circular basins with the inlet at one side and the outlet on the opposite side are not very efficient because of dead areas in the tank and short circuiting of water flow across the tank. The efficiency of circular tanks is much greater if the water is fed to the tank from an inverted siphon located in the center of the tank, and the effluent taken from a weir passing around the entire periphery.

14) Square basin may be operated in the same manner or may be fed from one side with effluent removed from the opposite side.

15) The use of baffles in sedimentation tanks should be limited to the inlets and outlets and as remedial measures in poorly designed tanks.

TABLE 4 - TYPICAL WEIR OVERFLOW RATES

TYPE OF SERVICE	WEIR OVERFLOW RATE m³/m.h
Water clarification Water treatment Light alum floc (low-turbidity water)	< 26 6 - 7.5
Heavier alum flow (higher-turbidity water)	7.5 - 11.2
Heavy floc from lime softening	11.2 - 13.4

e) Sludge handling

1) The bottom of a settling tank is normally sloped gently toward a sludge hopper where the sludge is collected.

2) The sludge usually moves hydraulically toward the hopper.

3) Sludge scraper mechanisms are used to prevent the sludge from sticking to the bottom and to help its flow.

4) The sloping bottom and the sludge hopper provide a certain amount of storage space for the sludge before it is removed.

5) The movement of the sludge scrapper mechanism should be quite slow so as not to disrupt the settling process or to resuspend the settled sludge. The velocity of the scrapers should be kept below 18.3 m/h for this reason.

6) Some scraer mechanisms in circular tanks carry vacuum suction pipes instead of squeegees for removing relatively light, uniform solids.

6.2.3 Equipment used in clarification

6.2.3.1 The equipment used for clarification can be many types; however, the equipment used should provide the correct environment to carry out each step coagulation, flocculation and sedimentation.

6.2.3.2 Older design for clarification Units provided separate chemical addition, flash mixing, flocculating and settling facilities. Modern combined Units provide all three steps in one Unit, such as sludge recirculation (solids contact) type or sludge blanket Unit and so on.

6.2.3.3 In theory, the sludge blanket Unit provides better clarification than the sludge recirculation type as a result of filtering action provided by the sludge bed and the gentle handing of the flocs.

6.2.3.4 A basic clarification system consists of the clarifier and a chemical feeding system which meters chemical additives in proportion to flow (as per Standard E-PR-491, Part IV, "Chemicals Injection Systems").

6.2.3.5 The size of standard clarification Unit is based upon an upflow rate of approximately 2.5 m³/m².h (1.2 - 3.7 range), with a total retention time of 1.5 - 4 hours. The clarified water will contain approximately 5 - 10 mg/kg of suspended matter.

6.2.3.6 Fig. 4 illustrates the addition of "tubes" to a clarifier. These tubes either substantially increase the allowable upflow rate or reduce carryover at the same upflow rate.

6.2.3.7 Greater throughput capacities can be achieved by the parallel plate of "lammella" type separator shown in Figs. 5 and 6.

6.2.3.8 Design criteria of clarifiers should be based on steady operation at maximum load. However, it is expected that the actual load will fluctuate over the range from 10 to 100% of design flow rate and the clarifier should have the capacity to perform satisfactory under these conditions.

Consideration should also be given to anticipation of flow rate limitations and chemical dosages during difficult treatment periods considering high turbidity, low temperature and/or polluted conditions. Manufacturer shall either take such potential difficulties into consideration in design or state the limitations imposed by such conditions.
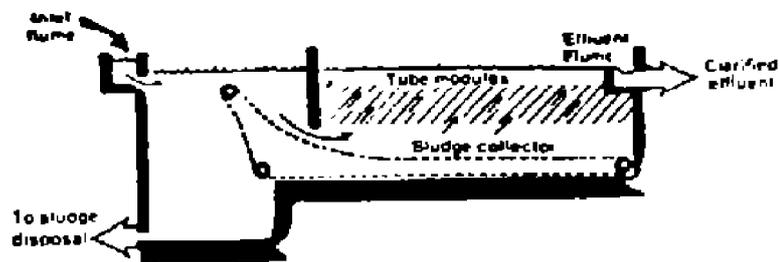
Rectangular Clarifier
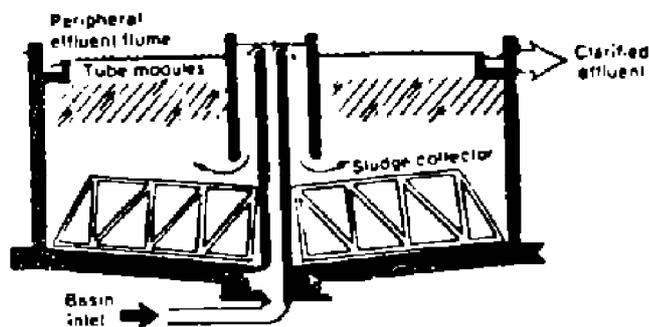
Circular Clarifier

TYPICAL TUBE SETTLER ARRANGEMENT
Fig. 4

TUBE-TYPE   **LAMELLA**
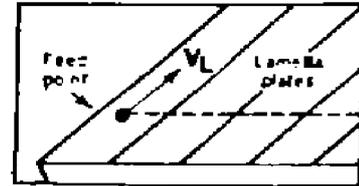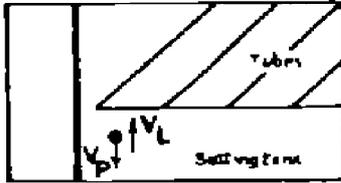
1a) Particles are carried up to tubes because their downward velocity (v_p) is less than the rise rate (v_L) of the liquid.

2a) Feed containing particles is presented to Lamella plates from the side by means of a bottomless feed box (see illustration at right).
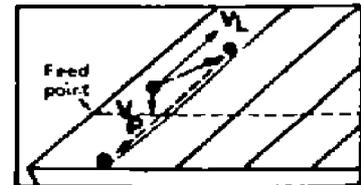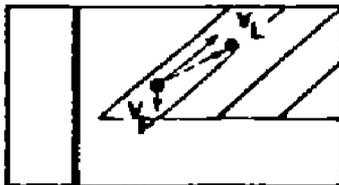
1b) Particles enter tubes where the resultant vector force carriers them to the tube walls.

2b) Particles enter Lamella plates where the resultant vector force carries them to the plate surfaces. However, unlike the tube settler, the particles slide down the plate past the point of entry into an area of "zero" velocity a feature found only in Lamella design.
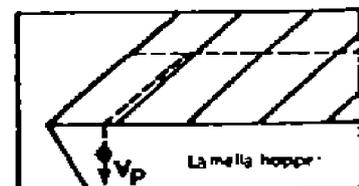
1c) Particles slide down tube walls. However, as particles leave tubes vL is still greater than vp, unless the particles have flocculated in the tubes. Thus, any increase in capacity achieved is limited to this further flocculation in the tubes.

2c) Particles exit Lamella plates into a quiescent zone where there is no upward liquid velocity to hinder solids settling.

LAMELLA GRAVITY SETTLER VS. TUBE-TYPE SETTER
Fig. 5
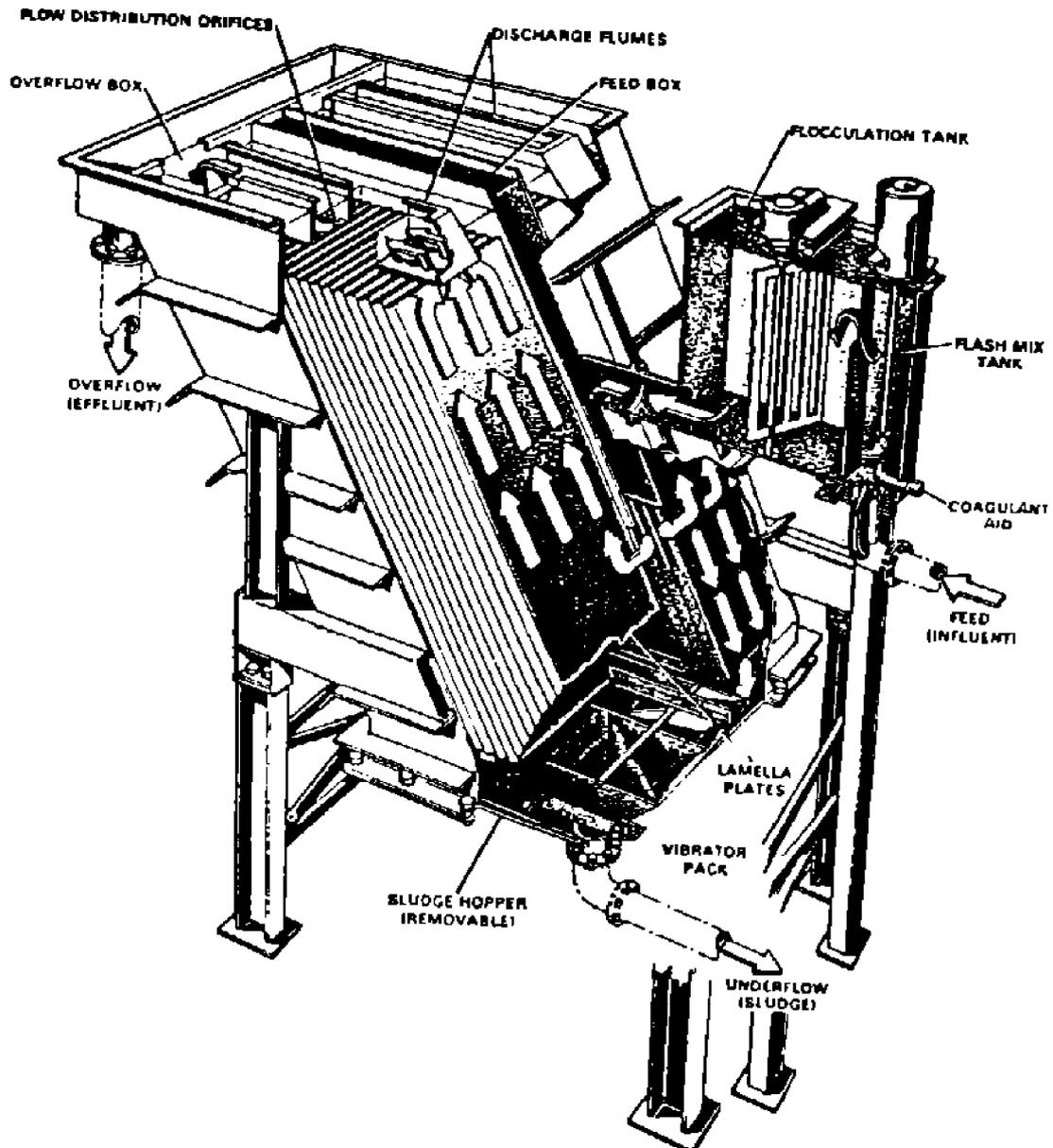
CLOSELY SPACED INCLINED PLATES (LAMELLA) MULTIPLY THE AVAILABLE SETTLING SURFACE IN A SMALL VOLUME AND REDUCE INSTALLATION SPACE
Fig. 6

6.2.4 Filters for water treating systems

6.2.4.1 Design criteria

6.2.4.1.1 Multiple Units shall be provided to allow continuous operation at full system design capacity with two Units out of service (for example: one Unit shutdown for maintenance and one Unit in backwash mode).

6.2.4.1.2 Design service flow rates shall be as described in Table 5.

TABLE 5 - FLOW RATES IN DIFFERENT TYPES OF WATER FILTERS

UNIT		FLOW RATE (MAXIMUM WITH ONE UNIT BACKWASHING) m³/m².h
1. Downflow, cold pressure type	(< 65°C)	9.7
2. Downflow, hot pressure type	(> 65°C)	10.8
3. Downflow, gravity type		9.7
4. Upflow type		*

* Vendor's recommendation if not specified in the project specification.

6.2.4.1.3 Air securing shall be used for Units treating effluent at temperatures less than 93°C. The design air scour rate shall be 90 m³/m².h minimum.

6.2.4.1.4 If plant air is unavailable, a separate air compressor shall be included within the system.

6.2.4.1.5 Subsurface washers shall be furnished for Units treating effluent at temperatures 93°C and greater. Subsurface wash rate shall be 12.3 m³/m².h minimum

6.2.4.1.6 Design backwash rate shall be per the following Table 6:

TABLE 6 - MINIMUM BACKWASH RATES IN DIFFERENT TYPES OF WATER FILTERS

FILTER MEDIA	MINIMUM BACKWASH RATE m³/m².h
Sand	36.7
Anthracite coal	29.2
Activated carbon	24.5

6.2.4.1.7 Bed depth in filters shall be 750 mm minimum. For "in-depth "filters at least two different density media, of different sizes, shall be furnished.

6.2.4.1.8 For hot pressure type Units only washed anthracite coal shall be used.

6.2.4.1.9 Freeboard shall be a minimum of two thirds total bed depth, measured from the top of the filter media to the tangent line at the top of vessel.

6.2.4.1.10 Filter media traps shall be furnished on the outlet of each pressure filter Unit to prevent filter media from entering downstream equipment in the event of underdrain failure. Maximum pressure drop through the trap shall not exceed 35 kPa when the Unit is operating at maximum design flow rate.

6.2.4.1.11 Characteristics of potable water filters shall be as per Table 7.

TABLE 7 - CHARACTERISTICS OF POTABLE WATER FILTERS

FILTER TYPE	PERMISSIBLE FILTRATION RATES m³/m².h		DESIGN PRETREATMENT TO REDUCE TURBIDITY IN APPLIED WATER TO: mg/kg		HEAD REQUIRED m		LENGTH OF FILTER RUN h		min. THICKNESS mm	
	max. Day	max. Rate	Avg.	max.	Clean Filter	max.	Avg.	min.	Gravel	Sand
Rapid-Sand Gravity	4.9	12.2	2	5	0.3	2.4	36	5	304.8	508
Pressure	4.9	12.2	2	5	0.3	7.6	48	5	304.8	609.6
Slow-Sand	2.4	7.3	1	3	0.6	1.2	1000	250	304.8	1066.8
Diatomite	2.4	7.3	1	3	2.1	21.3	6	0.5	—	—

6.2.4.1.12 Anthracite or marble should be used instead of quartz sand, when any trace of silica must be avoided in industrial process or when they are easier to obtain.

6.2.4.1.13 Other design consideration should be in accordance with IPS-E-PR-895, "Process Design of Solid-Liquid Separators" as referred to in Section 2 herein.

6.2.4.2 Quantities of suspended solids which can be removed by BED filteration

The following consideration should be made as a guiding principle:

a) The suspended solids lodge between the grains of the filter material.

Since sufficient space should always be left for the water to percolate, the sludge should not, on average, fill more than one quarter of the total volume of voids in the material.

b) Irrespective of grain size, one cubic meter of filtering material contains about 0.45 cubic meters of voids, the volume available for the retention of particles is about 0.11 cubic meters, provided that the effective grain size of the filtering medium is suitable to the nature of the particles.

c) When the suspended solids are based on colloidal floc, their dry matter content does not exceed 10 kg/m³; the quantity that can be removed per m³ of filter material is therefore no more than $0.11 \times 10 = 1.1$ kg.

6.2.5 Equipment used for boiler feed water treatment

6.2.5.1 Hot process treater

6.2.5.1.1 Design criteria

6.2.5.1.1.1 Vessel shall be of sludge blanket type employing a central downcomer. Separate (not integral) deaerator compartment is preferred.

6.2.5.1.1.2 The treater should be so sized that the rising rate of settled water is such that effluent treated water has a turbidity of less than 10 mg/kg.

6.2.5.1.1.3 Separate clean and dirty backwash compartments shall be sized to meet normal filter backwash and sodium zeolite regeneration requirements without increasing flow rate through the Unit to more than 10% of normal design.

6.2.5.1.1.4 The clean backwash water compartment should be replenished by filtered water at a much slower rate than the backwash rate.

6.2.5.1.1.5 The dirty backwash water should be returned at a set rate so that heat and water are recovered.

6.2.5.1.1.6 Treaters shall be insulated.

6.2.5.1.1.7 The treatment should be carried out at low pressure corresponding to vapor pressure for temperatures chosen between 102 and 115°C as required.

6.2.5.1.1.8 Units shall be designed for continuous service and uninterrupted operation for a period of 2 years.

6.2.5.1.1.9 All equipment shall be suitable for unsheltered outdoor installation for the climatic zone specified.

6.2.5.1.1.10 The total detention time of the vessel shall not be less than 90 minutes at rated capacity of flow.

6.2.5.1.1.11 The maximum allowable upflow rate (rinse rate) through the Unit shall be 3.7 m³/m².h at water temperatures above 90°C. This rate shall not be exceeded when backwashing filters rinsing softeners. This rate shall be reduced to 1.0 m³/m².h or less for waters containing appreciable organic matter turbidity or magnesium to meet guaranteed effluent turbidity of less than 10 nephelometric* units for a range of 10% to 100% of design raw water throughput.

* An instrument for determining the concentration of particle size of suspensions by means of transmitted or reflected light.

6.2.5.1.1.12 Chemical mix tanks and pumps should be provided for hot-process treater.

6.2.5.1.1.13 Incoming water should be provided at pressure sufficient to overcome the following losses:

1) pipe friction;
2) static head to the top of the softener;
3) vent condenser;
4) spray nozzle;
5) water flowmeter;
6) water level control valve; and
7) vessel operating pressure (exhaust steam pressure).

6.2.5.2 Ion exchange

6.2.5.2.1 Classification of ion exchange resins

Ion exchange resins are classified according to their specific application as per Table 8 (see DIN 19633).

TABLE 8 - CLASSIFICATION OF ION EXCHANGE RESINS

TYPE	Application ♣	Ionic Form in the Ready-to-Use Condition	Regenerating Agent. Aqueous Solution of
Cation exchange resins Strongly acidic	a)	Na	NaCl
	c)	H	HCl, H_2SO_4
Weakly acidic	b)	H	HCl, H_2SO_4, CO_2
	e)	H, Na	HCl, H_2SO_4, NaOH
Anion exchange resins Strongly basic	c)	OH	NaOH
	d)	Cl, HCO_3	NaCl, $NaHCO_3$
	f)*	Cl, OH	NaCl, NaOH
Weakly basic	c)	Free base	NaOH
	e)	Free base	NaOH
	f)*	Free base	NaOH

*) Macroporous types shall be used for this purpose.

♣)
    a) reduction of calcium ion concentration;
    b) reduction of hydrogencarbonate concentration;
    c) reduction of salt content;
    d) reduction of the content of certain ions, e.g., nitrate ions, sulfate ions;
    e) reduction of heavy metal ion content;
    f) reduction of the organic substance content, e.g., humic acids.

6.2.5.2.2 Design criteria

6.2.5.2.2.1 Design criteria for an ion exchange system should be based upon:

1) the required flow rate;
2) influent water quality,
3) desired effluent water quality;
4) exchange capacity and hydraulic characteristics of the exchanger;
5) period between regenerations;
6) type of operation-manual or automatic; and
7) flexibility required, that is the number of softener Units.

6.2.5.2.2.2 The ion exchangers are not economically suitable for demineralizing waters containing more than 1,000 - 2000 mg/kg of dissolved solids, except in a few specialized industrial applications (see AWWA).

6.2.5.2.2.3 The process of ion exchange for softening waters is preferable to precipitation process when one or more of the following conditions exist:

a) less than 100 mg/kg of hardness expressed as calcium carbonate is present in the water;
b) an extremely low dissolved solids content is required;
c) only a limited volume of treated water is required.

6.2.5.2.2.4 Relative exchange capacity of cation exchangers and regenerative salt dosage would be as per Table 9.

TABLE 9 - RELATIVE EXCHANGE CAPACITY OF CATION EXCHANGERS*

CATION EXCHANGER	NOMINAL EXCHANGE CAPACITY	REGENERATIVE SALT DOSAGE	
	g/L	Volumetric kg/m³	Effective kg/kg Hardness Removed
Greensand	6.4	20.2	3.1
Processed greensand	12.6	39.5	3.1
Synthetic siliceous			
Zeolite	25.2	79.2	3.1
Resin, polystyrene	73.2	201.7	3.1
Resin, polystyrene	50.3	80.0	1.7

* See AWWA.

6.2.5.2.2.5 The anion exchangers have typically an exchange capacity calculated as $CaCO_3$ of 27.4-57.2 g/L at a sodium dosage of 1.05-7 kg/kg removed (see AWWA).

6.2.5.2.2.6 For plant design of demineralized waters one procedure from Water Treatment Handbook, by Degremont (see Clause 2) has been illustrated typically in Appendix E.

6.2.5.2.2.7 Interstage degasification in demineralization systems should be considered at flow over 22.7 m³/h and alkalinity over 100 mg/kg.

6.2.5.2.2.8 When Ultra-pure water is required, using the mixed bed demineralizer is recommended.

6.2.5.2.2.9 The specification of demineralized Unit shall be as per Appendix F.

6.2.5.2.2.10 Typical flows and dimensions of ion exchangers is shown in Table G.1 in Appendix G.

6.2.5.2.2.11 The demineralized water storage(s) shall be designed in order to store the produced demineralized water and to cover the following users:

a) Make-up to deaerators.
b) Process Units.
c) Regeneration of condensate treatment.

6.2.6 Miscellaneous processes

6.2.6.1 Evaporation

6.2.6.1.1 Vapor compression and multi-stage flash evaporators may be recommended for producing high purity water from brackish and sea waters.

6.2.6.1.2 The process design of evaporators should be in accordance with IPS-E-PR-771, "Process Requirements of Heat Exchanging Equipment".

6.2.6.1.3 The process design of compressors should be in accordance with IPS-E-PR-750, "Process Design of Compressors".

6.2.6.1.4 The Vendor(s) Standard Specifications for required evaporation system may be considered upon the Company's approval.

6.2.6.2 Reverse osmosis

6.2.6.2.1 The applied pressure for brackish water purification is typically in the range of 2760 - 4140 kPa (ga) [27.6 - 41.4 bar (ga)] and for sea water purification, in the range of 5520 - 6900 kPa (ga) [55.2 - 69.0 bar (ga)].

6.2.6.2.2 Recovery of product (desalted) water with reverse osmosis Units ranges from 50 to 90% of the feedwater depending upon the feedwater composition, the product water quality requirement, and the number of stages utilized.

6.2.6.2.3 For water containing from about 250 to 1500 mg/kg dissolved solids, an economic comparison of ion exchange and reverse osmosis is recommended to select the more cost effective process.

6.2.6.2.4 Reverse osmosis may be considered for desalination of sea water.

6.2.6.2.5 In many cases, the reverse osmosis product water shall be treated by one of the ion exchanger processes, if high quality feedwater is required.

6.2.6.2.6 A pretreatment system shall be provided to avoid fouling or excessive degradation of the membrane. Typically pretreatment will include filteration to remove suspended particles and addition of chemicals to prevent scaling and biological growth.

6.2.6.2.7 Heating feed water to provide optimum operating temperature of 25°C for reverse osmosis system, shall be considered.

6.2.6.2.8 Process design of reverse osmosis system shall be based on feedwater and product water qualities and rates.

6.2.6.2.9 Different types of reverse osmosis modules layouts e.g., parallel, series including reject staging and product staging shall be proposed by Vendor(s) and the final configuration will be selected upon Company's approval.

6.2.6.3 Electrodialysis

6.2.6.3.1 Recovery of product (deionized) water with electrodialysis Units ranges from 50 to 90% of the feedwater depending upon the number of stages and degree of recirculation utilized.

6.2.6.3.2 Operating cost consist mainly of power costs (typically 1.6-2.7 kWh/m³ of product water) and membrane cleaning and replacement costs.

6.2.6.3.3 Based upon combined capital and operating costs, the electrodialysis process is most economical when used to desalt brackish water (1,000 to 5,000 mg/kg dissolved solids) to a product water concentration of about 500 mg/kg dissolved solids.

6.2.6.3.4 Process design of electrodialysis Unit shall be based on feedwater and product water qualities and rates.

7. RAW WATER AND PLANT WATER SYSTEMS

7.1 Design-General

7.1.1 Surface water intake

7.1.1.1 The entrance of large objects into the intake pipe should be prevented by use of a coarse screen or by obstructions offered by small opening in the cribwork or riprap placed around the intake pipe.

7.1.1.1.1 Fine screens for the exclusion of small fish and other small objects should be placed at an accessible point, as at the suction or wet well at the pumping station where the screens can be easily inspected and cleaned.

7.1.1.1.2 The area of the openings in the intake crib should be sufficient to prevent an entrance velocity greater than about 0.15 m/s, in order to avoid carrying settleable matter into the intake pipe.

7.1.1.1.3 Intake ports may be placed at various elevations so that water of the best quality may be taken. They should also be placed so that if one or more of the ports is blocked another can be opened.

7.1.1.1.4 Submerged ports should be designed and controlled to prevent air from entering the suction pipe. The difficulty can be minimized by maintaining an entrance velocity not greater than 0.15 m/s, preferably much less than this and maintaining a depth of water over the port of at least three diameters of the port opening.

7.1.1.1.5 The capacity of the intake should be sufficient for future demands during the life of the structure.

7.1.1.1.6 Grids with parallel bars, preferably removable, may be placed over intake ports with openings between bars not less than 25 to 50 mm.

7.1.1.1.7 The grids have sometimes been electrically charged to keep fish away.

7.1.1.1.8 Self-cleaning screens of moving-belt type over intake ports are in successful use.

7.1.1.1.9 Vigorous reversal of flow through the intake port and screen or grid is sometimes created as an expedient for cleaning. Provision should be made for such reversal in the design of the intake structure and conduit.

7.1.1.2 Intake conduit and intake well

7.1.1.2.1 The conduit conveying water from the intake should lead to a suction well in or near the pumping station.

7.1.1.2.2 Either a pipe, lying on or buried in the bottom of the body of water, or deep tunnels may be used as intake conduits.

7.1.1.2.3 The capacity of the conduit and the depth of the suction well should be such that the intake ports to the pumps will not draw air.

7.1.1.2.4 A velocity of 0.6 to 0.9 m/s in the intake conduit, with a lower velocity through the ports, will give satisfactory performance.

7.1.1.2.5 The horizontal cross-sectional area of the suction well should be three to five times the vertical cross-sectional area of the intake conduit.

7.1.1.2.6 Pumps should be started gradually to avoid drawdown in the suction well, and they should be stopped gradually to prevent surge.

7.1.1.2.7 The intake well acts as a surge tank on the intake conduit, thus minimizing surge.

7.1.1.2.8 The intake conduit should be laid on a continuously rising or falling grade to avoid accumulation of air or gas, pockets of which would otherwise restrict the capacity of the conduit.

7.1.1.2.9 Where air traps are unavoidable, provision should be made to allow gas to be drawn off from them. Where pipes are used, they should be weighted down to avoid flotation.

7.1.1.2.10 It is recommended that the intake works be in duplicate because of the almost complete dependence of the waterworks on its intake, the intake conduit, and the suction pit. Two or more widely separated intakes are highly desirable.

7.1.1.3 Aqueducts

7.1.1.3.1 An aqueduct is a conduit designed to convey water from a source to a point, usually a reservoir, where distribution begins.

7.1.1.3.2 An aqueduct may include canals, flumes, pipe lines, siphons, tunnels, or other channels, either open or covered, flowing at atmospheric pressure or otherwise.

7.1.1.3.3 The choice between available types of conduits in an aqueduct depends on topography, available head, quality of water and possibly other conditions.

7.1.1.3.4 Water in aqueducts should be protected against pollution by infilteration of non-potable ground water, the overflow into the aqueduct of polluted surface waters, and all other possible sources of pollution to which water flowing low or atmospheric pressure may be exposed.

7.1.2 Ground water intake*

7.1.2.1 It is important to keep water entrance velocity through the screen openings between 0.03 and 0.06 m/s. Such velocities will minimize head losses and chemical precipitation or encrustation.

7.1.2.2 Care should be taken in estimating the effective screen area. It is not uncommon to allow for as much as 50 percent plugging of the screen slots by formation particles.

7.1.2.3 The total open area required should be obtained by adjusting either the length or diameter of the screen because the slot is not arbitrary.

7.1.2.4 It is sometimes advisable to construct an artificial gravel-pack well to permit an increase in screen slot size. when a well screen is surrounded by an artificial gravel wall, the size of the openings is controlled by the size of gravel used and by the type of openings.

7.1.2.5 Actual screen design should not be final until samples of the aquifer front the actual well location, are available for proper sieve analysis. However, experience and samples from test wells in the area permit preliminary calculations of the openings.

7.1.2.6 The actual open area per meters of screen depends upon the type of construction and the manufacturer.

7.1.3 Water treatment of intake water

7.1.3.1 For intake water from surface water or ground water the preliminary water treatment should be considered as per 6.1.4.

7.1.3.2 For intake water from sea water, the water treatment should be done as per 6.2.6.1.

* **American Water Works Association, Manual M21. P-37.**

7.1.4 Pumping stations

7.1.4.1 Location

7.1.4.1.1 Conditions to be considered in the location of water-works pumping station include:

a) sanitary protection of the quality of water;
b) the hydraulics of the distribution system;
c) possibilities of interruption by fire, flood or other disaster;
d) availability of power or of fuel;
e) growth and future expansion.

7.1.4.1.2 Floods offer a hazard which may be minimized by favorable location and site protection.

7.1.4.1.3 To obtain the greatest hydraulic advantage, the station should be located near the middle of the distribution system.

7.1.4.1.4 The danger of interruption of service by fire should be considered and the station should be protected by fire walls, fireproofing and a sprinkler system.

7.1.4.1.5 Pumping stations may sometimes be located underground when conditions are favorable.

7.1.4.1.6 Underground locations require care to avoid flooding and dampness.

7.1.4.1.7 Attention should be given to accessibility illumination, ventilation, and heating and providing adequate space for operation and maintenance.

7.1.4.2 Choice of power

7.1.4.2.1 The type of primary or of auxiliary power selected should be the most reliable, the most available and the least expensive. If all three conditions cannot be fulfilled they should be rated in the order stated, with the greatest reliability as the most important.

7.1.4.2.2 Auxiliary sources of power include internal-combustion engines, gas turbines, steam engines, or a secondary source of electric energy.

7.1.4.3 Standby equipment

7.1.4.3.1 Standby pumping equipment should be provided in pumping stations.

7.1.4.3.2 One or more horizontal-shaft centrifugal pumps may be equipped with an electric motor on the pump axis on one side of the pump and an internal combustion engine on the other side; or two electric motors, driven from different circuits, may be placed on the same shaft.

7.1.4.4 Compressed air

7.1.4.4.1 Use of compressed air in pumping stations should be considered as an auxiliary power for starting engines, blowing boiler tubes, operating control systems, pumping wells and for other purposes.

7.1.4.4.2 The process design of compressed air system should be as per IPS-E-PR-330, "Process Design of Production and Distribution of Compressed Air Systems".

7.1.4.5 Power rating of pumping station

7.1.4.5.1 There should be sufficient power in a waterworks pumping station to supply the peak demand without dangerously overloading the power equipment.

7.1.4.5.2 The highest efficiency and the greatest economy of operation require that the total load on all the units in the pumping station should be divided among them in such a manner that each can operate at its rated capacity.

7.1.4.6 Piping in the pumping station

7.1.4.6.1 The layout of the piping in a pumping station may be as important as the efficiency of operation in affecting economy. Short, straight, well-supported pipe lines, devoid of traps for sediment or for vapor, sloping in one direction to drains and with adequate cleanouts, should be the object of the designer.

7.1.4.6.2 A few details to be observed in making connections to centrifugal pumps are:

a) the elbows on the suction side of a double suction pump should be normal to the suction nozzle, or a special elbow with guide vane followed by a piece of straight pipe to the suction nozzle should be used, to equalize the flow on each side of the impeller;

b) on the pump discharge, where change of direction is necessary, a constant-diameter bend should be used, followed by a long, straight reducer or increaser. Such an installation will most effectively interchange velocity and pressure heads;

c) eccentric reducers with the top of the pipe and the top of the reducer at the same level should be used in horizontal suction piping to avoid the creation of an air pocket;

d) an increaser whose length is ten times the difference in diameters may be considered "long".

7.1.5 Pipeline

The process design of pipeline should be as per IPS-E-PR-440 "Process Design of Piping Systems (Process Piping & Pipeline Sizing), Part II, "Design of Transmission Pipelines for 1-Liquid and 2-Gas".

7.1.6 Water storage tanks

The process design of water storage tanks should be as per IPS-E-PR-360 "Process Design of Liquid & Gas Transfer & Storage".

7.1.7 Refinery and/or plant, plant water

7.1.7.1 Raw water pumped from outside the refinery after treatment (see 6.1.4, 6.2.1, 6.2.2, 6.2.3 and 6.2.4) for surface water, or usually without any treatment for ground water would be stored as clarified water in storage tanks.

7.1.7.2 Raw water pumped from sea intake after treatment in desalination plant (see 6.2.6.1) would be stored as desalinated water in storage tanks.

7.1.7.3 Clarified (or desalinated) water stored in the clarified (or desalinated) water tanks is pumped to the plant water header for refinery and/or plant use, make-up water for the cooling tower, make-up water for the boiler feedwater treatment plant, feed to the potable water sand filters, and make-up for fire water tanks.

7.1.7.4 Sea water after desalination shall be considered as make-up for fire water, machinery cooling water and demineralization plant.

7.1.7.5 Sea water shall be considered in emergency as alternate source for fire water.

7.1.7.6 After branching from main header of plant water for fire water tanks and potable water system, one back-flow preventer should be installed on the header to insure against back-flow of possibly contaminated water from process Units into lines used for drinking and sanitary services.

7.1.7.7 Potable water system

7.1.7.7.1 Potable water is clarified water that has been filtered in sand filters and chlorinated.

7.1.7.7.2 Two potable water system should be provided one for refinery and or plant use and the other for the employee housing with identical flow scheme, if required.

7.1.7.7.3 The scheme of each system with different capacities should consist of: sand filteration, chlorination and storage tanks.

7.1.7.7.4 A cross connection should be provided to furnish water in an emergency from the discharge of refinery and/or plant potable water pumps to the housing potable water tanks.

7.1.7.7.5 Each system should have a separate chlorination system.

7.1.7.7.6 Piping design consideration should be as per Standard IPS-E-PR-440, "Process Design of Piping Systems (Process Piping & Pipeline Sizing), Part I "Process Pipe Sizing for Plant Located Onshore".

7.1.7.7.7 Design of chlorination system should be as per Appendix H, "Disinfection".

8. COOLING WATER DISTRIBUTION AND RETURN SYSTEM

For this Section reference is made to IPS-E-PR-790, "Process Design of Cooling Towers" with the following addendum:

8.1 Design-General

8.1.1 Water pumping station for once-through cooling-water system should be located at points where reliable quantities of suitable water are obtainable.

8.1.2 The choice between a once-through and recirculated cooling-water system should be based on availability of sufficient water of satisfactory quality, on process temperatures, on atmospheric conditions, and on equipment maintenance and operating costs.

8.1.3 Refinery waste waters, after effective treatment may be considered as part of make-up for recirculated cooling towers.

8.1.4 Where fresh-water supplies are limited and salt water is available, a once-through system should be selected.

8.1.5 At plants located on rivers or lakes or where abundant supplies of both salt and fresh water are present, a choice should be made between a recirculated or once-through system.

8.1.6 The choice of cooling water system should be based on comparisons of initial and operating costs.

8.2 Design Criteria

8.2.1 Stand-by pump (s) shall be provided for cooling-water recirculating pumps.

8.2.2 It is recommended to install two main recirculating pumps and one 50 percent capacity standby pump for recirculating water in cooling water system.

8.2.3 Steam ejector should be provided for each pump pit to remove water from that as it may accumulate from rain, leakage, etc.

8.2.4 The cooling water blowdown stream should be normally discharged into the non-oily water sewer system. Provision should be provided to divert this stream into the oily water sewer if oil is discharged into the cooling water return header.

8.2.5 Chemical feeders for cooling towers should be recommended as per Standard IPS-E-PR-491, "Process Requirements of Refinery Non-Licensed Units", Part IV, "Chemical Injection Systems".

8.2.6 Corrosion probe connections shall be provided at each recirculating pump suction and in the cooling water return header to the cooling tower.

8.2.7 Flow meters should be considered to measure the flowrates of supply and return headers.

8.2.8 Where the supply of fresh water is limited, a warm line softener or other treating systems may be provided to reduce cooling water make-up and blowdown by recovering a portion of the boiler plant blowdown and treating it in conjunction with slipstream taken from the cooling water return to the cooling tower.

8.2.9 The surge tank shall be provided upstream of the cooling water warm line softener.

8.2.10 Effluent from cooling-water warm line softener shall be pumped to the pressure filters for final treatment after a pH adjustment using acid.

8.2.11 For design criteria of warm line softener reference is made to 6.2.5.1.

8.2.12 In case sea water is used, the minimum pressure of the machinery cooling-water at the outlet of the machinery cooling water/sea cooling water cooler shall be higher than the normal pressure of the sea cooling-water circuit.

APPENDICES

APPENDIX A
WATER ANALYSIS

a) Water analysis are conventionally expressed, for both cations and anions in mg/kg except for hardness and alkalinity which are usually expressed in mg/L (mg/kg) of calcium carbonate ($CaCO_3$).

b) These mg/kg values can be converted to a common basis (such as milli-equivalents/liter) by dividing by the equivalent mass of the ion and multiplying by the relative density (specific gravity) of the water solution. This permits the summation of oppositely-charged ions such that total cations will then equal total anions.

c) Cation and anion concentrations in milli-equivalents/liter can be converted to mg/L (mg/kg) $CaCO_3$ by multiplying by the equivalent mass of $CaCO_3$ ($100.08/2 = 50.04$) and dividing by the mass density of the water solution.

Example A.1: Water analysis calculation

Water Analysis Ion		mg/kg	M*	Equivalent Mass
Calcium	(Ca^{+2})	100.1	40.08	$\frac{40.08}{2} = 20.04$
Magnesium	(Mg^{+2})	20.4	24.32	$\frac{24.32}{2} = 12.16$
Sodium	(Na^{+1})	12.0	23.0	$\frac{23.0}{1} = 23$
Bicarbonate	(HCO_3^{-1})	366.0	61.02	$\frac{61.02}{1} = 61.02$
Sulfate	(SO_4^{-2})	48.1	96.06	$\frac{96.06}{2} = 48.03$
Chloride	(Cl^{-1})	7.1	35.46	$\frac{35.46}{1} = 35.46$

* Relative molecular mass in kg/kmol or g/mol.

CATIONS

ION	milli-equivalents/liter (relative density = 1)		mg/L (mg/kg) $CaCO_3$	
Ca^{+2}	100.1/20.04	= 5.00	(5.0)(5.04)	= 250
Mg^{+2}	20.4/12.16	= 1.68	(1.68)(50.04)	= 84
Na^{+1}	12.0/23	= 0.52	(0.52)(50.04)	= 26
HCO_3^{-1}	—		—	
SO_4^{-2}	—		—	
Cl^{-1}	—		—	
Totals	7.20		360	

(to be continued)

APPENDIX A (continued)

ANIONS

ION	milli-equivalents/liter (relative density = 1)		mg/L (mg/kg) CaCO$_3$	
Ca^{+2}	—		—	
Mg^{+2}	—		—	
Na^{+1}	—		—	
HCO$_3^{-1}$	366/61.02	= 6.00	(6)(50.04)	= 300
SO$_4^{-2}$	48.1/48.03	= 1.00	(1)(50.04)	= 50
Cl^{-1}	7.1/35.46	= 0.20	(0.2)(50.04)	= 10
Totals	7.20		360	

Total hardness is the sum of calcium and magnesium and is therefore equal to 334 mg/L (mg/kg) as CaCO$_3$ (250+84). Correspondingly, alkalinity is the sum of CO$_3^{-2}$, HCO$_3^{-1}$ and OH^{-1} ions and is equal to 300 mg/L (mg/kg) as CaCO$_3$.

APPENDIX B

TYPICAL RAW WATER SPECIFICATIONS

TABLE B.1 - RAW WATER SPECIFICATION OF ARAK REFINERY

Source		Ground (Well) Water (mg/kg) mg/L	mg/L (mg/kg)
pH		8.1	"
Total Hardness,	as CaCO$_3$	181	"
Calcium,	as CaCO$_3$	123	"
Magnesium,	as CaCO$_3$	58	"
Total Alkalinity,	as CaCO$_3$	165.6	"
Sodium,	as CaCO$_3$	55	"
Sulfate,	as CaCO$_3$	43	"
Potassium,	as CaCO$_3$	3	"
Chloride,	as CaCO$_3$	25.4	"
Nitrate,	as CaCO$_3$	5	"
Silica,	as SiO$_2$	16	"
Total Iron		Trace	
Suspended Solids		5	"
Dissolved Solids		356.7	"
Chemical Oxygen Demand (COD)		1	"

TABLE B.2 - RAW WATER SPECIFICATION OF ESFAHAN REFINERY

Source Constituent	Surface (River) Water * mg/L (mg/kg) as CaCO$_3$
Calcium	146
Magnesium	45
Sodium	73
Total Cations	264
Bicarbonate	146
Chloride	50
Sulfate	68
Nitrate	Traces
Total Anions	264
Total Suspended Solids (as ions)	0 - 10
Iron as Fe	Traces
Silica as SiO$_2$	8.0
Temperature range	15.6°C - 37.8°C (60°F - 100°F)
pH	7.9

* Zayandeh Rud.

(to be continued)

APPENDIX B (continued)

TABLE B.3 - RAW WATER CHARACTERISTICS OF BANDAR ABBAS REFINERY

Source		Sea Water	
pH at 35°C		8.3	
Sulphate,	as CaCO$_3$	3650	mg/L (mg/kg)
Chloride,	as CaCO$_3$	25140	"
Calcium,	as CaCO$_3$	550	"
Magnesium,	as CaCO$_3$	1750	"
Bicarbonate,	as CaCO$_3$	175	"
Nitrate,	as CaCO$_3$	0.9	"
Nitrite,	as CaCO$_3$	0.01	"
Silica	as SiO$_2$	2.7	"
Dissolved solids		47000	"
Relative density (sp gr) @ 20°C		1.032	
Temperature Range		20°C - 35°C	

APPENDIX C
POTABLE WATER STANDARD SPECIFICATION

C.1 Bacteriologic Requirements

As an operating goal, the American Water Works Association (AWWA) committee recommends no coliform organisms on the basis that the water supplies of utilities with high standards of operation have shown a fraction of one coliform organism per liter over periods of many years.

The goal is considered practical in view of modern disinfection procedures and desirable for improved health conditions.

C.2 Physical Characteristics

Table C.1 compares the levels for turbidity, color, taste and odor as expressed in Public Health Service Drinking Water Standards (USPHS) and the report of AWWA Committee 2640 P.

TABLE C.1 - COMPARISON OF PHYSICAL CHARACTERISTICS OF WATER

CHARACTERISTIC	RECOMMENDED LIMITS*	AWWA GOALS ♣
Turbidity-Units	5	< 0.1
Color-Units	15	< 3
Odor (Threshold Odor Number)	3	No Odor
Taste		None Objectionable

* Limits that should not be exceeded according to latest USPHS Drinking Water Standards.

♣ The figures in this column are taken from AWWA committee report.

- The committee report presents those levels that should be approached by well designed and operated systems and which reflect a high degree of consumer acceptability.

C.3 Chemical Characteristics

Table C.2 gives the maximum concentration of various chemical substances allowed by the USPHS Standards and recommended by the AWWA report, and the recommended lower, optimum, and upper control limit for flouride concentrations, are shown in Table C.3.

- The AWWA Committee report establishes a hardness of 80 mg/L (as $CaCO_3$) as the desirable objective for potable water supplies. Although this is not of concern to utilities with sources of supply that are naturally quite soft, it is significant to utilities in hard water areas because softening must be provided to achieve this goal.

- A number of limits expressed in Table C.2 are based on aesthetic rather than health considerations. For example, the limits for iron and manganese are based on the staining and other objectional properties of these elements.

- Limits for the concentration of sodium have not been set by the Standards or Committee report.

(to be continued)

APPENDIX C (continued)

TABLE C.2 - COMPARISON OF CHEMICAL CHARACTERISTICS

SUBSTANCE		USPHS DRINKING WATER STANDARDS		AWWA COMMITTEE
		Concentration that should not be exceeded mg/L	Concentration which, if exceeded, constitutes grounds for rejection of supply mg/L	Goal mg/L
Alkyl Benzene Sulfonate	(ABS)	0.5		
Aluminium	(Al)			< 0.05
Arsenic	(As)	0.01	0.05	
Barium	(Ba)		1.0	
Chloride	(Cl)	250		
Cadmium	(Cd)		0.01	
Chromium	(Cr^{+6})		0.05	
Copper	(Cu)	1		< 0.20
Carbon Chloroform Extract	(CCE)	0.2		< 0.04
Cyanide	(CN)	0.01	0.2	
Iron	(Fe)	0.3		< 0.05
Lead	(Pb)		0.05	
Manganes	(Mn)	0.05		< 0.01
Nitrate	(NO_3)	45		
Phenols		0.001		
Selenium	(Se)		0.01	
Silver	(Ag)		0.05	
Sulfate	(SO_4)	250		
Total Dissolved Solids		500		200
Zinc	(Zn)	5		< 1.0

- Fluoride is considered as an essential constituent of drinking water for prevention of tooth decay in children. Conversely, excess fluoride may give rise to dental fluorosis (spotting of the teeth) in children. In the Drinking Water Standards is also recommended that fluoride in average concentrations greater than twice the optimum values shall constitute grounds for rejection of the supply (see Table C.3).

(to be continued)

APPENDIX C (continued)

TABLE C.3 - ALLOWABLE FLUORIDE CONCENTRATION

ANNUALL AVG OF MAX DAILY AIR TEMPERATURE ♣°C	RECOMMENDED CONTROL LIMITS, FLUORIDE CONCENTRATIONS, mg/L *			MAXIMUM CONTAMINANT LEVEL (MCL)
	Lower	Optimum	Upper	
12 or Lower	0.9	1.2	1.7	2.4
12.1 - 14.6	0.8	1.1	1.5	2.2
14.6 - 17.7	0.8	1.0	1.3	2.0
17.7 - 21.4	0.7	0.9	1.2	1.8
21.5 - 26.2	0.7	0.8	1.0	1.6
26.3 - 32.5	0.6	0.7	0.8	1.4

* From "Drinking Water Standards", U.S. Public Health Service, No. 956, 1962.

♣ Based on temperature data obtained for a minimum of 5 years.

C.4 Radioactivity

- In establishing reasonable, long-term limits for radioactivity in potable water, the population's total exposure to radiation must be considered. This requires the assessment of the intake from such sources as food and milk, as well as from potable water, together with an evaluation of the effects of specific radioactive substances.

- The USPHS standards specify that water supplies other sources of radioactivity intake of radium-226 and strontium-90 when the water contains these substances in amounts not exceeding 3 pico curie (pCi) per liter and 10 pCi (10×10^{-12} Ci) per liter respectively.

- In the known absence of strontium-90 and alpha emitters, the water supply is acceptable when the known concentration do not exceed, 1,000 pCi per liter.

- A through considerable knowledge has been acquired on the treatment of water to remove radioactive substances, it is desirable to maintain the levels of radioactivity in raw water well below the established limits.

APPENDIX D
COMMON DEPOSITS FORMED IN WATER SYSTEMS

Name	Chemical Composition	Deposit Formation Conditions			
		$T < 100°C$	$T > 100°C$	$T > 100°C$	Water
		With or Without Evaporation	No Evaporation	Evaporation	Vapor or Steam
Acmite	$Na_2O.Fe_2O_3.4SiO_2$			×	
Analctive	$Na_2O.Al_2O_3.4SiO_2.2H_2O$			×	×
Anhydrite	$CaSO_4$		×	×	
Aragonite	$CaCO_3$	×	×	×	
Biological					
(a) Nonspore bacteria		×			
(b) Spore bacteria		×			
(c) Fungi		×			
(d) Algae and diatoms		×			
(e) Crustaceans		×			
Brucite	$Mg(OH)_2$		×	×	
Burkeite	$Na_2CO_3.2Na_2SO_4$				×
Calcite	$CaCO_3$	×	×	×	
Calcium hydroxide	$Ca(OH)_2$			×	
Carbonaceous		×	×	×	×
Copper	Cu			×	
Cuprite	Cu_2O		×		
Ferrous oxide	FeO		×		
Goethite	$Fe_2O_3.H_2O$	×	×	×	
Gypsum	$CaSO_4.2H_2O$	×	×	×	
Halite	$NaCl$				×
Hematite	Fe_2O_3			×	
Hydroxylapatire	$Ca_{10}(PO_4)_6(OH)_2$	×	×	×	
Magnesium Phosphate(basic)	$Mg_3(PO_4)_2.Mg(OH)_2$		×	×	
Magnetite	Fe_3O_4		×	×	×
Oil (chloroform extractable)		×	×	×	×
Quartz	SiO_2				×
Serpentine	$3MgO.2SiO_2.2H_2O$		×	×	
Siderite	$FeCO_3$				×
Silica (amorphous)	SiO_2				×
Sodium carbonate	Na_2CO_3				×
Sodium disilicate	$Na_2Si_2O_6$				×
Sodium ferrous phosphate	$NaFePO_4$			×	
Sodium silicate	Na_2SiO_3				×
Tenorite	CuO			×	
Thenardite	Na_2SO_4			×	×
Xonotlite	$5CaO.5SiO_2.H_2O$			×	

Note:

Symbol "×" means the formation of deposits in the relevant conditions.

APPENDIX E
TYPICAL PLANT DESIGN OF DEMINERALIZED WATER*

Based on following data the plant design of demineralized water should be done:

- TAC concentration of the raw water in French degrees;

- SAF concentration of the raw water in French degrees ($SO_4^{-2} + Cl^{-1} + NO_3^{-1}$);

- Silica content as T SiO_2 (1 French degree = 12 mg/L SiO_2 based on Table E.1);

- T CO_2: Content of carbon dioxide (carbonic acid) in the water after passing through the cation exchanger and where appropriate after elimination of carbon dioxide (carbonic acid), in French degrees;

- Volume V of water to be supplied between regeneration processes, in m³, including service water if appropriate;

- Exchange capacity C of the resins expressed in French degrees/liter per liter of consolidated resins.

The anion exchanger is calculated first: the volume in m3 to be used is given by one of the following equations:

$$V_a = \frac{V \times SAF}{C} \qquad \text{(for a weakly-basic exchanger)} \qquad \text{(Eq. E.1)}$$

or,

$$V_a = \frac{V \times (SAF + TCO_2 + TSiO_2)}{C} \qquad \text{(for a strongly-basic exchanger)} \qquad \text{(Eq. E.2)}$$

Then the volume in m³ of cation exchanger is calculated, allowing for the additional water α. V_a necessary to rinse the anion exchanger, where (may vary from 5 to 20 depending on the type of resin.

$$V_c = \frac{(V + \alpha. V_a). (SAF + TAC)}{C} \qquad \text{(Eq. E.3)}$$

The volumes calculated shall then be compared with the hourly output to be treated. There are upper limits to the flow rate or to the bed volume.

If V_c or V_a are too low, they should be adjusted, possibly by increasing the cycle volume V.

* This calculation method is based on Water Treatment Handbook, By Degremont (PP-324) , 1979 (See References 2).

(to be continued)

APPENDIX E (continued)

TABLE E. 1 - TABLE SHOWING THE CONCENTRATION OF SOLUTION

(VALUES OF THE DIFFERENT DEGREES)

	FORMULA	MOLE-CULAR MASS	VALUE IN mg/L OF THE VARIOUS UNITS			
			Meq/L	Fr.°	Germ.°	Eng.°
1. Calcium and magnesium salts and oxides causing hardness in water (degree of hardness)						
Clacium carbonate	$CaCO_3$	100	50	10.0	17.8	14.3
Calcium bicarbonate	$Ca(HCO_3)_2$	162	81	16.2	28.9	23.1
Calcium sulphate	$CaSO_4$	136	68	13.6	24.3	19.4
Calcium chloride	$CaCl_2$	111	55.5	11.1	19.8	15.8
Calcium nitrate	$Ca(NO_4)_2$	164	82	16.4	29.3	23.4
Quicklime	CaO	56	28	5.6	10.0	8.0
Hydrated lime	$Ca(OH)_2$	74	37	7.4	13.2	10.5
Magnesium carbonate	$MgCO_3$	84	42	8.4	15.0	12.0
Magnesium bicarbonate	$Mg(HCO_3)_2$	146	73	14.6	26.1	20.9
Magnesium sulphate	$MgSO_4$	120	60	12.0	21.4	17.1
Magnesium chloride	$MgCl_2$	95	47.5	9.5	17.0	13.5
Magnesium nitrate	$Mg(NO_3)_2$	148	74	14.8	26.4	21.2
Magnesia	MgO	40	20	4.0	7.1	5.7
	$Mg(OH)_2$	58	29	5.8	10.3	8.2
2. Anions						
Carbonate ion	CO_3	60	30	6.0	10.7	8.6
Bicarbonate ion	HCO_3	61	61	12.2	21.8	17.4
Sulphate ion	SO_4	96	48	9.6	17.3	13.7
Sulphite ion	SO_3	80	40	8.0	14.3	11.4
Chloride ion	Cl	35.5	35.5	7.1	12.7	10.2
Nitrate ion	NO_3	62	62	12.4	22.1	17.7
Nitrite ion	NO_2	46	46	9.7	16.4	13.1
Phosphate ion	PO_4	95	31.66	6.32	11.25	9.03
Silicate ion	SiO_2	60	60	12.0	21.4	17.1
3. Acids						
Sulphuric acid	H_2SO_4	98	49	9.8	17.5	14
Hydrochloric acid	HCl	36.5	36.5	7.3	12.8	10.3
Nitric acid	HNO_3	63	63	12.6	22.5	18
Phosphoric acid	H_3PO_4	98	32.66	6.52	11.64	9.31
4. Cations and oxides						
Clacium	Ca	40	20	4.0	7.15	5.7
Magnesium	Mg	24.3	12.1	2.43	4.35	3.47
Sodium	Na	23	23	4.6	8.2	6.6
	Na_2O	62	31	6.2	11.1	8.8
Potassium	K	39	39	7.8	13.9	11.2
	K_2O	94	47.1	9.4	16.8	13.4
Iron	Fe	55.8	27.9	5.6	10.0	8.0
Aluminium	Al	27	9	1.8	3.2	2.6
	Al_2O_2	102	17	3.4	6.1	4.85
5. Bases						
Sodium hydroxide	$NaOH$	40	40	8.0	14.3	11.4
Potassium hydroxide	KOH	56	56	11.2	20.0	16.0
Ammonia	NH_4OH	35	35	7.0	12.5	10

(to be continued)

APPENDIX E (continued)

TABLE E.1 - (continued)

6. Various salts						
Sodium bicarbonate	$NaHCO_3$	84	84	16.8	30	24
Sodium carbonate	Na_2CO_3	106	53	10.6	18.9	15.1
Sodium sulphate	Na_2SO_4	142	71	14.2	25.3	20.3
Sodium chloride	$NaCl$	58.5	58.5	11.7	20.9	16.7
Sodium phosphate	Na_3PO_4	164	54.7	10.9	19.5	15.6
Sodium silicate	Na_2SiO_3	122	61	12.2	21.8	17.4
Potassium carbonate	K_2CO_3	138	69	13.8	24.6	19.7
Potassium bicarbonate	$KHCO_3$	100	100	20	35.7	38.5
Potassium sulphate	K_2SO_4	174	87	17.4	31.1	24.8
Potassium chloride	KCl	74.5	74.5	14.9	26.6	21.2
Potassium phosphate	K_3PO_4	212.3	70.8	14.1	25.2	20.2
Ferrous sulphate	$FeSO_4$	152	76	15.2	27.1	21.7
Ferric sulphate	$Fe_2(SO_4)_3$	400	66.6	13.3	23.8	19
Ferric chloride	$FeCl_3$	162.5	54.2	10.8	19.3	15.4
Aluminium sulphate	$Al_2(SO_4)_3$	342	57	11.4	20.3	16.3

APPENDIX F
STANDARD SPECIFICATION OF DEMINERALIZING UNIT

F.1 Scope

This Standard Specification covers the general requirements for the design, construction and inspection of automatic regenerating type demineralizing Units for the production of boiler feed water.

F.2 Codes and Standards

For materials, design, fabrication and inspection of the demineralizing Units not specified in this Standard Specification, the specified code or standard in each individual case shall be applied per the latest editions.

F.3 Design

F.3.1 General

The demineralizing Unit shall consist of but not necessarily be limited to the following equipment:

- Cation resin bed for exchanging acidic hydrogen.

- Anion resin bed for exchanging basic hydroxide.

- Degasifier (decarbonator) removing carbon dioxide formed in the cation resin bed, if required.

- Mixed bed polisher containing strong cation and anion resin for exchanging acidic hydrogen and basic hydroxide respectively, if required.

- Regenerating equipment including chemical storage tanks, measuring tanks, pumps, blowers, instrumentation for control, neutralizing equipment for regeneration-effluent, interconnecting piping and others.

F.3.2 Chemical for resin regeneration

F.3.2.1 The following chemicals shall be used for the regeneration of resin:

- H_2SO_4 or HCl solution for cation exchanger.

- NaOH solution of anion exchanger.

- Skid mounted chemical storage tanks shall be provided and equipped with a chemical transfer pump for regeneration purposes.

- The capacity of each chemical storage tank shall be designed to enable maximum operation within five cycles.

F.3.2.2 Two separate chemical transfer pumps shall be provided, for each chemical. These chemical pumps shall be driven by individual motors, one for sulfuric acid transfer and the other for caustic solution transfer.

F.3.2.3 The Unit shall be designed to minimize consumption, and its guaranteed values shall be satisfied.

(to be continued)

APPENDIX F (continued)

F.3.3 Demineralized water quality

The following data on demineralized water quality shall be specified:

- Electrical conductivity.
- Total hardness.
- Silica.
- pH.
- Other requirements.

F.3.4 Type of demineralizing unit

Type of demineralizing Unit is to be decided, based on the raw water analysis. The use of a two-bed two-tower, two-bed three-tower Unit or others suitable for the specified raw water quality and treated water quality shall be considered.

F.3.5 Capacity and operation

- The Unit shall continuously produce a net flow to the service. However, where adequate demineralized water storage is available to meet standby and service requirements, a single Unit may be permitted.

- Expected turn-down ratio of a demineralized water flow rate to a designed value shall be suitable for boiler feed operation, as specified.

F.3.6 Control system

F.3.6.1 Basically, operation of the demineralizing Unit shall be controlled automatically from the local panel.

F.3.6.2 Regeneration of the Unit shall be started automatically by the following signals:

- Signal when conductivity is exceeding the set value.
- Signal when scheduled water volume is obtained.
- Signal when automatic generation is manually initiated.

F.3.6.3 In addition to the above automatic regeneration, the regeneration system shall enable manual operation of each value.

F.3.7 Installation

The demineralizing Unit shall be installed in a non hazardous area. Therefore, the Unit shall be designed for suitable outdoor installation.

F.4 Equipment Design

F.4.1 Resin vessel

- Cation/Anion resin vessels shall be made of carbon steel with an inner rubber-lining or equivalent to protect against corrosion.

- Where diluted sulfuric acid and caustic soda is used, vessel internals shall be made of rubber lined-carbon steel, Type 316 stainless steel or equivalent.

(to be continued)

APPENDIX F (continued)

F.4.2 Feed pump

- The raw water feed pump design shall be based on the hydraulic calculations applicable between the raw water feed line and the rundown line to the demineralized water tank.

- To make the earliest possible determination of the pump specifications, the pressure drop at the demineralizing Unit shall be assumed to be less than 140 kPa (1.4 bar) and it is recommended that the pressure drop be less than 100 kPa (1.0 bar) under normal operation.

F.4.3 Regeneration water pump

F.4.3.1 Regeneration water pumps shall be provided.

F.4.3.2 The design of chemical pumps for the regeneration of the resin shall be based on the following considerations:

- Capacity of demineralizing Unit.
- Operating schedule of demineralizing Unit.
- Concentrations of chemical solutions.

F.4.4 Piping

The demineralized water (treated water) outlet piping shall be made of rubber lined-carbon steel or stainless steel.

F.4.5 Miscellaneous

- Resin traps shall be provided in the outlet of each Unit.
- Resin charges for each resin vessel shall be included.
- Activated carbon removing system, where applicable, shall be provided.

F.4.6 Neutralization equipment

- Neutralization equipment shall consist of recirculation and/or discharge pumps, mixing blower or mixer and bulk waste water tank with adequate internals.

- Operation of this system shall be done automatically as a rule. However, manual regeneration may be employed for Unit whose regeneration interval is more than 7 days.

F.5 Inspection and Testing

F.5.1 Shop tests and inspections

The following tests and inspections on respective parts or equipment in the demineralizing Unit shall be performed after completion at the fabrication shop:

- Dimensional inspection.
- Material check against the mill test certificate.
- Mechanical running test of the equipment.
- Electrical test.
- Instrument checks.
- Pressure and leakage test on vessels.

(to be continued)

APPENDIX F (continued)

F.5.2 Field test

The following tests shall be done after completion in the field:

- Instrument test.
- Running test on overall system.
- Performance test.
- Leakage test on piping.

F.5.3 Performance characteristics

The following performance characteristics shall be guaranteed:

F.5.3.1 Treated water output capacity per hour and per cycle.

F.5.3.2 Inlet water flow rate of both operation and regeneration.

F.5.3.3 Treated water quality per items:

- Electrical conductivity.
- Silica.
- Total hardness.
- pH at 250°C.

F.5.3.4 Operating/regeneration cycle time.

F.5.3.5 Chemicals both for regeneration and neutralization per cycle (kg/cycle) and per each treated water (kg/m³).

F.5.3.6 Waste water quantity per cycle (m³/cycle) and per each treated water (m³/m³).

APPENDIX G
TABLE G.1- TYPICAL ION EXCHANGE FLOWS AND DIMENSIONS

Diameter (mm)	Area (m²)	min. Resin (m³ at 760 mm)	BACK WASH			SERVICE FLOW		
			+	♣ (m³/h)	b	1 Unit	2 Units	3 Units
						(m³/h max.)*		
610	0.25	0.23	2.04	4.31	8.63	4.31	5.68	11.36
762	0.46	0.34	3.41	6.81	13.40	6.81	9.08	18.17
914	0.66	0.51	4.77	9.54	19.30	9.54	12.72	25.43
1067	0.89	0.68	6.59	13.17	26.34	13.17	17.49	34.97
1219	1.17	1.91	8.63	17.03	34.06	17.03	22.71	45.42
1372	1.48	1.13	10.90	21.57	43.15	21.57	29.52	59.05
1524	1.82	1.39	13.40	26.80	53.37	26.80	36.34	72.67
1676	2.21	1.70	16.12	32.47	64.72	32.48	43.15	86.30
1829	2.63	2.01	19.30	38.61	77.21	38.61	52.23	104.47
1981	3.08	2.35	22.71	45.42	90.84	45.42	61.32	122.63
2134	3.58	2.72	26.12	52.23	104.46	52.23	70.40	140.80
2286	4.11	3.12	29.98	60.18	120.36	60.18	79.48	158.97
2438	4.67	3.57	34.06	68.13	136.26	68.13	90.84	181.68
2591	5.28	4.02	38.61	72.21	154.43	77.21	102.19	204.39
2743	5.91	4.53	43.15	86.30	172.60	86.30	113.55	227.10
2896	6.59	4.98	48.37	96.52	193.03	96.52	129.45	258.89
3048	7.29	5.55	53.37	106.74	213.47	106.74	143.07	286.15
3353	8.83	6.80	64.72	129.45	258.90	129.45	170.32	340.65

* Service flow is based on rates of 14.7 m³/m².h, single Unit maximum rate, and 19.6 m³/m².h short term rate, on multiple Units when one Unit is out of service for regeneration. To provide a continuous supply of treated water, most plants use two Units, so that while one is being regenerated the other continues to provide finished water. Plants having variable demand store finished water to eliminate surges in flow, minimizing equipment size. Treated water storage permits smaller plants to install only a single Unit, relying on stored water to provide requirements during regeneration. This is risky, since it provides no margin for error or for normal maintenance.

+ Backwash rate of 7.3 m³/m².h for anion resins at 21°C.

♣ Backwash rate of 14.7 m³/m².h for cation resins at 21°C.

b Backwash rate of 29.3 m³/m².h for cation resins at 104°C.

APPENDIX H
DISINFECTION

H.1 General Description

The purpose of disinfection is to render water safe for human consumption, free from pathogenic bacteria and therefore incapable of transmitting disease.

Chlorine, in its various forms (liquid, gas, or hypochlorite) is the major chemical widely used in disinfecting water. Other disinfectants are iodine, bromine, ozone, chlorine dioxide, ultraviolet light, and lime, which might be considered if chlorine gas is not readily available. The important applied disinfectants are as stated below:

H.1.1 Chlorination

While the principal use of chlorine is as a disinfectant, its application is practiced for prevention and destruction of odors, iron and/or color removal simultaneously. Chlorination is classified according to its point of application and its end result.

H.1.2 Plain chlorination

Whenever surface waters are used with no other treatment than chlorination, its role is extremely important as the principal if not the only safeguard against disease.

Such otherwise untreated waters are likely to be rather high in organic matter and require high dosages and long contact periods for maximum safety. The chlorine can be added to the water in the pipe leading from an impounding reservoir to the residential township. For disinfection alone a does of 0.5 mg/L or more may be required to obtain a combined available residual in the township distribution system.

H.1.3 Prechlorination

Apart from diatomaceous earth filters for which prechlorination is a must, in case of all kinds of rapid filters, the chlorine may be added in the suction pipes of raw-water pumps or to the water as it enters the mixing chamber. Its use in this manner may improve coagulation and reduce tastes and odors, may keep the filter sand cleaner and increase the length of filter runs. Frequently the dosage is such that a combined available residual of 0.1 to 0.5 mg/L goes to the filters. The combination of prechlorination with postchlorination may be advisable or even necessary if the raw water is so highly polluted that the bacterial load on the filters must be reduced in order that a satisfactory coliform count or MPN be obtained in the final effluent.

H.1.4 Postchlorination

This usually refers to the addition of chlorine to the water after all other treatments. It is standard treatment at rapid sand filter plants, and when used without prechlorination and with low residuals it is sometimes called marginal chlorination. The chlorine may be added in the suction line of the service pump, but it is preferable to add it in the filter effluent pipe or in the clear well so that an adequate contact time will be assured. This should be at least 30 minutes before any of the water is consumed if only postchlorination is given. Dosage will depend upon the character of the water and may be 0.25 to 0.5 mg/L in order to obtain a combined available residual of 0.1 to 0.2 mg/L as the water leaves the plant. Greater residuals will probably be needed if it is desired to hold a disinfecting effect throughout the distribution system.

(to be continued)

APPENDIX H (continued)

H.1.5 Break-point chlorination (see 3.2)

Depending on the amount of free and saline ammonia existing in filtered water, the breakpoint curve varies as shown in Fig. H.1.

The breakpoint indicates complete oxidation of the available ammonia and any other organic amines, and the residual above the breakpoint is mostly free available chlorine. Usually the chlorinous and other odors will disappear at or before the breakpoint. Dosage are likely to be 7 to 10 mg/L in order to obtain a free available residual of about 0.5 mg/L or more. The chlorine, when the breakpoint procedure is applied, usually, but not always, is added at the influent to the plant. In some cases ammonia has been added to water lacking in it in order to form a more pronounced breakpoint.
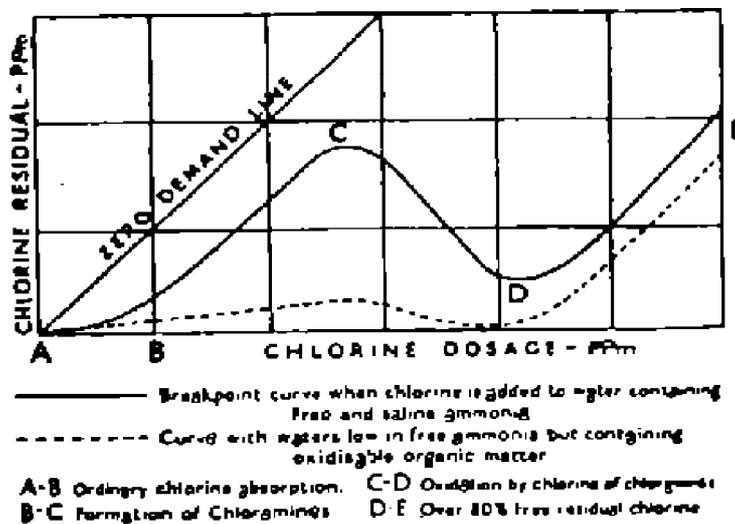
BREAKPOINT CURVE WHEN CHLORINE IS ADDED TO WATER CONTAINING FREE AND SALINE AMMONIA
Fig. H.1

H.1.6 Ammonia chlorine treatment (Chloramination)

The chlorine combines with the ammonia and other organic amines to form chloramines. They are less active than hypochlorous acid (HOCl) and their disinfecting efficiency is considerably less than HOCl but its bactericidal effects is maintained over a longer period. The beneficial aspect of ammonia chlorine treatment is that little or no combination of chlorine with organic matter occurs, to produce undesirable odors. Hence chloramines have been used as an odor preventive with satisfactory bactericidal effects, if longer contact periods are provided.

Ammonia is usually added in the ratio or 1 part of ammonia to 4 parts of chlorine, although experiment may indicate the desirability of a higher or lower proportion.

It is used as the gas, as a solution of the gas in water, or as ammonium sulfate or ammonium chloride. The ammonium sulfate used is the chemical fertilizer, which is sufficiently pure to be used for this purpose.

If taste and odor control is the main object of chloramination, the ammonia should be added in advance of the chlorine.

(to be continued)

APPENDIX H (continued)

H.1.7 Superchlorination and dechlorination

The process of superchlorination followed by dechlorination is best defined as the application of chlorine to water to produce free residual chlorination, in which the free available chlorine residual is so large that dechlorination is required before the water is used. Whenever highly polluted waters have to be disinfected for drinking purposes, adoption of this process is recommended.

Where superchlorination or alternatively breakpoint chlorination is practiced it is desirable to provide a baffled contact tank of approximately 30 minutes' retention and in no case less than 20 minutes, in order to ensure complete sterility. The most common dechlorinating agent is sulfur dioxide, which is added either at the end or in the last bay of the contact tank so as to ensure complete mixture and dechlorination to leave the desired residual. It is normally found that the dose of sulfur dioxide is approximately 20 percent greater than the theoretical amount calculated to combine with the chlorine removed. In certain small supplies sodium thiosulphate or sodium bisulphite have been employed as dechlorinating agents. If complete dechlorination is desired then passage of the highly chlorinated water through a bed of granular carbon is often used.

Very occasionally a small dose, 0.2 - 0.5 mg/kg (mass ppm_m or ppm by mass), of potassium permanganate is also added to the contact tank prior to filteration in order to control tastes.

H.2 Chlorinators

For injection of chlorine gas into water a variety of chlorinators have been designed and manufactured. The two recommended types are shown in Figs. H.2 and H.3.

The type to be chosen largely depends upon the capacity needed. Chlorine gas is obtained in pressurized cylinders ranging from 45 to 1000 kg capacity. Small plants commonly use the 45 kg cylinders, while large plants requiring 75 to 100 kg/day generally use 1000 kg containers as a matter of convenience and economy.

A satisfactory chlorinators must feed the gas into the water at an adjustable rate, and it must do this although the pressure in the gas container changes as the temperature changes. While some chlorinators apply the measured amount of gas to the water through a porous porcelain diffuser, most types dissolve the gas in water and feed the solution.
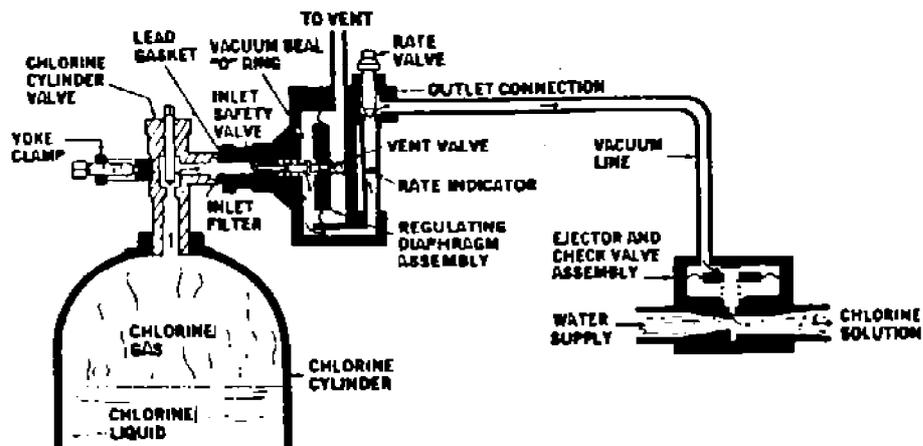

CHLORINATION APPARATUS
Fig. H.2

(to be continued)

APPENDIX H (continued)

In chlorinator of Fig. H.2 a water operated aspirator draws chlorine through a regulator and measuring device. The flow can be set to provide a predetermined dosage of chlorine. The quantity of water required and the pressure at which it must be delivered are a function of the size and design of the system. At the injector the chlorine is dissolved in the water and is conveyed to the point of application. In some instances the injector may be at the point of application. The inlet valve closes if the vacuum fails. If it should not close, the chlorine pressure forces the seal of the vent, and the chlorine is discharged outside the building.
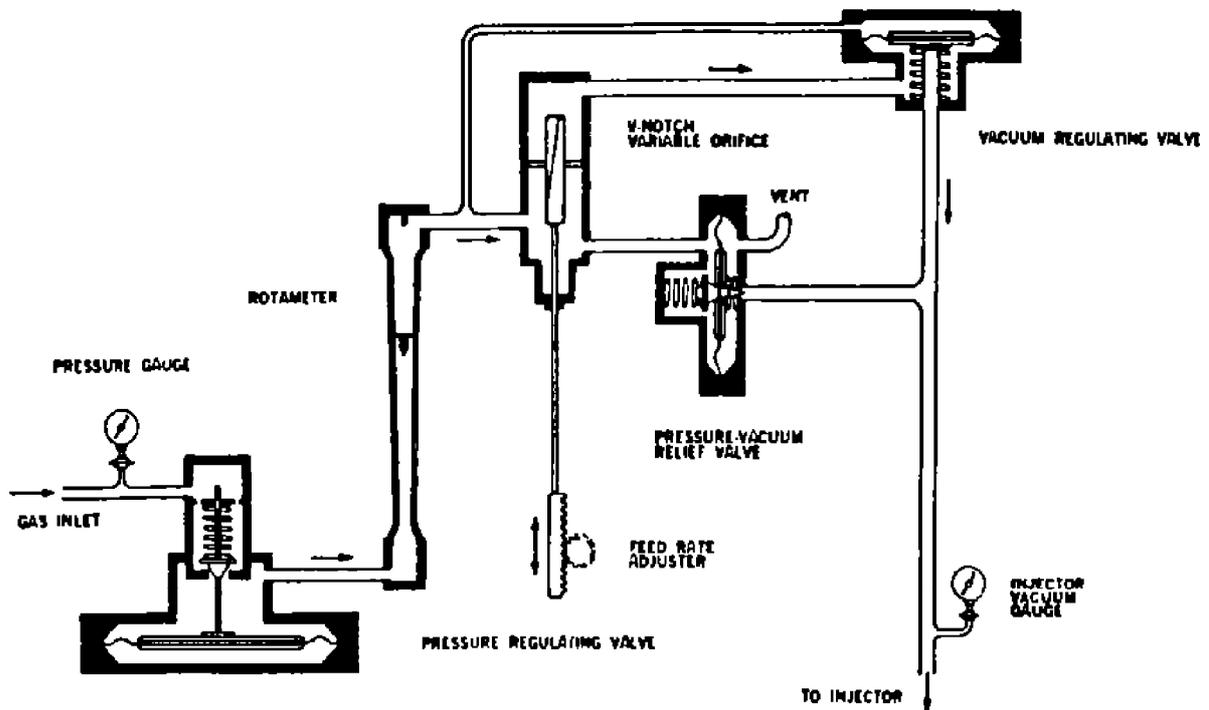
SIMPLIFIED DIAGRAM OF THE V-NOTCH CHLORINATOR
Fig. H.3

The V-notch chlorinator of Fig. H.3 also operates under a vacuum generated by an injector, with the chlorine flow controlled by a variable V-notch orifice. The amount of chlorine fed is shown by a feed rate indicator of the rotameter type. The differential valve and the chlorine pressure regulating valve maintain a constant vacuum differential across the V-notch. The feed rate is changed by changing the area of the V-notch orifice.

Certain precautions are needed in chlorination practice. Chlorinators and cylinders of chlorine should be housed separately and not in rooms used for other purposes. Ventilation should be provided to give a complete air change each minute and the air outlet should be near the floor since chlorine is heavier than air. Switches for fans and lights should be outside the room and near the entrance. The entrance door should have a clearglass window to allow observation from outside. Chlorinator rooms should be heated to 15°C with protection against excessive heat. Cylinders should be protected against temperatures greater than that of the equipment.

(to be continued)

APPENDIX H (continued)

H.3   Hypochlorination

Chlorinated lime has been largely displaced, not only by chlorine gas, but also by improved commercial compounds of sodium and calcium hypochlorite.

Hypochlorination is especially applicable to emergency use where supplies are endangered and there would be considerable delay in obtaining chlorine gas and chlorinators.

H.4   Ozonation

Chlorination has been proved to be responsible for increases in the concentration of volatile halogenated organics, particularly chloroform, bromodichloromethane, dibromochloromethane and bromoform, which are commonly found in chlorinated water.

Ozone is a strong oxidizing agent and may be applied in any situation where chlorine has been used. Dosages range from 0.25 mg/L for high quality groundwaters to 5 mg/L following filteration for poor quality surface waters.

Effective ozone dosages for viruses range from 0.25 to 1.5 mg/L at contact times of 45 seconds to 2 minutes. Ozone, unlike chlorine and the other halogenes, is not particularly sensitive to pH within the range of pH 5-8, but is significantly affected by temperature.

The disadvantages of ozonation, which have restricted its, use worldwide, are its cost relative to chlorine, the need to generate it at the point of use, and its spontaneous decay which prevents maintenance of a residual in the distribution system. However, the fact of production of halogenated hydrocarbons by present popular chlorination practice would make the said disadvantages of lesser importance specially if production of ozone should be or is generated for other needs.

H.5   Activated Carbon

Activated carbon is used in water processing primarily as a short-term treatment to correct seasonal taste and odor problems.

Powdered activated carbon is generally less than 0.075 mm in size and thus has an extremely high ratio of area to volume.

It is applied as a slurry at points of raw water entry, at the mixing basin, split feed: with a portion in the mixing basin and the balance just ahead of the filters, either at constant rate or at a heavy rate immediately after the filter is washed, followed by a light rate (during seasonal time period).

The dosages used vary from 0.25 to 8 mg/L with 7 to 2 mg/L most common.

The carbon can be used in impounding reservoirs also to reduce algae or either odors. In this case it should be applied as a slurry and sprayed over the water surface at 1 to 10 g/m².

The required dosage of activated carbon can be controlled by means of the threshold odor test.