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| | | April 2011 |
| KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru Malaysia | PROCESS DESIGN OF WATER SYSTEMS (PROJECT STANDARDS AND SPECIFICATIONS) | |

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SCOPE

This Project Standards and Specifications specifies the minimum requirements for the process design and selection of various water supply systems, used in OGP Industries

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. ABMA (American Boiler Manufacturers' Association)
2. ASME (American Society of Mechanical Engineers)
3. AWWA (American Water Works Association, Inc)
 - "Water Treatment Plant Design", 1971
 - Manual M21, "Ground Water", Latest Edition
4. API (American Petroleum Institute)
 - "API Glossary of Terms Used in Petroleum Refining", 2nd., Ed., 1962
5. GPSA (Gas Processors Suppliers Association)
 - "Engineering Data Book", Section 18, 1987
6. USPHS (US Public Health Service)
 - "Drinking Water Standards", No. 956, 1962

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.

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

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phenolphthalein endpoint at a pH \approx 8.3). Several ions contribute to alkalinity, but it is generally due to bicarbonate (HCO₃)⁻¹, carbonate (CO₃)⁻² and hydroxyl (OH)⁻¹ ions.

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.

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.

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.

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.

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.

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

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.

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

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

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Chlorine Requirement - The amount of chlorine, expressed in mg/kg, required to achieve under specified conditions the objectives of chlorination.

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

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.

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

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

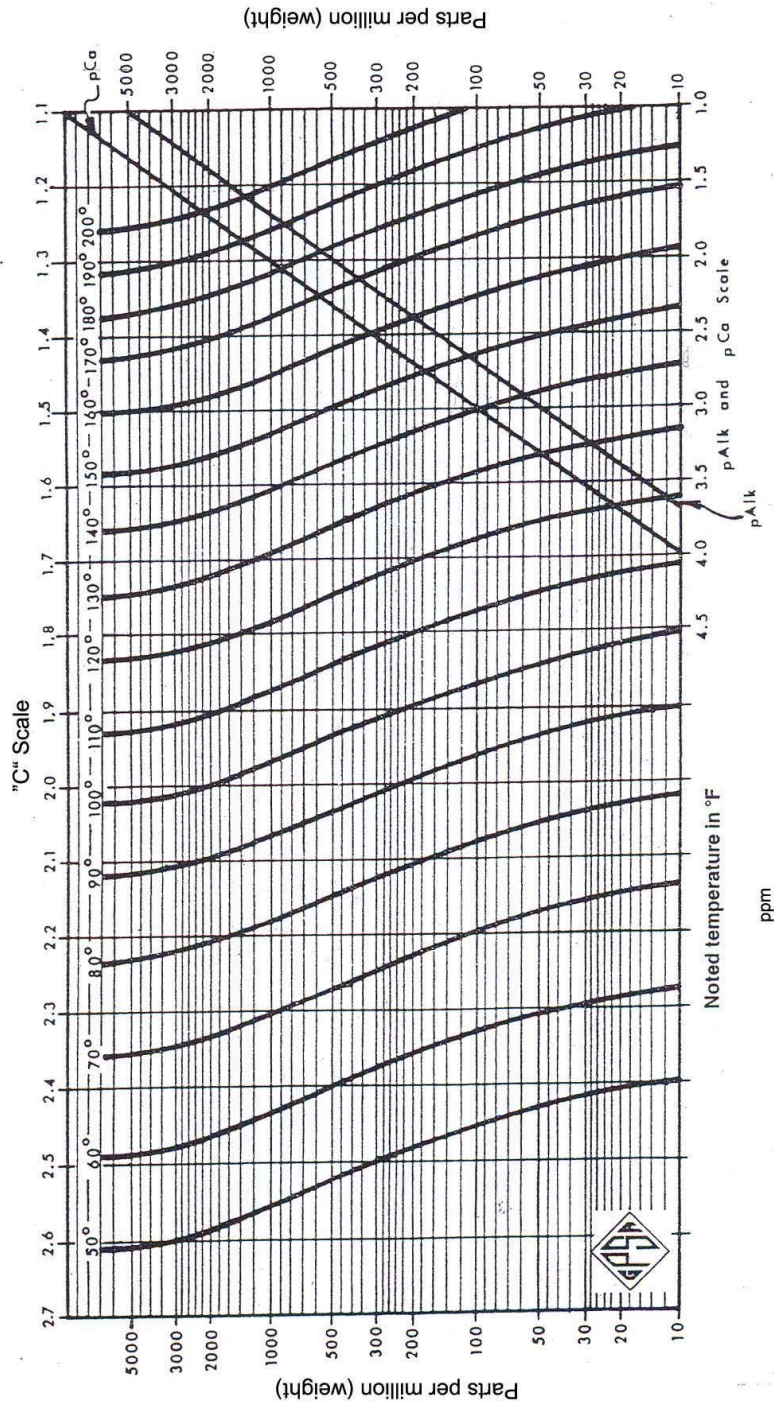
Fresh Water - Water having less than approximately 1,000 mg/L of dissolved matter.

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

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

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 (pHS) 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 $pH - pHS$. Fig. 1 is a chart used for determining Langelier's Index. The interpretation of the results obtained are shown below:

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



To determine:
 pCa: Locate ppm value for Ca as CaCO₃ on the ppm scale. Proceed horizontally to the left diagonal line down to the pCa scale.
 pAlk: Locate ppm value for 'M' Alk as CaCO₃ on the ppm scale. Proceed horizontally to the right diagonal line down to the pAlk scale.
 Total solids: Locate ppm value for total solids on the ppm scale. Proceed horizontally to the proper temperature line.

Example:
 Temp. = 140°F, pH = 7.80
 Ca hardness = 200 ppmw
 M alkalinity = 160 ppmw
 Total solids = 400 ppmw

pCa = 2.70
 pAlk = 2.50
 C at 140°F = 1.56
 Sum = pH_s = 6.76
 Actual pH = 7.50
 Difference = 1.04
 = Saturation index

Courtesy of Betz Laboratories, Inc.

Fig. 1 Langeller Saturation Index Chart

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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.

Raw Water - Untreated water.

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

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.

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.

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

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.

$$\text{Stability Index} = 2\text{pHS} - \text{pH} \quad (\text{Eq. 1})$$

Where:

pHS = 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:

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

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

SYMBOLS AND ABBREVIATIONS

| <u>SYMBOL/ABBREVIATION</u> | <u>DESCRIPTION</u> |
|----------------------------|--|
| A | Surface area of the settling basin, in (m ²). |
| 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. |
| 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 (m ³ /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. |

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|----------------|--|
| V | Volume of water to be supplied in (m ³). |
| 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). |

UNITS

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

WATER TREATMENT SYSTEM

General

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

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

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

1. Source water types

- a. Source or make up water is normally either ground or surface water, neither of which is ever chemically pure.
- b. Ground waters contain dissolved inorganic impurities which come from the rock and sand strata through which the water passed.
- c. Surface waters often contain silt particles in suspension (suspended solids) and dissolved organic impurities (dissolved solids).
- d. 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.

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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, barium 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, electro dialysis |
| 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 ₂ SO ₄ , HCl, etc. expressed as CaCO ₃ , titrated to methyl orange end-point | Corrosion | Neutralization with alkalis |
| Carbon Dioxide | CO ₂ | Corrosion in water lines and particularly steam and condensate lines | Aeration, deaeration, neutralization with alkalis, filming and neutralizing amines |
| PH | Hydrogen ion concentration defined as: $pH = \log \frac{1}{(H^{+1})}$ | 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 alkalis 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, electro dialysis |
| Chloride | Cl ⁻¹ | Adds to solids content and increases corrosive character of water | Demineralization, distillation, reverse osmosis, electro dialysis |

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| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|------------------|---|---|---|
| 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, electro dialysis |
| Fluoride | F ⁻¹ | Not usually significant industrially | Adsorption with magnesium hydroxide, calcium phosphate, or bone black, Alum coagulation, reverse osmosis electro dialysis |
| 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 |
| Oil | Expressed as oil or chloroform extractable matter, ppm | 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 ₂ S | Cause of "rotton egg" odor; corrosion | Aeration, chlorination, 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 micromhos, 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 electro dialysis |
| 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" |

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2. Quality of source waters

- a. Type of water treatment depends on the quality of the source water and the quality desired in the finished water.
- b. 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.
- c. 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.
- d. 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.
- e. 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.
- f. Surface water supplies receive greater exposure to wastes, including accidental spills of the variety of substances.
- g. Generalizations like the above, although useful, are not a substitute for the definitive information required for plant design.
- h. 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.
- i. In connection with deep reservoirs, multiple intakes offer flexibility in selecting water from various depths, thus overcoming poorer water quality resulting from seasonal changes.
- j. For ground water sources, the location and depths of wells should be considered in order to avoid pollution and secure water of favorable quality.

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.

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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.

- a. In case of surface water, general protection should be provided against clogging and deposits.
 - i) 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).
 - ii) 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 filtration through silicious 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.
- b. In case of ground water the main risks are abrasion by sand or corrosion.
 - i) 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 filtration through sand, straining under pressure or use of hydrocyclones, if the grit is of the right grain size.
 - ii) Corrosion frequently occurs on systems carrying underground water and leads to the formation of tuberculiform 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 filtration 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.

5. Treatment process selection

- a. 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.
- b. Often various types and combination of treatment Units would be used to achieve the performance desired (see Table 1). Determination of the most

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- suitable plan should be on a comparative cost study which includes an evaluation of the merits and liabilities of each proposal.
- c. The experience acquired through treatment of the same or similar source shall provide an excellent guide in selecting a plan.
 - d. 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. 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.
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 required by relevant national standards. As reference, potable water standard specification of AWWA is included in Appendix C.
8. Boiler water quality criteria
- a. Boiler water chemistry

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

 - i) 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.

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- ii) 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.
 - iii) Dissolved gases, such as oxygen and carbon dioxide, which can cause corrosion.
 - iv) Silica, which can volatilize with the steam in sufficient concentrations to deposit in steam turbines.
- b. 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.
- c. 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:
- i) 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.
 - ii) 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.
 - iii) 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.

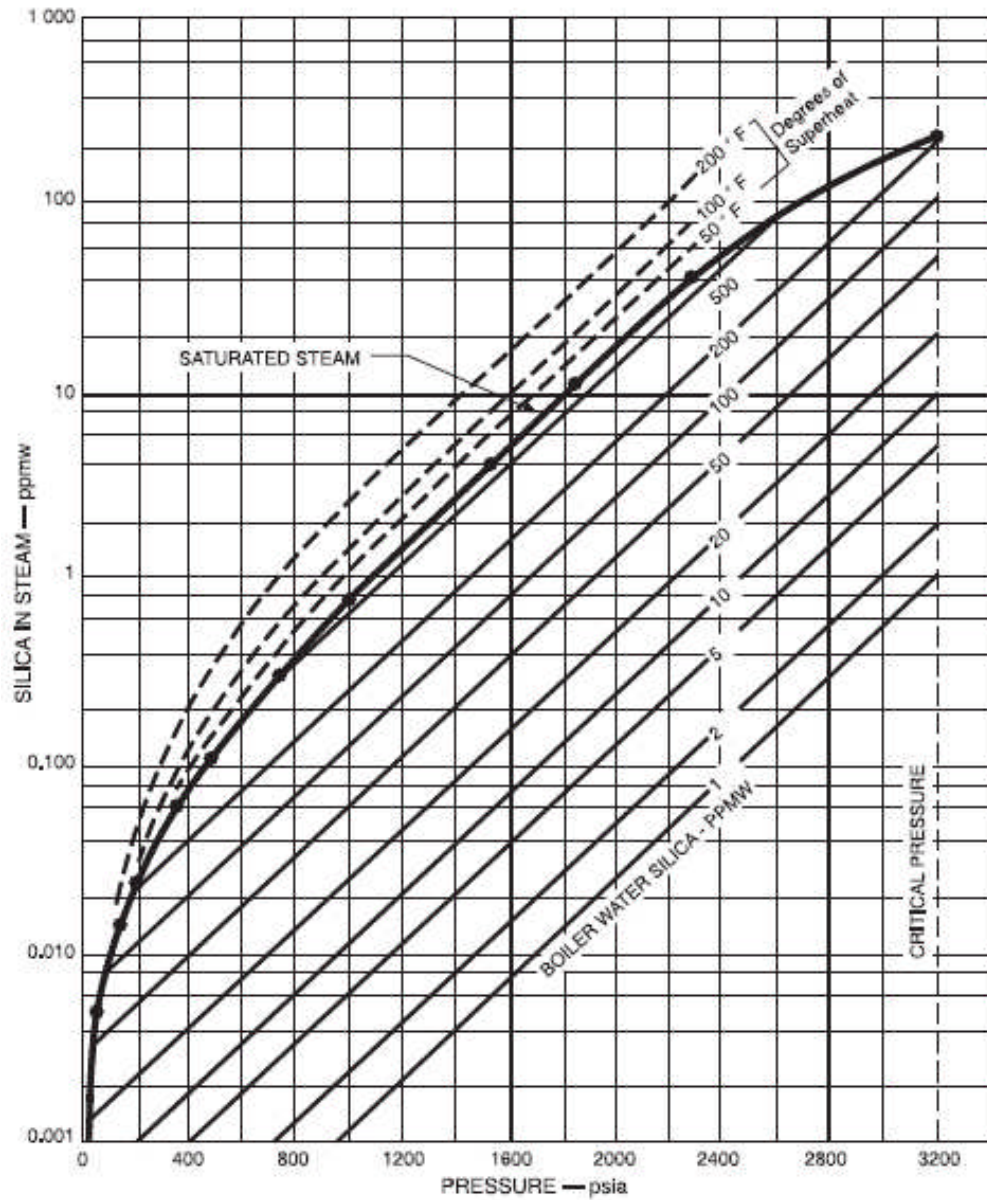


Fig. 2 Relationship Between Boiler Pressure, Boiler Water Silica Content and Silica Solubility in Steam

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iv) 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.

- v) 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.

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.

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 |

Processes-Design

1. Coagulation & flocculation

a. General information

- i) 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.
- ii) Flocculation is the massing together of discharged particles as they are brought into contact with one another by stirring. This leads the

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formation of flakes or floc. Certain products, called flocculating agents, may promote the formation of floc.

- iii) Separation of the floc from the water can be achieved by filtration alone or by settling.
 - iv) Coagulation and flocculation are frequently used in the treatment of potable water and preparation of process water used by industry.
 - v) Certain dissolved substances can also be adsorbed into the floc (organic matter, various pollutants, etc.).
- b. Main coagulants
- i) The most widely used coagulants are based on aluminum or iron salts. In certain cases, synthetic products, such as cation polyelectrolytes, can be used
 - ii) 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.
- c. pH value for coagulation and dosage
- i) For any water, there is an optimum pH value, where good flocculation occurs in the shortest time with the least amount of chemical.
 - ii) For actual application of coagulating agents, the dosage and optimum pH range should be determined by coagulation control or a jar test.
- d. Choice of coagulant
- Coagulant should be chosen after the raw water examination in laboratory by means of flocculation test, while considering following factors:
- Nature and quantity of the raw water.
 - Variations in the quality of the raw water (daily or seasonal especially with regard to temperature).
 - Quality requirements and use of the treated water.
 - Nature of the treatment after coagulation, (filter coagulation, settling).
 - Degree of purity of reagents, particularly in the case of potable water.

2. Sedimentation

- The process by which suspended or coagulated material separates from water by gravity is called sedimentation.
- Sedimentation alone, is an effective means of water treatment but is made more effective by coagulation.
- Presedimentation basins or sand traps are sometimes used when waters to be treated contain large amounts of heavy suspended solids. This

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decreases the amount of sediment which accumulates in the sedimentation basin as a result of the coagulation and sedimentation process.

- If water is to be filtered in the course of treatment, coagulation and sedimentation will reduce the load on filters.
- a. Type of sedimentation tanks
 - i) 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.
 - ii) The hydraulic characteristics of a settling tank depend on both the geometry of the tank and the flow through the tank.
 - iii) Most sedimentation tanks used in water purification today are of the horizontal-flow type.
 - iv) 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.
 - v) Fig. 3 shows the flow patterns in horizontal-flow type of sedimentation tanks.
 - vi) 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.
 - vii) The sedimentation basins should be equipped with mechanical equipment for continuous removal of settled solids.