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GLOSSARY

Alkalinity	Alkalinity can be described as bicarbonate, carbonate, phosphate, and hydroxide. Each of these components will contribute some amount of basicity to a water solution. The sum of all alkalinity components is referred to as total alkalinity.
Boiler water	Cycled up feedwater inside the boiler. Blowdown from the steam drum of a watertube boiler and bottom or surface blowdown from a firetube boiler are typically considered representative of the water chemistry inside the boiler.
Caustic Gouging	The dissolution of carbon steel by localized high concentrations of sodium hydroxide to form sodium ferroate and sodium ferroite. Thick, black deposits typically remain in the gouged area. Corrosion also requires a concentrating mechanism, such as steam blanketing or boiling within porous deposits, and buildup of a thermal barrier from cooling water.
Cycles of Concentration	In the absence of carryover, it is the feedwater flow rate divided by blowdown flow rate. It is the extent of evaporative concentration of feedwater dissolved solids in the boiler and can be calculated by (boiler water chloride / feedwater chloride) for softened makeup. It is often estimated by (boiler water specific conductivity / feedwater specific conductivity) although some of the specific conductivity can be due to boiler water treatment chemicals or alkalinity decomposition upon entrance into boiler. Sometimes tracer chemicals are fed to feedwater and monitored in boiler water to determine cycles of concentration.
Deaerated water	The process of deaeration removes oxygen from water by either mechanical or chemical means. Mechanical deaerators that are functioning properly and operating at design conditions should reduce oxygen to ≤7 µg/L (ppb) oxygen as O_2. Deaerating heaters may only achieve removal to <40 µg/L (ppb) oxygen as O_2. Scrubbing/reboiler deaerating heater performance can be significantly reduced at low flow rates.

Direct spray water used for steam attemperation	Also known as attemperation water. Direct spray water is injected into superheated steam to control its temperature. Any solids present in direct spray water can potentially cause deposits and/or corrosion within the attemperator or directly downstream, so this water must be essentially solids free.
Electrode, forced circulation jet type boiler	Electric steam generators produce steam rapidly and can be taken offline very quickly. The electrode forced circulation jet type electric boiler uses the conductive and resistive properties of water to generate steam. Because water has electrical resistance, the current flow from electrodes immersed in or sprayed with boiler water generates heat directly in the water and steam production occurs.
Feedwater	Water supply going to the boiler. It is typically a combination of condensate return and water supplied from the makeup treatment system. Tables specify deaerated water, which typically is achieved by a deaerator located before the boiler feed pump(s).
Holding Time	Boiler volume divided by blowdown flow rate. This is the length of time to remove one boiler volume of water.
High purity water	Treated water that has all or most of the dissolved minerals removed. See Section 5.1 for minimum effluent purity assumed. Removal is usually by membrane separation, ion exchange (demineralization), distillation (evaporation), and combinations of these processes. Commonly called demineralized water or deionized (DI) water.
Industrial watertube boiler	Industrial watertube boilers are composed of drums and tubes. Water and steam are contained on the inside of boiler tubes, while heat is applied to the exterior of the tubes. The water provides cooling to the tube metal and prevents overheating. A multitude of boiler designs, sizes, and manufacturers exist. All forms of fuel can be burned. Steam produced can be saturated or superheated.

Industrial firetube boiler	The industrial firetube boiler consists of a shell filled with water through which hot gases are passed on the inside of tubes located within the shell. They are typically limited to less than 300 psig, produce saturated steam, and are generally smaller in size than industrial watertube boilers. Firetube boilers are limited to burning liquid and gas type fuels, although a few hybrids exist that can also burn biomass.
Industrial coil watertube steam generator	Industrial coil watertube steam generators are available from several manufacturers; each OEM having unique design characteristics. The main design feature of these generators is a heated coil or series of coils through water travels, entering as water on one end and leaving as a mixture of steam and water on the other end. The coil is followed by a steam separator generally capable of achieving steam qualities greater than 98%. Coil steam generators will typically have a low water volume to boiler horsepower ratio, small footprint, and quick steaming capability.
Limit	Values presented as limits in this document are suggested consensus values.
Marine propulsion watertube boiler	Marine propulsion refers to the mechanism or system used to generate thrust and move a ship through the water. Most modern ships are propelled by mechanical systems consisting of an electric motor or engine turning a propeller. Although the steam turbine was the source of this electricity for most marine vessels at one time, new-build ships with steam turbines are generally limited to merchant vessels where the cargo can be used as fuel (e.g., LNG or coal carriers).
Nonvolatile TOC	An unofficial modification of the TOC test suggested by this task group in which the TOC test is conducted on a sample after atmospheric boiling with the subsequent subtraction of a calculated carbon value equivalent to the carbon content of any nonvolatile organic treatment chemicals fed

Nonvolatile treatment chemical	A nonvolatile treatment chemical, such as phosphate, polymer, or sulfite, will leave solids/deposits when water in which it is dissolved is boiled to dryness.
Oily matter	Includes all nonvolatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases, and related matter which are extractable in hexane or halogenated solvents at low pH. This grouping unfortunately excludes some potentially damaging organic feedwater contaminants and includes some beneficial organic compounds because of their solvent solubility.
Organic matter	Broad category of potential contaminants which contain one or more carbon atoms in their structure.
Phosphate Gouging	The dissolution of carbon steel by localized high concentrations of mono- or disodium phosphate to form maricite ($NaFePO_4$) and other sodium iron phosphate compounds. Crusty alternating black-and-white layered deposits may remain with knife-edge-like surfaces in the gouged area. Corrosion also requires a phosphate concentrating mechanism, such as steam blanketing or boiling within porous deposits, and buildup of a thermal barrier from cooling water.
Phosphate Hideout	Apparent loss of boiler water phosphate in high-pressure water-tube boilers operating under high load conditions. The salts reappear when the load is reduced.
Process Waste Heat Boilers	These are process industry boilers that utilize waste heat sources primarily from the refining and chemical process industries such as Transfer Line Heat Exchangers (TLE). It does not include gas turbine heat recovery steam generators.
Softened water	The term softening typically refers to the reduction of the calcium and magnesium hardness from a water source. This can be accomplished by a variety of pretreatment processes including lime softening, ion exchange, membrane separation, or evaporation. See Section 5.1 for more information.

Specific conductivity	Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount and nature of the dissolved solids present in the water. Pure water, such as distilled water, will have a very low specific conductance while water with a high dissolved solids concentration will have a much larger specific conductivity. Due to its general correlation with dissolved solids concentration and the ease with which it is determined, specific conductivity is often used instead of measuring TDS. Specific conductivity may also be referred to as unneutralized specific conductivity or unneutralized conductivity.
Steam purity	An expression of the quantity of non-water components contained in the steam. These components can be dissolved in the steam, dissolved in water droplets entrained in the steam, or carried as discrete solid particles with the steam.
Steam quality	Relates to the quantity of moisture present in the steam with 100% steam quality specifying no moisture content and 0% quality specifying all liquid.
Superheater	A superheater is a component of the boiler that heats steam above its saturation temperature. It has tubes with steam flow on the interior and heat on the exterior. Steam heats up as it flows through the tubes. Superheated steam has no moisture, i.e., has a steam quality of 100%, and must lose all superheat before condensation can occur.
Total dissolved solids (TDS)	Total dissolved solids are a measure of the dissolved content of all inorganic and organic substances present in a liquid in molecular and ionized form. TDS is limited in the boiler water to primarily prevent carryover, and to a lesser degree, to prevent scaling and corrosion. (Scaling and corrosion in the boiler are largely controlled by feedwater quality.) Since the TDS measurement requires boiling a known amount of water to dryness and subsequent determination of the weight of solids left behind, it cannot be automated. Specific conductivity, which can be automated and is much easier to determine, is often substituted for the TDS measurement.

Volatile Organic Matter	Volatile organic matter (VOM) can include both harmful and non-harmful compounds. It travels with the steam and may cause damage to turbines and other steam system equipment. Potentially harmful VOM commonly present includes low molecular weight organic acids such as formic, acetic, and glycolic.

APPENDIX A. ESTIMATING BOILER WATER SILICA LIMITS

As stated in Section 4.5, the silica limits in Tables 1-5 are set to avoid silica deposits within boilers operating at ≤900 psig. When there is a turbine manufacturer or other definitive limit for silica in the steam, it is suggested to use the following sequence for estimating an appropriate boiler water silica limit. This process was developed primarily from the cited references: Silica in Steam Generating Systems and The Chemical Treatment of Boiler Water [26 and 40].

1. Determine silica target (ppm SiO_2) in steam (Si_{target}) to the turbine or other limiting condition for the system. For nonreheat condensing turbines, the steam silica limit usually is 0.020 ppm. In noncondensing turbines, consult turbine manufacturer recommendations or solubility data [23,26,28].

2. Determine the highest proportion (%) of attemperation water (A) commonly injected into the steam and total silica (ppm SiO_2) in the attemperation water (Si_{attemp}).

3. Determine saturated steam silica target:
   $(Si_{sat}) = (Si_{target} – (A \times Si_{attemp}))/(1\text{-}A)$ in ppm

4. Determine the boiler water silica target to maintain steam purity. These formulas are setup to be used in spread sheets. Spread sheets automatically interpret % to be a fraction (e.g. 0.033% = 0.00033). However, when solving these equations on a calculator, the “% Mechanical Carryover” will need to be divided by 100% to cancel the percentile.

   a. For boilers with drum pressures of ≤500 psig, volatile carryover is sufficiently low and the estimates for mechanical carryover in Table 1 should be sufficiently conservative to provide a quick estimate for meeting a saturated steam silica limit.

      $Si_{boiler} = Si_{sat}$ / (% mechanical carryover).

   b. For a more conservative estimate of the boiler water silica needed to achieve a given steam silica concentration (and for all boilers operating over 500 psig), one should combine the mechanical and volatile silica carryover to obtain a total silica carryover estimate. For this calculation only, Committee advises to use half of the mechanical carryover level noted in Table 1 (to account for the boiler manufacturer’s factor of safety in carryover) plus the following McCoy volatility formula. Table 8 presents the results of example calculations using this formula, 0.020 ppm of silica in the steam, and assumed pH values. Higher boiler water pH values decrease silica volatility which will reduce steam silica at the same boiler water silica concentration.

% Volatile Silica Carryover = 10 ^(0.0106 x Ts - 0.17 x (EPM_{OH})^0.5-8.27).

Where:

Ts = Saturation Temperature °F.

EPM_{OH} or equivalents per million of hydroxide = 1000 x 10^(pH-14).

Alternatively, EPM_{OH} may be estimated as 2% of the Barium chloride hydroxide alkalinity (i.e., hydroxide alkalinity in mg/L $CaCO_3$/50).

% Total Silica Carryover = %Mechanical Carryover/2 + % Volatile Silica Carryover

$Si_{boiler} = Si_{sat}$ / (% Total Silica Carryover).

5. Compare this target to the silica targets based on the boiler pressure in the appropriate table (Tables 1-7 of this guideline) and pick the lower of the two silica targets. However, since silica limits for boilers operating above 901 psi (>6.22 MPa) in Table 1 were set to achieve 20 ppb SiO_2 based on the maximum pressure in each column, tabular values may be stricter than necessary for some boilers in the lower end of each pressure range.
6. If predicted silica concentration at the maximum allowable or planned blowdown may exceed the selected target, then improve makeup and/or condensate purity.
7. When boiler water silica concentrations are normally elevated (>9 ppm), the caustic alkalinity in mg/L $CaCO_3$ should be at least 2.5 times the silica concentration [p. 413 of Ref 44]. This is consistent with other sources [43]. Beardwood set limits at 2.8 ppm $CaCO_3$ of hydroxide alkalinity per ppm of silica in boiler water. Higher silica concentrations may be possible with certain polymers designed to inhibit silica deposition.

8. Direct testing of steam silica and boiler water silica concentrations can be used to ensure that the estimated boiler water silica limits are appropriate to satisfy steam purity requirements.

For low pressure boilers without steam turbines, the boiler water silica limits can be due to factors other than steam purity such as avoiding the formation of complex silicates. Lower boiler water concentrations may be required if deposits are noted from silica concentrating under deposits or from silica combining with hardness, iron, aluminum or other cations. Where possible, makeup and condensate treatment should be improved to minimize concentrations of these cations. Higher silica concentrations than listed in the tables may be safely utilized in some cases.

EXAMPLE CALCULATIONS OF BOILER WATER SILICA LIMIT, 0% ATTEMPERATION, 0.020 PPM SATURATED STEAM SILICA

TABLE 8

Limit Table	Drum Pressure, psig	Sat. Temp., °F	Mini-mum pH (1)	Estimated OH Alkalinity, ppm $CaCO_3$ (2)	EPM of Hydroxide	%Mech. Carry-over	% Volatile Silica Carry-over	%Total Silica Carry-over	Si_{Boiler}, ppm SiO_2
1	300	422	10.00	5.0	0.10	0.029%	0.014%	0.029%	69.9
1	450	460	10.00	5.0	0.10	0.033%	0.036%	0.052%	38.3
1	600	489	10.00	5.0	0.10	0.040%	0.072%	0.092%	21.6
1	750	513	10.00	5.0	0.10	0.050%	0.130%	0.155%	12.9
1	900	534	9.80	3.2	0.06	0.067%	0.223%	0.256%	7.8
1	1000	546	9.70	2.5	0.05	0.080%	0.302%	0.342%	5.9
1	1500	598	9.50	1.6	0.03	0.100%	1.093%	1.143%	1.7
1	2000	637	9.40	1.3	0.03	0.200%	2.853%	2.953%	0.7
5	850	527	10.00	3.2	0.06	0.067%	0.188%	0.221%	9.2
5	1250	574	9.70	2.5	0.05	0.100%	0.598%	0.648%	3.1
7	1800	622	9.50	1.6	0.03	0.200%	1.963%	2.063%	1.0

NOTES TO TABLE 8

1. Assumed minimum pH and estimated alkalinity and EPM from pH.
2. Higher hydroxide alkalinities may be recommended to reduce risk of silica deposits.