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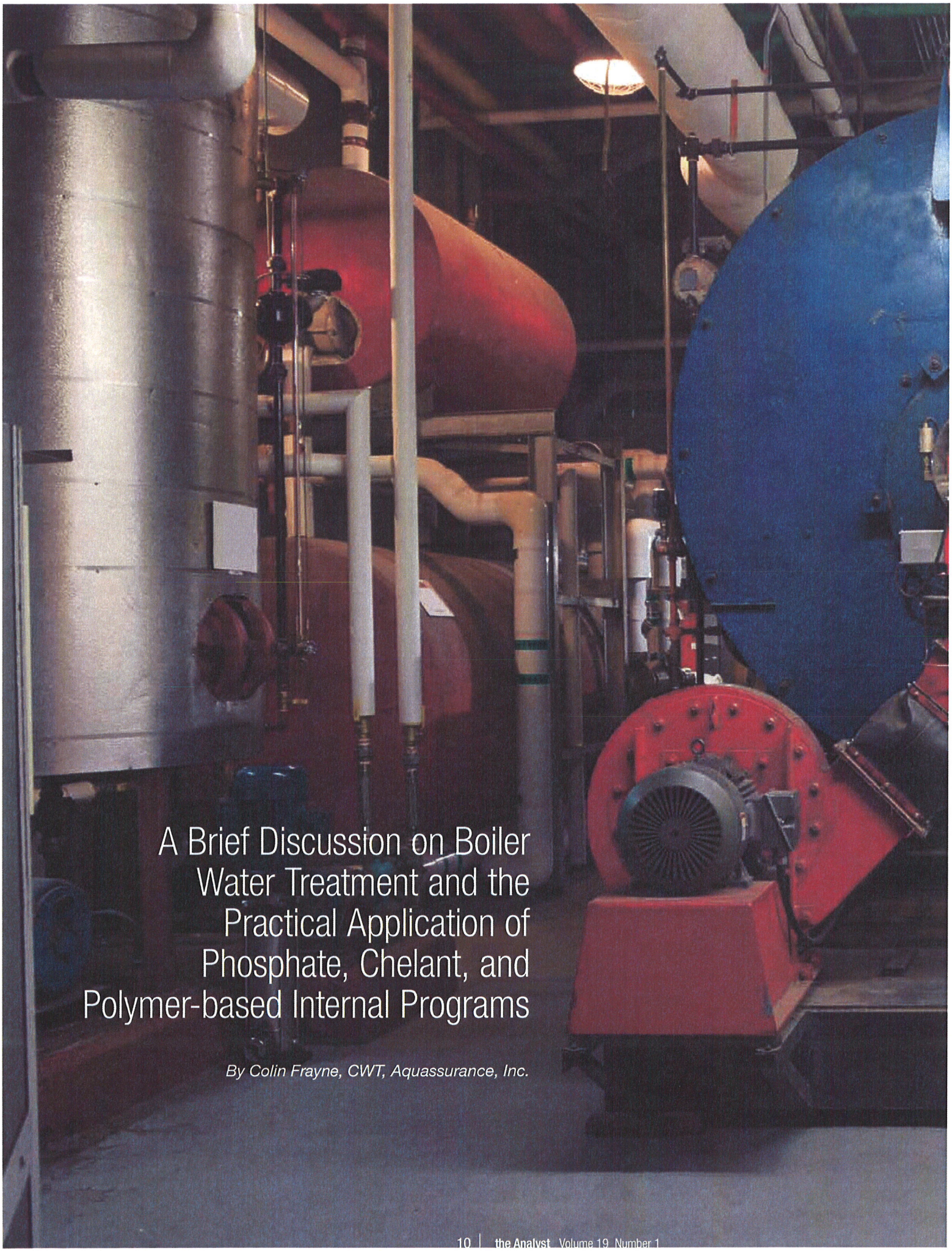
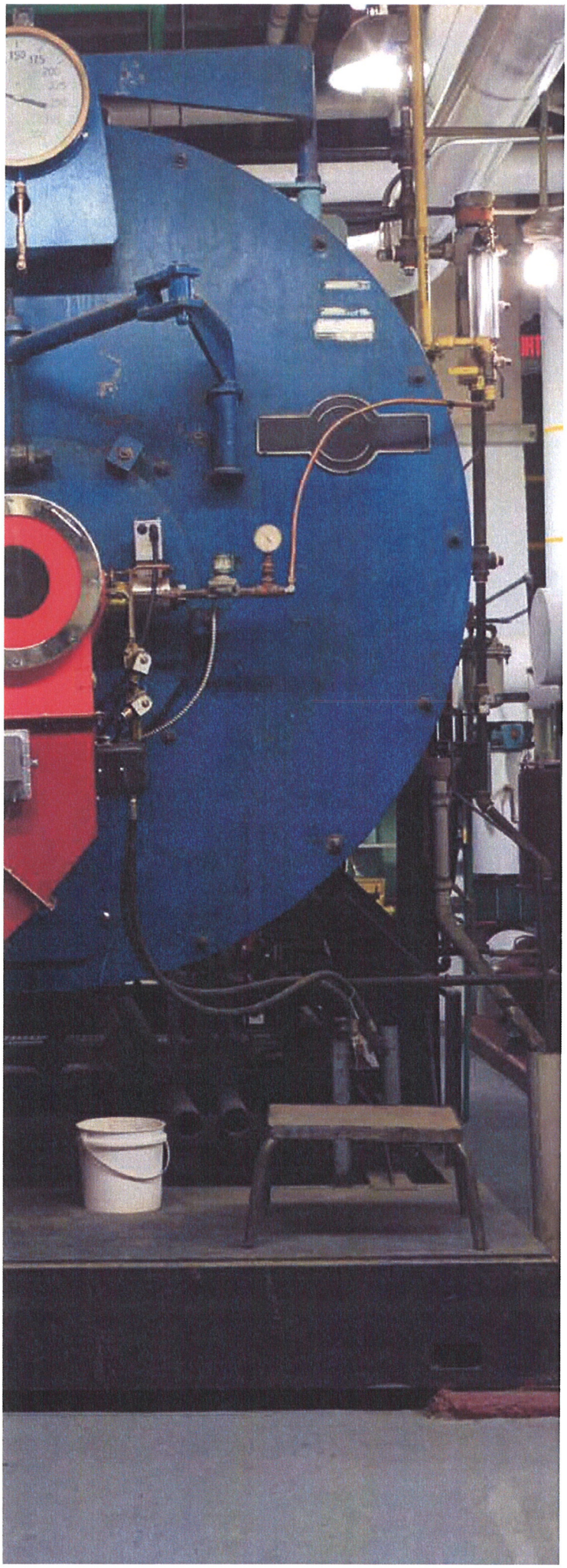


A Brief Discussion on Boiler Water Treatment and the Practical Application of Phosphate, Chelant, and Polymer-based Internal Programs

By Colin Frayne, CWT, Aquassurance, Inc.



What Is Boiler Water Treatment?

Boilers transfer heat to water, and (in steam generators) separate steam under pressure from water most efficiently if the quality of the makeup water (MU), feedwater (FW) and boiler water (BW), are effectively and continuously controlled. The universal problem is that these water sources all contain natural suspended or dissolved impurities to some degree or other, and often, inadvertently, process and operational contaminants. The effect is to hinder the heat-transfer and steam generation processes, to adversely affect the quality and purity of steam, and to act as primary instigators in the corrosion and wastage of materials of boiler plant system construction (including boilers, auxiliaries, appurtenances, etc.). Various chemical reactions and physical mechanisms can and will take place, including the deposition of various crystalline and non-crystalline scales on the waterside of heat-transfer surfaces, the formation of sludges, metal corrosion, and carryover of contaminants into the steam.

The function of boiler water treatment, therefore, is to control the waterside chemistry of boiler plant systems within certain agreed and relevant parameters and specifications. However, BW treatment is a misnomer as, in reality, we are treating the boiler FW and the contaminants it contains. As the adverse conditions described above are by no means limited to the boiler itself, in practice, BW treatment also includes pre- and post-boiler functions, operational control, and a proactive treatment and management program.

As a minimum, such boiler water treatment programs typically require:

1. The selective use of external equipment, such as softeners, dealkalizers, deaerators and condensate polishers.
2. The addition and monitoring of small amounts of internal specialty chemical treatments, including primary treatments and secondary adjuncts or conjunctionals.
3. The control of steam/water and internal surfaces chemistry within narrow limits.
4. The interpretation and communication of observations and analyses, together with advice on corrective actions and waterside management, such as control over steam purity (effect of BW carryover) and steam quality (effect of entrained water).

What Feedwater Quality Is Required?

For simple hot water (HW) and low-pressure (LP) steam heating applications, the water quality requirements are unlikely ever to be onerous, but as pressure ratings and heat-flux densities increase, water quality becomes increasingly more important. Thus, in general, FW/BW qualities are related to pressure and heat-flux density, such that increasingly higher pressure or highly rated boilers tend to require higher quality/purity FW. Also, higher pressure and highly rated boilers often tend to be larger and more complex; consequently, larger boilers incline towards demanding FW of higher quality and tighter water chemistry control ranges than smaller boilers. Additionally, where boilers are particularly compact or of special design, for any given pressure or heat-flux rating they are apt to require a higher quality FW than otherwise provided.

Where process applications demand particularly high quality/purity steam, FW/BW quality must also be of a higher standard and water chemistry tightly controlled. Most raw water (RW) sources are supplied clean and relatively free of suspended solids, colloidal material, organics and iron. In hard water areas some reduction in hardness and alkalinity may also be provided. Where boiler plant RW quality is still unacceptable for the particular boiler plant needs, additional external pre-treatment may be required.

If a higher quality MU water is required, it passes through one or more pre-treatment steps. The term "higher quality" generally means FW with significantly lower levels of TDS than typically employed in lower-rated boilers. Additionally, it implies the reduction of certain specific minerals or ions (such as silica, sodium or alkalinity) and non-condensable gases to meet very low concentration specifications. When "higher quality" applies to condensate return (CR) it refers to a reduction in iron and copper, and sometimes also nickel and chromium, and thus, may require a polishing process.

Also, for all but the most basic of HW heating systems, the effective removal of oxygen from FW is also critical. For this process, a combination of FW heating and chemical oxygen scavenging is generally employed. Small boiler plants will often supplement the heat derived from CR by employing steam coils, steam sparge pipes or electric heaters. Larger facilities will use economizers, closed FW heaters and deaerators.

What Do Boiler Water Treatment Chemicals Control?

Corrosion control—This typically requires a combined approach that includes oxygen scavenging, maintenance of passivated films, and pH and alkalinity control. Sometimes, certain additional conjunctional treatments are required, such as sodium nitrate for protection against embrittlement.
Scale and deposit control—primarily hardness salts and other scale forming minerals.
Sludge control—includes control over a variety of foulants.
Carryover control—foam, priming (surging), misting and process contaminants.
Specific contaminant control—including silica, iron, copper, sodium, chloride, and caustic.
Steam/condensate line corrosion control—oxygen, carbonic acid, and ammonia.

Control over problems such as the supersaturation of dissolved solids, short and long-term overheating, and boiler priming (surging), rely at least as much on good operation.

What Types of Internal Treatment Program Are Commonly Employed?

Internal treatments for BW are chemical formulations having potentially beneficial single-, dual- or multifunctional effects. Globally, there are thousands of formulations available, and, for the most part, they can each be loosely classified as described below.

Anodic inhibitor programs: These employ nitrite, silicate or molybdate chemistries for light-duty multifunctional programs in HW heating and LP steam boiler systems.
Tannin programs: These use blends of certain natural or synthetic tannins and provide oxygen scavenging, passivating and sludge conditioning functions.
Coagulation and precipitation programs: These are widely used and employ various types of phosphates as a precipitant to provide control over the unwelcome deposition of hardness scales. Carbonates and polysilicates were once commonly used.
Chelant programs: These are commonly prescribed for both FT and WT boilers either as replacements for, or used in combination with, phosphate precipitation programs.

All-polymer/all-organic programs: Many specialty polymers are now available and widely used in every type and size of boiler. Typically, multifunctional blends are used as phosphate replacements, to act as sludge conditioners, and to provide control over specific problems such as iron transport that can affect many boiler plant facilities.

Chelant, phosphate or polymer-based, dual or multifunctional programs: Many permutations of dual- or multifunctional programs exist, and based on either chelant or phosphate, together with polymers and related organics are widely employed.

Coordinated phosphate programs: These avoid the formation of hydroxyl alkalinity (free caustic) in higher-pressure WT boilers and require very careful control. Variants include congruent control and equilibrium phosphate treatment.

All-volatile programs (AVPs): These are employed in higher-pressure boilers (generally power boilers) and utilize only volatile chemicals, such as ammonia, amines (such as diethylhydroxylamine, DEHA) and other vapor phase inhibitors (VPIs).

In addition, certain primary and secondary functional chemicals (adjuncts), such as outlined below, are generally also required when providing a comprehensive program.

Primary support chemicals encompass oxygen scavengers and condensate treatments. Oxygen scavengers include inorganics such as sodium sulfite and organics such as hydrazine. Condensate treatments include neutralizing amines such as morpholine and filming amines such as octadecylamine (ODA). Adjuncts include antifoams/defoamers (generally polyethoxlyates), problem-specific polymers (typically for iron transport and silica control) and alkalinity boosters.

What Briefly Do I Need to Know about Modern Precipitation Program Chemistries?

Today, this means phosphate-cycle programs, which date from the turn of the 20th century and were researched and formalized in the 1920s. Formulation developments included combined phosphate/carbonate-cycle programs, which incorporated the best of both products while minimizing corrosion problems due to carbonate breakdown. Phosphates are very versatile and are employed in boil-out, cleaning, lay-up and passivation products, due to functional properties that include corrosion inhibition, hardness stabilization, crystal distortion, sequestration, buffering, deflocculation and synergism (with detergents, wetting agents, emulsifiers and dispersants). Globally, phosphate-cycle programs are still the most commonly encountered form of internal BW treatment, although all-polymer/all-organic programs are slowly overhauling most other chemistries. Related programs, such as phosphate-chelant and phosphate-polymer are simply modifications of the basic phosphate-cycle and they still rely on the precipitation of calcium (or other metal ions) as a dispersible, phosphate sludge.

The calcium phosphate solubility constant is extremely small and phosphate will quickly react with calcium, when present, in warm-to-hot, alkaline BW in the ortho-form. This reaction is complete and superior to the soda ash precipitation reaction, producing either tricalcium phosphate $Ca_3(PO_4)_2$ or hydroxyapatite, a complex composed of a mixed phosphate and hydroxide $Ca_{10}(OH)_2(PO_4)_6$. In addition, calcium phosphate is stable and does not decompose. Hydroxyapatite produces a soft sludge that is not as sticky and can be more easily managed (dispersed) by a (polymeric) sludge conditioner than tricalcium phosphate. But sufficient caustic is required to maintain a suitable OH alkalinity reserve, and tests to should be conducted frequently, normally at least once per day.

The BW pH should be above 10.2 to ensure than hydroxyapatite preferentially precipitates. Also, where magnesium is present, the pH should be above 10.5, in order that magnesium hydroxide [brucite, $Mg(OH)_2$] precipitates, rather than the more sticky and adherent magnesium phosphate [$Mg_3(PO_4)_2$]. In any event, where possible, it is preferable to work with a BW pH of close to 11.0, as this is an optimum passivation pH for steel. As the reaction between calcium and orthophosphate is rapid, it is not generally advisable to add the phosphate to the feedline, as the precipitation of phosphate sludge can quickly foul the line and eventually cause a complete blockage. Phosphate should ideally be added continuously, direct to the boiler shell or steam drum, and in proportion to the FW consumption. Where this is not possible other options exist.

Where hardness levels are continuously low, the phosphate reserve should be maintained closer to the minimum of the specified range (typically between 30 to 60 mg/L PO_4 for FT boilers operating up to 30 bar,

435 psig). Conversely, the phosphate reserve should be higher with variable or higher FW hardness levels. If higher phosphate reserves are required, the hydroxide alkalinity should be increased accordingly. Higher incoming hardness levels ultimately result in a reduction in BW alkalinity, as the various hardness/phosphate reactions consume alkalinity in the production of tricalcium phosphate and hydroxyapatite. Low BW alkalinity is often the first sign of trouble with the softener.

How Much Phosphate Do I Need?

First, it is necessary to ensure adequate BW alkalinity. The alkalinity feed-rate requirement is based on FW consumption and calculated in the chart below:

Typically, for moderately rated FT boilers operating below 435 psig (30 bar):

Maintain BW total (M) alkalinity at 350 to 700 mg/L $CaCO_3$

M alkalinity should generally not exceed 20% of the TDS

Maintain OH alkalinity at a minimum reserve level of 350 mg/L $CaCO_3$

Maintain phosphate reserve at 30 to 60 mg/L PO_4 (50 to 100 mg/L Na_3PO_4)

If maintaining phosphate reserves towards the upper end of the range, ensure caustic alkalinity is also high. Try to ensure an $OH:PO_4$ ratio of 10 or 12 to 1

$$\left[0.67 \times FWCaH + \left(FWMgH - FWMA + \frac{RBWPA}{COC}\right)\right] \times \frac{100}{\%\ PO_4 \text{ in product}} = \text{lb. of product required, per } 1\times 10^6 \text{ lb of boiler FW}$$

Where:
- FWCaH = FW calcium hardness, in mg/L $CaCO_3$
- FWMgH = FW magnesium hardness, in mg/L $CaCO_3$
- FWMA = FW methyl orange/total alkalinity, in mg/L $CaCO_3$
- RBWPA = Required BW phenolphthalein alkalinity, in mg/L $CaCO_3$
- COC = Cycles of FW concentration required in the BW

Note 1: If the value within brackets is negative, then adequate free alkalinity exists in the FW and the addition of supplementary alkalinity is not required.

Note 2: The factor 0.67 above originates from the phosphate to calcium ratio, i.e. $2(PO_4^{3-}) + 3(Ca^{2+})$ $Ca_3(PO_4)_2$, The ratio of 2:3 = 0.67

Example:
- Boiler steam = 250,000 lb./day. ..... CR = 75% (assume clean CR B no contaminants)
- MU water Ca hardness = 8 mg/L $CaCO_3$..... MU water Mg hardness = 4 mg/L $CaCO_3$
- MU water M alk. = 60 mg/L $CaCO_3$ ..... RBWPA = 500 mg/l $CaCO_3$
- COC = 25x ..... Alkalinity-furnishing product contains 15% NaOH

Therefore:
- FWCaH = 2 (8 x 25%) ..... FWMgH = 1 (4 x 25%)
- FWMA = 15 (60 x 25%)..... RPBWA = 500
- COC = 25 ..... % NaOH = 15

Substituting:

$$\left[0.67 \times 2 + \left(1 - 15 + \frac{500}{25}\right)\right] \times \frac{100}{30} = \text{approx 24 lb. of alkalinity furnishing product required, per million lb. of boiler FW, or 6 lb/day}$$

Additionally, the phosphate feed-rate requirement for FW must be calculated. The following formula will suf ce:

$$\left[0.67 \times FWCaH + \left(\frac{RBWPO_4}{COC}\right)\right] \times \frac{100}{\%\ PO_4 \text{ in product}} = \text{lb of product required, per } 1\times 10^6 \text{ lb of boiler FW}$$

Where:
- FWCaH = FW calcium hardness, in mg/L $CaCO_3$
- $RBWPO_4$ = Required BW phosphate reserve in mg/L PO_4
- COC = Cycles of FW concentration present/desired in the BW

What Briefly Do I Need to Know about Chelant Program Chemistries?

Chelant programs are solubilizing programs and are commonly prescribed for both FT and WT boilers either as replacements for, or used in combination with, phosphate precipitation programs. They are relatively high-molecular weight compounds and react stoichiometrically with cations. Chelant programs offer a number of benefits over phosphate programs, including the fact that hardness is controlled as a soluble complex rather than being precipitated. Also, boiler surfaces tend to be cleaner with little or no suspended solids or sludge present, resulting in improved heat-transfer. Additionally, the lack of sludge reduces the need for BD, which further improves efficiency.

In higher hardness waters the consumption of chelant-based programs can be both excessive and expensive, so chelants tend to be used only in low-hardness FW hardness boilers, where very clean waterside surfaces are needed to maximize heat-transfer. Here the formulation may be essentially a "straight" chelant with minimal additional ingredients, or it may be a balanced chelant-polymer program. Also, chelants may be used as a continuous support to an existing program that is struggling to maintain overall effectiveness, or under variable FW conditions where waterside fouling has occurred and on-line cleaning is needed. Initial cleaning may use a high-chelant formulation with a low-chelant formulation employed for maintenance. Chelants, or chelating agents, are typically organic chemicals that react with polyvalent metal ions to tie-up metals and deactivate them, forming stable ring structures. Chelation involves the donation of a pair of electrons to a substrate species (such as iron, copper, calcium or magnesium) and a reconfiguration of the shape of the new molecule to provide a minimum of bond strain. The affinity of chelants for particular substrates differs, but copper, chromium and iron are more attracted than calcium or magnesium. Chelation is also affected by pH and other conditions, and so correct chelant selection is vital. Apart from tying up alkaline earth metals to reduce waterside fouling and solubilizing old formed deposits, formulators have also long used chelants because of buffering, product stability and oxidation/reduction control effects.

Although citric acid, sodium glucoheptonate, phosphonates and polyphosphates are also chelants, the most common chelants employed are:

38% Ethylenediaminetetraacetic acid (EDTA), where 10 mg/L of chelant will sequester 1 mg/L of calcium hardness. It begins to decompose at only 400 psig (441 °F, 27.5 bar, 227 °C), but is very effective and, in practice, is employed at up to 1200 psig (82.7 bar) and up to 1500 psig (103.4 bar) when employed as an overlay product.
40% Nitrilotriacetic acid (NTA), where 10 mg/L of chelant will sequester 1.56 mg/L of calcium hardness. It is considerably cheaper that EDTA, but generally less effective, although stable up to 900 psig (530 °F, 62 bar, 222 °C).

If the BW contains phosphate, the preferred reaction is for calcium to precipitate forming hydroxyapatite, rather than to chelate with EDTA or NTA (competing anion effect), but in practice, the chelant acts to solubilize existing deposits, producing a very clean boiler. The most reliable way to control the chelant program is to base it on FW chelant demand, rather than to aim at maintaining a chelant residual in the boiler, as the field tests are widely inaccurate and EDTA begins to breakdown at pressure over 400 psig. Nevertheless, it is useful to conduct these tests on a purely qualitative basis, simply in order to gain some confidence that a small residual exists. Needless to say, it is imperative that the chelant demand is made on a truly representative FW sample, or series of samples.

Optimum chelation pH is 11.0 to 11.2, corresponding to a P alkalinity in the boiler of approximately 300 to 500 mg/L $CaCO_3$. The lowest practical caustic alkalinity is 100 mg/L.

Chelant corrosion can take place when a number of unfavorable boiler operating factors are collectively present, including an overfeed of chelant and the presence of DO. Thus, extremely good controls over oxygen levels are critical. The injection point of chelant should be into the boiler FW as far downstream as possible from the deaerator and chemical oxygen scavenging point, to permit sufficient time for effective oxygen removal to take place. Typically, the injection point is the high-pressure side of the FW pump. This serves to dilute the chelant before it enters the boiler drum and provides for low-temperature complexing so that any hydrolytic breakdown is minimized.

How Much Chelant Do I Need?

Chelant demand can be calculated by referring to the formula and table below.

$$\text{FW chelant demand (mg/L)} = (A + B + C) + \frac{\text{BW chelant residual}}{\text{COC}}$$

Where: (A + B + C) = sum of individual FW contaminant substrates x respective chelant demand for speci c chelant employed.

COC = Cycles of FW concentration present/desired in the BW

Note 1: Chelant demand assumes product supplied is either 38% EDTA or 40% NTA

Note 2: BW chelant residual = typically 3 to 5 mg/L max.

Table 1: Chelant demand (mg/L product) per 1 mg/L substrate

Substrate	38% EDTA	40% NTA
Hardness, (as mg/L $CaCO_3$)	10.0	6.5
Calcium, (as mg/L Ca)	25.0	17.3
Magnesium, (as mg/L Mg)	41.0	28.3
Iron, (as mg/L Fe)	17.9	12.3
Copper, (as mg/L Cu)	15.7	10.8
Aluminum, (as mg/L Al)	37.1	25.5

What Briefly Do I Need to Know About All-Polymer/All-Organic Programs?

A significant proportion of any BW chemical program is now invariably organic based, and often polymeric. Sludge conditioners have always been of organic origin and many have been employed for more than 50 years, including carboxymethylcellulose (CMC), tannins, hydrolyzed starches and lignins (as lignosulfonates) and still remain useful today. However, these materials now tend to be consigned to the smaller and relatively lower-pressure end of the BW treatment market. Since the '60s, many novel organic BW chemistries have periodically been introduced, including polyacrylates, polymethacrylates, polyacrylamides, phosphonates and maleates. These are often extremely effective as replacements for traditional sludge-conditioners and deposit control agents; but, in addition, they can also support, enhance, or sometimes even totally replace, anodic inhibitors, tannins, carbonates, phosphates and chelants. Some are particularly thermally stable, tolerating pressures up to 1500 psig and possibly higher. They can function as deposit control agents, threshold agents, deflocculators, antiscalents, chelants/sequestrants, dispersants, antifoulants, metal surface cleaners, sludge fluidizers, stabilizers, transport agents or problem-specific polymers.

The essential quality of all-organic programs is their high-efficiency performance and ability to produce ultra-clean waterside surfaces, but they only work effectively with good quality FW. They are not suitable for variable quality and hard FWs. Also, not all polymers are the same, do the same job, or provide equal performance. Careful selection is necessary. Also, careful control of usage is essential as too much or too little polymer is likely to be both unpredictable and unsuccessful. Test methods for polymer residuals are often poor, so various tagging and tracer systems have been devised in recent years.

All-organic chemistries permitted in the food industries under the U.S. Code of Federal Regulations (CFR) 21 §173.310 Boiler water additives, include: sodium carboxymethylcellulose, sodium lignosulfonate, tannins including quebracho, sodium humate, sodium alginates, polyacrylates (PAA), polymethacrylates, acrylate/acrylamide copolymer, acrylic acid/2-acrylamido-2-methyl propane sulfonic acid copolymer (AA/AMPS), phosphinopolycarboxylic acid (PCA), polymaleic acid (PMA) and polyethylene glycol (PEG).

If novel chemistry polymer overlays or all-polymer programs are used to improve boiler cleanliness, technical support services should include providing energy balance summaries linked to dirt loadings and FW contaminant mass balance summaries. Pressure limitations for tannins is 350 psig, HEDP is 400 psig, PAA is 650 psig, PCA is 1000 psig, PMA is 1300 psig, and some terpolymers up to 1500 psig. If employed correctly, the polymers will not add to the total organic carbon content of steam. For phosphate overlay programs, PAA is generally satisfactory, but where phosphate control is required or for on-line cleaning of fouled boilers using phosphate-cycle, SS/MA or AA/AMPS should be used. These products will also perform in the presence of iron.

How Much Organic/Polymer Do I Need?

Polymer feed rates can be calculated based on a 1:1 stoichiometric ratio with FW hardness or total metals (Ca/Mg/Fe/Cu/Al/Ni). If, for example, a boiler operating at 950 psig and operates at 50x COC is supplied with FW containing 0.05 mg/L total metals, this may require 0.05 x 50 = 2.5 mg/L polymer "actives" in the BW. Further guidelines are:

0 to 350 psig: 15 to 25 mg/L polymer "actives" in the BW
350 to 650 psig: 10 to 15 mg/L polymer "actives" in the BW
650 to 950 psig: 5 to 10 mg/L polymer "actives" in the BW
950 to 1250 psig: 2 to 5 mg/L polymer "actives" in the BW
1250 to 1550 psig: 2 to 3 mg/L polymer "actives" in the BW
1550 to 1800 psig: 1 to 2 mg/L polymer "actives" in the BW

Note: All-polymer type programs seldom contain more than 15 to 20% w/w organics, and so whole product reserves in the boiler may need to be five or six times the level indicated above.

What Waterside Analytical Controls Should I Keep?

Some tables follow indicating FW and BW requirements and conditions using hard, partially/fully softened water and demineralized MU with different types of programs.

Table 2 is for FT boilers using phosphate (All-organics can only be used with soft FW)
Table 3 is for WT boilers using phosphate (All-organics can only be used with soft FW)
Table 4 is for WT boilers using chelant or All-polymer/All-organic programs

Note: All charts assume oxygen scavenger, polymer and other necessary water chemistry controls are in place.

Table 2: Phosphate-Cycle Precipitation Program. Recommended BW Control Limits for Non-Highly-Rated FT Boilers Employing Hard, Partially Softened, or Fully Softened FW

FW hardness, mg/L $CaCO_3$	**40 to 50**		**5 to 10**		**1 to 2**
Pressure, psig/bar max. (approx.)	150/ 10	250/ 17	150/ 10	250/ 17	350/ 25
BW chemistry control limits					
BW TDS, mg/L max.	2000	1750	2500	2000	3500
Silica, mg/L SiO_2 max.	140	140	140	140	175
Suspended solids, mg/L max.	300	250	200	150	50
T Alk., mg/L $CaCO_3$ max.	700	600	900	700	1200
OH Alk., mg/L $CaCO_3$	In all cases this should be 350 min.				
Phosphate, mg/L PO_4	In all cases this should be 30 to 60				

Table 3: Phosphate-Cycle Coagulation and Precipitation Program. Recommended BW Control Limits for Non-Highly-Rated WT Boilers Employing Hard, Partially Softened, or Fully Softened FW

Pressure, psig/bar max. (approx.)	350/25	650/45	950/65
FW hardness, mg/L, $CaCO_3$	40 to 50	10 to 20	5 to 10
BW chemistry control limits			
TDS, mg/L max.	2000	2000	1500
Silica, mg/L SiO_2max.	0.4*x* OH alk.	0.4x OH alk.	0.4x OH alk.
Suspended solids, mg/L max.	300	200	100
T Alk., mg/L $CaCO_3$ max.	700	600	500
OH Alk., mg/L $CaCO_3$ min.	350	300	250
Phosphate, mg/L PO_4	30 to 60	30 to 50	20 to 40

Table 4: EDTA Chelant or All-Polymer/All-Organic Program. Recommended BW Control Limits for Fired WT Boilers Employing Demineralized or Similar Quality FW

Pressure, psig/bar max. (approx.)	350/25	650/45	950/65
FW chemistry control limits			
Hardness, mg/L $CaCO_3$ (max.)	2	1	0.2
Total Fe/Cu/Ni, mg/L (max.)	0.05	0.05	0.03
BW chemistry control limits			
Conductivity, s/cm/25°C max.	3000	2000	1000
Silica, mg/L SiO_2 max.	0.4x OH alk.	0.4x OH alk.	0.4x OH alk.
OH Alk., mg/L $CaCO_3$	50 to 250	50 to 100	20 to 50
Polymer, mg/L actives	15 to 25	10 to 15	5 to 10
OR Chelant reserve, mg/L $CaCO_3$	4 to 8	3 to 6	2 to 3

Colin Frayne, CWT, is president of Aquassurance, Inc. Mr. Frayne has been a contributor to the Analyst and at AWT conventions. He is the author of several books, including the 2-volume set, Boiler Water Treatment Principles and Practice, and its companion Cooling Water Treatment Principles and Practice, published by Chemical Publishing, NY, NY. Mr. Frayne can be contacted by phone at (561) 267-4381 or by email at aquassurance@msn.com.

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Question #1

You have just acquired a new steam boiler system that you would like to treat with a phosphate/polymer treatment product that contains 10% disodium phosphate. Disodium phosphate contains 67% PO4. The target boiler water phosphate residual for this product is 45 ppm PO4. The boiler system has 50% high quality condensate return and operates at 15 cycles of feedwater concentration. Makeup is sodium cation softened water that averages 3 ppm calcium as CaCO3. How many ppm of product in the boiler feedwater will you need?

1. 37.4 ppm
2. 40.0 ppm
3. 52.4 ppm
4. 59.8 ppm
5. 74.8 ppm

Question #2

Ethylenediaminetetraacetic acid (EDTA) is often used to treat steam boilers for scale control. However this chelant has limited thermal stability. At what steam pressure does EDTA begin to decompose?

1 350 psig
2 400 psig
3 900 psig
4 1200 psig
5 1500 psig

Question #3

Your company has a chelant/polymer treatment for boiler scale control that contains 20% Versene 100 (38% EDTA). You would like to use this product to treat a boiler system that has 50% condensate return. The condensate averages 0.5 ppm ferrous iron. Makeup water is sodium cation softened that averages 3 ppm Calcium as Ca++ and 0.5 ppm Magnesium as Mg++. How many ppm of product will be required to satisfy chelant demand? The feedwater cycles of concentration are 10.

1. 26.1 ppm
2. 104.5 ppm
3. 261.1 ppm
4. 180.5 ppm
5. 361.0 ppm

Question #4

When properly controlled, which of the following is a non-precipitation type boiler water scale control treatment?

1. Phosphate-Chelant
2. Phosphate-Polymer
3. All Polymer-All Organic
4. Chelant-Polymer
5. Coordinated Phosphate-pH

Question #5

Which of the following is considered the most effective overall chelant type boiler water scale control treatment for general application?

1. Sodium EDTA
2. Sodium NTA
3. Sodium Glucoheptonate
4. HEDP
5. Sodium Citrate

Question #6

The Code of Federal Regulation (CFR) 21 §173.310 lists boiler water additives approved for use in food plants. Which of the following is not on the approved list?

1. Sodium carboxycellulose
2. Sodium polyacrylate
3. Quebracho
4. Sodium Humate
5. Sodium NTA

Question #7

For a 300 psig fire tube boiler using a phosphate program to treat 1 ppm of total feedwater hardness, what is the recommended maximum level of TDS in the boiler water?

1. 2000 mg/l
2. 1750 mg/l
3. 2500 mg/l
4. 2000 mg/l
5. 3500 mg/l

Question #8

For a 300 psig water tube boiler using an EDTA/Polymer treatment, what is the recommended maximum specific conductance of the boiler water?

1. 1000 μS/cm
2. 2000 μS/cm
3. 3000 μS/cm
4. 4000 μS/cm
5. 5000 μS/cm

Question #9

Hydroxy Ethylene Diphosphonate (HEDP) is sometimes used as an overlay in phosphate scale control programs. Like many boiler water additives it tends to thermally degrade at higher temperatures associated with increased boiler pressures. What is considered the upper pressure limit for HEDP?

1. 350 psig
2. 400 psig
3. 650 psig
4. 1000 psig
5. 1300 psig

Question #10

Recommended boiler water active polymer concentrations are usually based on a 1:1 ratio of polymer to feedwater total metals (Ca/Mg/Fe/Cu/Al/Ni). For a boiler operating at 300 psig and with a feedwater total metals of 0.5 mg/l, what should the boiler water polymer *product* level be if the feedwater is cycled 15 times? The polymer product is 25% active.

1. 10 mg/l
2. 20 mg/l
3. 30 mg/l
4. 40 mg/l
5. 50 mg/l

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