4.3 Chemical Cleaning

4.3.1 Introduction & Definitions

Cleaning Purpose

The purpose of chemical cleaning is to remove waterside deposits without causing appreciable internal metal loss. Achieving this will minimize tube damage caused by overheat and/or corrosion. The chemical cleaning covered in this document is to be performed on a boiler that is **off-line in a non-operating state**.

Typical Recovery Boiler Cleaning Focus Areas

Chemical cleaning focus areas are the wetted surfaces of a boiler, including drums, tubes, and headers. Additional circuitry may or may not include the feedwater air heater, economizer, and sweetwater condenser. Recovery boiler operating systems may vary with respect to component and circuit design. Any variation may impact how the guidelines and monitoring tools in this document are employed.

While superheaters may become contaminated with deposits, chemical cleaning of superheaters is a specialized process that is rarely performed on a recovery boiler and requires specialized engineering. Chemical cleaning of superheaters is not covered in this document.

Definitions

Acid Cleaning - The removal of deposits by means of an acidic solvent.

Air Bladders - A pneumatic device used to prevent a solvent from entering an area of the boiler that is not to be cleaned.

Alkaline Boilout - A procedure for removing organic residue (for example: rolling compounds, preservatives, cutting oils, or black liquor) and debris from wetted surfaces following new construction, refurbishment, or a contamination event.

Backfilling/Forward Filling - Filling any boiler component with properly treated water to establish and verify a water block. Backfilling adds properly treated water to a superheater, while forward filling adds properly treated water to the inlet of the economizer.

Chelant Cleaning - The use of an organic solvent (such as EDTA or citric acid) that sequesters the metallic components of a deposit.

Chemical Cleaning - The use of chemicals to remove waterside deposits. This may be a pre-operational cleaning or the removal of waterside deposits that have accumulated during the operation of a boiler.

Composite Drain Sample - A representative sample of a chemical cleaning stage collected over the duration of draining the solvent from the boiler.

Deposit Analysis - A laboratory procedure for the identification and quantification of inorganic and organic components within a tube sample deposit. The composition and concentration of these components can be determined as needed.

Deposit Weight Density (DWD) - A measure of the amount of deposit on the wetted surface of a tube sample over a given area (usually in g/ft^2 or mg/cm^2).

EDTA (Ethylenediaminetetraacetic Acid) - An organic sequestering/chelating agent that is used in different forms, depending on the application, to remove deposits.

Excursion - Deviations outside standard control limits.

Inhibitor - A chemical that is added to the chemical cleaning solvent to minimize attack on the parent metal.

Iron Oxide - A reaction product of iron with oxygen. There are two primary iron oxide forms in boiler deposits; hematite (red - Fe_2O_3) and magnetite (black - Fe_3O_4).

Loss on Ignition (LOI) - A measurement that includes organic components in a tube sample deposit. The measurement may include decomposition products of the LOI test, and therefore requires subject matter expert interpretation of the results.

Mill Scale - Iron oxide deposits formed during tube fabrication.

Neutralization - The pH adjustment of a residual cleaning solvent to halt a reaction on metal surfaces. It is also a process for pH adjustment of chemical cleaning waste streams.

Passivation - A process for establishing a protective oxide coating on a cleaned metallic surface.

Phosphate Hideout - A condition where phosphate complexes reversibly with iron and sodium under changing boiler load. It typically manifests as lower-than-expected phosphate levels and an increase in pH for a given phosphate dosage.

Pre-Operational Chemical Cleaning - The removal of organic matter, mill scale, and debris from the waterside surface of a new boiler or boiler component prior to being put into operation. It typically includes an alkaline boilout followed by mill scale removal. A vapor-phase cleaning and/or steam blow may be incorporated into a pre-operational cleaning, but is outside the scope of this document.

Solvent Efficacy Test (Dissolution Test) - A laboratory test on a tube sample to validate a proposed chemical cleaning process. This test is performed prior to a chemical cleaning.

Videoscope - A tool used to visually inspect boiler waterside surfaces. Also referred to as a borescope. For boiler inspection purposes, a videoscope should have recording capabilities.

Water Block - The use of water to stop the flow of a cleaning solution into boiler circuits that are not intended to be cleaned. Backfilling a superheater is an example.

4.3.2 Cleaning Determination Protocol

This section covers key information that should be considered when evaluating whether a chemical cleaning is necessary.

4.3.2.1 Determine History

- **Evaluate previous cleanings.** Valuable information can be learned from a review of past chemical cleanings. Note if there were any departures from the cleaning plan.

- **When last performed/frequency history.** Make a note of how often the unit has been cleaned and when the last cleaning occurred.

- **Deposits removed during previous chemical cleanings.** A history of composite drain sample analyses from past cleanings are often indicative of the deposits to expect during future cleanings. One-time upsets or evidence from a deposit analysis may indicate the need to consider deviation from previous chemical cleaning formulations.

- **Quantitative & qualitative data.** DWD and deposit analysis will play a significant role in determining what chemistries to use for a cleaning. Deposits can be highly localized, and may not be accurately reflected in a single tube sample. Analysis of deposit composition is another consideration, as certain deposits are much more likely to result in overheating of tube walls. Other useful data may include:

    - Rate of growth of the DWD
    - Tube failures from waterside deposits
    - Tube temperatures from chordal thermocouples.

  Deposits can cause overheating of tubes. High heat zones, low flow circuits, bends in tubes, and sloped/horizontal tubes can lead to higher deposit levels. During boiler inspections watch for signs of overheated tubes. Items to monitor should include:

    - Tube thinning/erosion
    - Surface irregularities
    - Visible bulges on the outside of tubes
    - Fireside corrosion.

- **Water quality changes or upsets.** Feedwater quality changes may alter deposit accumulation in the boiler. Water quality upsets have the potential to create new deposits or relocate existing boiler deposits. Some examples are listed below:

    - Condensate or makeup water contamination
        - High or low pH excursion
        - Liquor contamination
        - Fuel oil contamination
        - Hard water contamination
    - Phosphate hideout
    - Water treatment program changes.

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4.3.2.2 Review Major Rebuilds/Modifications

Rebuilds, upgrades, or changes in operating practices can alter heat release locations in a boiler, which may alter where deposits form. Changes in operating pressure affect flow rates in tubes, which can create areas of high deposition in regions that have not historically experienced such issues.

If sections of wall panels have been replaced, and a mill typically uses these areas for tube samples, the inside surfaces of the sample may not reflect conditions in the rest of the boiler.

4.3.2.3 Determine Current Conditions

- **Ability of tubes to withstand a chemical cleaning.** Evaluate whether a chemical cleaning is practical. Examples of conditions to consider:
    - Plugged tubes
    - Evidence of overheat
    - Reduced wall thickness
    - The amount/layering/composition of scale on boiler tubes.

4.3.2.4 Coordinate Pressure-Part Replacement Plans

If major pressure-part replacement is planned, the new components should receive an alkaline boilout. This can be performed once the tubes are in the boiler, or it may be performed prior to installation.

If an alkaline boilout is to be performed, the economics of a full chemical cleaning should be evaluated. If the pressure-part replacement was due to excessive deposits, the entire unit should be chemically cleaned.

4.3.2.5 Typical Cleaning Criteria

Time-Based Criteria -

Policies are commonly set that dictate a maximum time between chemical cleanings of a recovery boiler. A typical interval is 5 - 10 years. Many operators prefer time-based intervals because data-based decisions are from information that is subject to interpretation. Additionally, the selected sites for tube samples may not reflect where the heaviest deposits are located.

Time-based intervals should be shortened in the event of a significant water chemistry excursion. Time-based intervals are often used in conjunction with data-based criteria, wherein specific data drives the interval as long as the predetermined time interval is not exceeded.

Data-Based Criteria -

There are several types of information that can be used to make a data-based chemical cleaning decision. These are listed below. An educated decision requires assessment of more than one type of data.

- **DWD/Deposit Analysis -** Operating companies should develop a DWD criteria for determining when to clean a recovery boiler. See Section 4.2.3 for DWD frequency recommendations. The following are some OEM recommendations for evaluating chemical cleaning needs:

  B&W

  B&W recommends *planning* a chemical cleaning if hot side DWD values, obtained via the mechanical scraping method, are:

  - < 1000 psi; 20 - 40 g/ft^2 for low pressure boilers (< 70 bar; 21 - 42 mg/cm^2)
  - 1000 - 2000 psi; 12 - 20 g/ft^2 and for all recovery or refuse-fired boilers (70 - 140 bar; 13 - 21 mg/cm^2)
  - > 2000 psi; 10 - 12 g/ft^2 for high pressure power boilers (140 bar; 11 - 13 mg/cm^2).

  Reference A: B&W PSB-44

  Valmet

  Valmet recommends *chemically cleaning* any boiler in a paper mill if the hot side or cold side deposit, as obtained preferably via bead blasting, is:

  - < 1000 psi; 20 - 40 g/ft^2 (<70 bar; 21 - 42 mg/cm^2)
  - 1000 - 2000 psi; 12 - 20 g/ft^2 (70 - 140 bar; 13 - 21 mg/cm^2)
  - Or if there are any localized heavy deposits visible on the waterside of a tube.

  Reference B: Valmet Technical Paper Series Paper Mill Boiler Chemical Cleaning - Why, When and How. September 2016

  Andritz

  Andritz defers to Teollisuuden Vesi for *chemically cleaning guidelines* for a recovery boiler. Andritz recommends a chemical cleaning for a new recovery boiler, after major retrofits, or an existing recovery boiler which exceeds the following DWD readings:

  - 40 - 70 bar; < 50mg/cm^2 (575 - 1000 psi; 46 g/ft^2)
  - 70 - 100 bar, 30 - 45 mg/cm^2 (1000 - 1440 psi; 28 - 42 g/ft^2)
  - 100 - 140 bar, 20 - 30 mg/cm^2 (1440 - 2000 psi; 19 - 28 g/ft^2)
  - > 140 bar, 15 - 25 mg/cm^2 (> 2000 psi; 14 - 23 g/ft^2).

  Reference C: Teollisuuden Vesi Chemical Cleaning Guidelines, dated May 31, 2019

Thermal conductivity varies due to deposit composition, therefore chemical cleaning thresholds should not be based on DWD alone. Samples should be taken at high heat zones and areas of low circulation; however, high deposition has occasionally been found in areas of low heat input. Other locations where a tube sample extraction for DWD analysis may be warranted include areas of visible overheat. If a boiler has experienced tube failures from overheat, it would be prudent to take a sample from an adjacent tube.

- **Excursions -** The history of feedwater/boiler water excursions since the last chemical cleaning should be used in the evaluation process. See Section 4.3.2.1 for some examples of excursions. The severity and duration of the excursion(s) also need to be considered.

- **Tube Failures -** The history of boiler tube failures caused by waterside corrosion and/or deposits should be considered.

- **Videoscope (Borescope) Inspection -** Videoscope inspection is an additional nondestructive means of determining the condition of internal tube surfaces. It also provides a record of the condition of a given tube from outage-to-outage. The deposition as seen by videoscope is qualitative and subject to interpretation.

- **Other Nondestructive Tests -** There are other methods that may provide tube deposit indication. Methods that have been employed include x-rays, thermal scans, and specialized ultrasonic technology.

4.3.3 Chemical Cleaning

4.3.3.1 Pre-Cleaning Tasks

A tube sample should be sent out for analysis as soon as practical; prior to the scheduled chemical clean. The tube sample should be dry saw-cut. After extraction, the tube sample should be handled carefully so that the internal deposit is not dislodged and immediately taped at both ends to prevent loss of deposit. Detailed guidance on tube sample removal, shipment, and analyses is available from ASME (see Reference D: ASME Section CRTD-Vol 103).

Several sections of this tube should also be retained for the chemical cleaning company to use as test material for a selected chemistry. Chemical cleaning labs prefer tube samples that are at least 18" (45 cm) in length. Ensure that the original tube sample is long enough to send a portion to an analytical lab and a portion(s) to the chemical cleaning lab.

4.3.3.2 Chemical Cleaning Selection Criteria

The cleaning process is typically selected based on the composition of the deposit, the density of the deposit, and morphology of the deposit. Certain deposits will shield others, and can yield an ineffective overall clean if the cleaning agents are not applied in the correct sequence. Multiple stages of the chemistry sequences may be required to ensure a thorough cleaning.

The table below represents typical relative effectiveness of common cleaning solvents.

	Makeup of Deposit				
Type of Cleaning	**Organics**	**Iron**	**Copper**	**Silica**	**Hardness (Ca/Mg)**
Phosphate Boilout	Good	N/A	N/A	N/A	N/A
Permanganate	Good	N/A	N/A	N/A	N/A
Hydrochloric w/ABF*	N/A	Good	Poor	Medium	Good
HCl w/ABF & Thiourea	N/A	Good	Medium	Medium	Good
EDTA**	N/A	Good	Medium	Poor	Varies***
Citric Acid	N/A	Good****	Medium	Poor	Poor
Citric Acid with ABF	N/A	Good	Medium	Medium	Poor
Bromate	N/A	N/A	Good	N/A	N/A

Notes:
*ABF - Ammonium Bifluoride
**EDTA - Ethylenediaminetetraacetic Acid
***Effectiveness is dependent on the specific formulation.
****Addition of ammonia at a pH of 3.5 – 5.5 improves iron removal.

4.3.3.3 Efficacy (Dissolution) Testing

The effectiveness of a selected cleaning strategy should be confirmed through laboratory testing. It may take several iterations, as the layering of deposits is not always easy to determine. The tube material for this laboratory testing should be a representative tube sample taken from the boiler. The laboratory chemistry tests should also emulate the time, temperature, conditions, and agitation anticipated for the cleaning.

4.3.3.4 Material/Solvent Compatibility & Corrosion Assessment

Prior to the cleaning, evaluate the potential for corrosion of the boiler and contiguous components. Carefully assess whether there are any dead legs in the circuits that can come in contact with cleaning solutions. Determine whether and how they can be flushed and neutralized.

Sweetwater condensers often have tubes (stainless steel, nickel/copper alloys, etc.) that are incompatible with certain solvents. If the water and shell side of the sweetwater condenser contains these materials and cannot be adequately isolated from the boiler for the cleaning, alternative solvents may be required.

If the boiler is known to have significant waterside damage (including, but not limited to, hydrogen damage, SAC, pitting, FAC, cracking) additional solvent selection criteria may need to be considered.

4.3.3.5 Waste Disposal

Regulations may vary by state, province, or country. Environmental considerations should be part of the planning process. This includes:

- Chemical approval of the proposed chemical cleaning process should be obtained as early as possible.
- Waste generated in the cleaning process can include metals removed from the waterside surfaces that are subject to environmental limits.

4.3.3.6 Pre-Engineering

- **Engineering required.** Every job should be carefully planned from chemical selection to waste disposal. Aspects include ensuring that all circuits receive the proper circulation for the chemistry utilized. A means of isolating components that are not part of a cleaning must be properly designed. Prior to resuming operation, all non-vertical tubes and headers should be flushed to remove debris (refer to Section 4.3.6.1). Pay particular attention to tubes that contain restriction orifices and to headers that may contain baffles.

  There are numerous additional details that require careful design to ensure that the cleaning is effective and does not harm the unit.

- **Equipment requirements.** Most recovery boilers are not designed to be chemically cleaned. Therefore, additional temporary piping is typically required to complete the cleaning. In addition, chemical mixing headers, pumps, flow meters, and tanks are part of a chemical cleaning.

  Consideration for utilities including electrical, hot and cold water, steam, nitrogen, and instrument air must be reviewed.

- **Schedule**. Sufficient time must be allocated for the chemical cleaning including, but not limited to:
  - Installation and removal of temporary piping
  - Removal of internal drum components
  - Tie-in points to the boiler
  - Chemical cleaning stages
  - Inspection and flushing
  - Reinstallation of drum internals and pressure-parts
  - Hydrostatic tests
  - Iron removal and magnetite formation during start-up.

4.3.3.7 Perform Pre-Cleaning Piping Modifications & Associated Tasks

Thorough drawings and detailed scopes of work decrease the chance of an error. Pressure testing temporary piping reduces the possibility of leaks during execution of the cleaning. Careful attention to insulating the boiler, closing dampers, and otherwise avoiding drafts through the flue gas path ensures that the chemistry will remain in its most effective temperature range.

Boiler instruments are rarely compatible with cleaning chemistry. Instrument tubing is susceptible to plugging from the suspended deposits. It is important to isolate or remove tubing-connected instruments prior to a cleaning. A means of verifying the level of chemistry within the boiler is part of pre-cleaning design.

All existing piping and valves that are to be subjected to cleaning chemicals should be carefully reviewed prior to the boiler shutdown to identify leaks. These leaks should be repaired prior to the cleaning.

Valves that need to be operated during the cleaning should be lubricated and stroked before the job; repair or replace valves as needed. Blowdown piping should be purged while the boiler is operating under pressure. Drain piping should be blown down while the boiler is under pressure without a fire or residual bed in the unit.

Note: Certain jurisdictions require registration of temporary valves and piping connected to a boiler. Review applicable regulatory requirements for any alterations to the boiler, including temporary tie-ins.

4.3.4 Chemical Cleaning Tasks

Safety is a foremost concern with any chemical cleaning. A well-planned cleaning includes informing operating personnel of the hazards and steps in the entire process well in advance of the actual start of the cleaning. It is important to ensure that all operating personnel in the area are familiar with the written plan, as they may need to enter the area to operate valves. Personnel not essential to the cleaning should be restricted from entering the area.

4.3.4.1 Water Block Circuit Isolation

Verify that any circuit isolation achieved by means of a water block rather than blanks, valves, or bladders is in place before adding any cleaning chemicals to the boiler.

4.3.4.2 Verify Boiler Volume with Heating Water Fill

Fill the boiler with hot water using temporary flow meters to determine the volumes of critical levels of the circuits to be cleaned. This volume can be used to validate the estimated chemical cleaning volumes determined in the planning stage. When preheating boiler tubes, do not exceed 100°F temperature rise.

4.3.4.3 Ensure Chemistry for the Stage is Correct

Chemistry stages vary widely. Nevertheless, any chemical cleaning procedure should include the following:

- A procedure specific to the particular unit to be cleaned
- Verification of corrosion inhibitor
- Boiler metal temperatures specific for the chemistry
- Temperature, concentration, and estimated contact time for each stage
- Periodic testing of chemistry
- Circulation/agitation
- Rinse stage(s)
- Neutralization stages
- Neutralization of spent solution.

If stages are drained to the sewer, the draining must be maintained at a proper pH for that sewer. For example, draining acid to an alkaline sewer containing sulfides will liberate hydrogen sulfide gas. The neutralization solution should be of the appropriate concentration to facilitate adequate control.

4.3.4.4 Routine Testing of Cleaning Solution Samples

A representative sample of the solution in the boiler should be routinely tested to monitor the progress of the cleaning. Testing consistent with the chemistry utilized for each cleaning stage should be outlined in the procedure.

4.3.4.5 Maintain Logs & Retain Solvent Samples

Maintain detailed logs of all activity and testing. A composite sample of each stage must be collected and retained for calculating the amount of deposits removed and for environmental evaluation.

4.3.4.6 Be Prepared for Leaks

Removing corrosion products in pits or crevices with significant underdeposit corrosion may reveal leaks. If these leaks are significant enough, a cleaning may need to be aborted. An adequately sized holding tank or neutralization plan should be in place to drain the partially spent solution. The potential to reclaim partially spent cleaning chemicals could be considered.

4.3.5 Post-Cleaning Tasks

4.3.5.1 Flush & Inspect Drums, Tubes & Headers

A thorough flushing of drums, tubes, and headers is necessary to ensure that deposits loosened from tube surfaces do not redeposit once the boiler is put back into service. Water quality should be low TSS (total suspended solids), low pressure, and high volume. It may be necessary to remove bellyplates in drums. Careful inspection of the headers and drums should follow. Photographs and/or videoscopes of accessible tubes, drums, and headers are highly recommended.

4.3.5.2 Start-Up Water Quality & Operating Practices

Best practice is to ensure the boiler is started up as soon as possible following a chemical cleaning to minimize flash-rusting of cleaned surfaces. The start-up procedure for water chemistry and firing practices is designed to reestablish a magnetite layer as quickly as practical.

A start-up water quality procedure should be established in advance of the cleaning. It should be a collaboration between the mill, cleaning consultant, and water treatment subject matter experts. It is important to maintain water chemistry control and additional blowdown until targeted iron concentrations can be achieved. Topics that should be addressed in the written procedure include iron concentration, continuous blowdown, mud drum blowdowns if necessary, drum pressure, water chemistry, supplemental water treatment chemicals, venting and load schedule, and testing intervals.

4.3.6 SOPs

4.3.6.1 - *Deposit Weight Density* - DWD is a measurement of the weight of deposit material for a given surface area of the inside of a tube sample. For boiler waterside surfaces, this deposit is typically measured on the hot and cold sides of the tube.

ASTM D3483 provides three different test procedures for determining DWD. It is important to utilize the same procedure over time to ensure accurate comparison of successive tube DWD samples.

- ASTM D3483, Method A - Mechanical Removal by Scraper or Vibrating Tool
- ASTM D3483, Method B - Chemical Removal by Solvent
- ASTM D3483, Method C - Mechanical Removal by Glass Bead Blasting

Reference E: ASTM D3483

4.3.6.2 - *Tube Sample Deposit Analysis* - A tube sample extracted from a boiler should be analyzed for DWD and composition of the deposit. Morphology of the deposit and the overall condition of the inside of the tube surface can also be determined from a tube sample. All of these can provide valuable information about the condition of the internal tube surface.

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	The composition of the deposit will have a significant impact on the heat transfer characteristics and can impact the potential for underdeposit corrosion. Typical constituents of a deposit include, but are not limited to: • Iron • Copper • Calcium • Silica • Phosphate • Magnesium • Manganese • Aluminum • Organic matter • Sulfate. The morphology is an indication of how the deposits layer on the waterside surface. The composition and morphology of the deposit will have an impact on chemical cleaning formulation and steps. Visual inspection of the inside of the tube surface, after deposits have been removed, may indicate corrosion of the tube surface.
	Guideline #1: It is recommended that a subject matter expert specify and plan a chemical cleaning. The subject matter expert should also oversee the clean. The importance of a subject matter expert becomes more critical as the complexity of the deposits increase.
	Guideline #2: The use of a qualified cleaning contractor is recommended to ensure that a chemical cleaning is executed as designed.
	Guideline #3: A chemical cleaning is a substantial time and cost commitment. When the decision is made to schedule a chemical cleaning, a mill should commit the time and resources to ensure that it is properly executed. If shortcuts are taken either in the design or execution of a cleaning, it is possible to harm the boiler, or result in an ineffectual clean.
	Guideline #4: The decision to chemically clean an economizer should be made on a case-by-case basis with input from appropriate subject matter experts.
	Guideline #5: Sweetwater condensers should receive careful consideration when planning a cleaning. Their relatively small tubes are prone to plug with deposits carried from the boiler circuitry. Review the metallurgy of the sweetwater condenser to ensure the compatibility with proposed cleaning solvents.

	Guideline #6: A written procedure shall exist for all stages of the cleaning. This procedure should include SDSs for products brought on-site, safety protocols, required PPE, and a barricade plan.
	Guideline #7: A detailed log shall be maintained during the chemical cleaning stages. At a minimum, it shall include the volumes of chemicals added, the volumes drained from a boiler, the concentration and/or amount of chemicals added, and solution temperatures.
	Guideline #8: If any corrosion coupons were installed in the boiler during the chemical cleaning, they shall be removed prior to start-up.
	Guideline #9: A written plan shall exist for start-up water quality and passivation assurance. It shall include dosage of boiler treatment chemicals, frequency of water tests, pH targets, target iron levels over time, blowdown levels, and contingency actions. Strong consideration should be given to maintaining a dedicated water test operator during start-up.

4.3.7 ESOPs

ESOPs should be established prior to the cleaning process to contend with unforeseen incidents that can occur during this process. These procedures vary by mill, but may include:

- Spills
    - Temporary piping failures
    - Containment failures
    - Overfilling of the boiler
    - Tank failures
- Emergency tanks
- Emergency drains
- Loss of site power/utilities/water/air
- Cross contamination
- Draining into incompatible sewers
- Leaks
- H_2S mitigation
- Chemical vapors/flammable gases
- Personnel exposure.

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4.3.8 Monitoring	
	4.3.8.1 - *Deposit Weight Density* - Any tube collected for analysis should have the DWD determined. Tube samples from the high heat zone in a furnace are typically utilized for analysis. Boiler manufacturers may be able to provide information on the best locations to collect tube samples. Note that the highest deposits in a boiler are not always in the high heat zone of a furnace.
	4.3.8.2 - *Deposit Composition Analysis* - Tube sample testing should include waterside deposit composition analysis. Deposit composition analysis can identify water chemistry issues that may not be noted in routine review of routine water chemistry data. The deposit composition can be determined quantitatively by analyzing the elements by a variety of techniques including atomic absorption spectrophotometry, inductively coupled plasma (ICP), and X-ray fluorescence (XRF). Organic composition is typically indicated by LOI. The amount of organic material in the sample is key information that is necessary when formulating a chemical cleaning. It is not always included when a tube is sent for analysis, but should be specified.
	4.3.8.3 - *Dissolution Test* - Laboratory should perform solvent tests to find the most effective chemical cleaning solvent(s) to be used. Any tube that is tested in a laboratory to determine effectiveness should include photographic documentation of the cleaning effectiveness.
	4.3.8.4 - *Venting* - The boiler shall have an appropriately sized vent for the cleaning which should be routinely monitored during the cleaning for evidence of foaming.
	4.3.8.5 - *Temporary Sight Glass* - A properly designed, temporary level indication should be in use to verify that boiler steam drum level remains within the procedural specification during cleaning stages.
	4.3.8.6 - *Solvent Inhibitor Test* - The chemical cleaning contractor should perform a solvent inhibitor test approved and witnessed by the mill prior to introducing any mineral acid solvent to the boiler.
	4.3.8.7 - *Solvent Sampling* - Periodic solvent samples shall be collected from the boiler during cleaning stages to determine the concentrations of the solvent and amount of deposits removed. A composite drain sample shall be collected and analyzed for each solvent stage performed.

References:

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A. Babcock & Wilcox Plant Service Bulletin PSB-44B Chemical Cleaning Guide, 1999.
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D. ASME. Consensus on Best Tube Sampling Practices for Boilers and Nonnuclear Steam Generators. New York, NY: ASME, 2014. CRTD-Volume 103.
E. ASTM D3483-14 Standard Test Methods for Accumulation of Deposition in a Steam Generator Tube.