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# Keys to successful chemical cleaning of boilers

## Scope

This paper is designed to answer the question, "How do we avoid having failures in chemical cleaning boilers?" It covers key points in assuring successful boiler chemical cleaning projects, but is not intended to be an exhaustive treatment of the subject of chemical cleaning. It is an overview, with references for those interested in pursuing the subject further.

This paper does not address how the decision is made as to when chemical cleaning is necessary. That is a major topic that would require a paper of its own, larger than this one, for adequate treatment.

Keys to successful chemical cleaning projects can be divided into two major topics:

• Solvent selection.
• Engineering and execution of the project

Once a solvent is selected, boiler preparations must be made in order to accommodate:

• Safety
• Boiler venting, filling and draining.
• Permanent instrument protection.
• Solvent agitation and uniform distribution within the boiler.
• Protection of the superheater.
• Solvent heating.
• Solvent sampling.
• Monitoring of solvent level in the steam drum.
• Solvent disposal

## Safety precautions

Personnel protection must be integrated into the project engineering. The following steps should be taken:

• Barricading of the boiler, manifold area, injection hoses, and temporary equipment in order to prevent nonparticipants from entering areas where they might be exposed to the chemicals.
• No welding or torch cutting is to be performed on the boiler during the cleaning process, nor in the immediate area because chemical cleaning usually generates flammable hydrogen gas.
• Personal protective equipment including chemical proof clothing, goggles, and respirators should be worn when entering the barricaded areas when chemical exposure is a risk.
• Hydrogen sulfide monitors should be in place.
• Escape routes should be planned and communicated.
• Adjacent operating areas should be informed of the operation and the associated hazards.
• First aid and eye wash facilities should be immediately accessible.
• A safety meeting, with both plant and cleaning contractor personnel attending, should be held before the project starts.
• Check valves should be on all water and steam supply lines.

## Definitions

*Beaker tests* – Laboratory tests to determine the solubility of the deposit in various cleaning solutions. These tests are done at the same conditions (temperature, concentration, etc.) as may be used on the cleaning project.
*Chemical cleaning* - the removal of deposits by dissolving or disintegrating the deposits in chemical solutions.
*Corrosion inhibitors* – Substances added to acids and other corrosive liquids to mitigate corrosion of the equipment materials of construction that occurs during cleaning.
*Deposit* – Unwanted solid matter, which separates out of fluids in a process stream, coating equipment surfaces and interfering with process efficiency.
Deposit weight density (DWD) – The weight of deposit material per equipment surface area unit. It is generally expressed as milligrams per square centimeter ($mg/cm^2$) or as grams per square foot ($g/ft^2$).
*Dynamic loop* - A pilot scale cleaning apparatus that simulates the circulation cleaning of a boiler (or other tubular equipment). (See Fig. 1.)
*Neutralization* - The elevation of the pH of the cleaned metal surfaces to above 7.0 in order to prevent acid corrosion during post cleaning activities including operation.
*Passivation* - The formation of a thin, nonporous layer of magnetic iron oxide on the surface of the cleaned metal in order to prevent rusting before startup.
*Soft metals* **–** Reactive metals with low corrosion resistance. This includes zinc (galvanizing), aluminum, and magnesium.
*Solvent* – Any liquid, aqueous or non-aqueous, used to chemically clean equipment.

## Introduction

Waterside deposits are not evenly distributed in boiler tubes. High heat flux areas of boilers tend to have heavier deposit buildups. Deposits act as insulating layers, reducing heat transfer and raising tube metal temperature unevenly. A light, fluffy, insulating organic deposit may be even worse than a heavier amount of a dense adhering deposit that conducts heat better. Areas where metal temperature becomes excessive experience significant loss of yield strength, and they are frequently the sites of tube failures. Several waterside corrosion mechanisms also contribute to tube failures.[1] Cleaning to remove the waterside deposits will improve heat transfer, and can mitigate some of the corrosion mechanisms.

Mechanical methods of cleaning boiler tubes include "rattling the tubes," sending scrapers through the tubes, or high-pressure water jetting. Chemical cleaning of boilers is generally favored over mechanical methods because of more complete removal of deposits and shorter cleaning times. Paper mills have sometimes experienced failure to adequately remove the deposits when chemical cleaning their boilers. Such failures can generally be avoided by detailed execution of good procedures.

Chemical cleaning uses detergents, alkalis, organic solvents or oxidants to remove organic deposits such as oil, grease, tar or carbon. Inorganic deposits (minerals) are removed by low pH cleaners such as acids, or by chelants. Chelant cleaning solutions can have low, neutral or high pH. Acids tend to work faster than chelants, but can be more corrosive to the metal equipment if not properly inhibited.

## Solvent selection

### Sampling

***Proper selection of the solvent system to clean a boiler requires laboratory analysis of a recent sample of the deposit.*** Great care should be exercised in taking the sample and in shipping it properly, since the analysis is essential to the proper selection of a solvent for the project.



The best sample is a tube cut from the water wall at an area that historically had the heaviest deposit, usually the high heat flux area of the boiler. Several tube cuts should be taken if uncertainty exists as to where to sample.

Deposit samples chipped off of the metal surface may suffice in place of a tube cut if no tube section is available.

All deposit layers must be included in the sample. Tube sections generally are better for five reasons:

• The DWD can be determined.
• A tube section allows determination of whether the deposit can be removed from the metal surface even though it may not all be dissolved.
• A cross section of the deposit on the metal can reveal layers that may be missed in a loose scale sample.
• In solubility tests, loose deposits in the beaker may react differently with the solvent than the deposit on a metal surface, such as a boiler tube.
• The surface of the cleaned tube section can be examined.

All tube sections and deposit samples should be labeled with clear distinguishing descriptions to prevent confusion. Labeling on exteriors of tube sections should be in paint that will not rub off. Metal stamping should not be used, as the pounding can knock some of the deposit loose and it may be lost. The ends of the tube sections should be sealed to avoid sample loss in transit and to avoid ash from the outside of the tube contaminating the inside. A tube section being shipped should be packaged in a hard case, such as a wooden box or a plastic pipe with hard caps. Cardboard or paper packages are often cut through in transit by the sharp edges of the heavy tube sections.

If a current tube cut cannot be obtained, a sample from the most recent opening of the boiler can be submitted for analysis. Historical information from past cleanings is also helpful, but both of these approaches may fail to account for later episodes of contamination of the boiler water that can cause layers of deposit which may be more difficult to remove. Water samples, and deposit samples taken from drums, provide only limited information about the deposits in boiler tubes. Such limited information can be misleading, and should not be relied upon as the sole

basis for solvent selection.
Laboratories usually require minimum sample sizes. A typical minimum size for a loose deposit sample is 30
g (one ounce). When selecting a tube sample, ASTM D 3483 specifies a minimum tube length of 0.6 meter (2 feet)
for removal by dry sawing or grinding. For torch cut tube sections, NACE recommends a minimum tube length of
0.9 meter (3 feet). The longer length requirement when the tube section is taken using a cutting torch is because the
ends are contaminated by slag and will be cut off and discarded by the lab. Tube sections from tubes that failed
should not be used since the violence of the tube blowout will have removed some of the deposit.
Some boiler owners like to cut a long tube section into shorter ones to send to different labs for analysis.
Typical would be three sections, one to the chemical cleaning contractor, a second to the water treatment company,
and the third to an in-house lab or to an outside engineering consulting company. Even though the sections may be
adjacent cuts from the same tube, there will sometimes be significant differences in the reports. This is due to
differences in uneven deposits along the length of the tube, and to differences in test procedures used by the
laboratories. All the results should be taken into account for an accurate picture of the deposit unless one is
obviously out of line with the others.

**The lab report**

When the samples are sent, a clear understanding should exist about what will be reported. Allow two to four
weeks for normal handling and reporting. At a minimum, the lab report(s) should provide the following information
for each tube section:

- DWD.
- Chemical composition of the deposit.
- Results of solubility tests.
- Descriptions of unusual observations or appearances.

**Deposit weight density.** There are several methods for determining DWD[2]. Each tends to give different results.
The most commonly used methods are:

- Shot blasting with glass beads,
- Scraping with brushes and spatulas or a metal scriber, and
- Chemical deposit removal.