TECHNICAL ARTICLE

# Alkaline Boil-out vs. Acid Chemical Cleaning in Industrial Boilers

VGB-S-513 aligned commissioning cleaning: method selection, pH, chemicals, duration, quality verification, and decision guidance

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# 1. INTRODUCTION

In industrial boiler commissioning and maintenance projects, the terms alkaline boil-out and acid chemical cleaning (pickling) are often used interchangeably under the generic label “chemical cleaning.” In practice, the two methods differ in solution pH, the types of fouling they target, the circuits they clean, and the field infrastructure they require. Alkaline boil-out removes oil, grease, and loose construction debris in a high-pH environment; acid chemical cleaning dissolves adherent mill scale, iron oxide, and operational deposits using inhibited acid solutions.

This article compares both methods within the framework of VGB-S-513 in terms of chemicals, typical durations, cleaning objectives, quality verification, and selection criteria. The principal finding is that neither method substitutes for the other: on new boilers, alkaline boil-out is commonly applied together with steam blowing, whereas on high-pressure plants and in-service boilers, acid chemical cleaning should be treated as a separate engineering decision.

On site, treating “alkaline cleaning” and “acid cleaning” as equivalent is not merely a terminology issue; selecting the wrong method creates direct operational risk. For example, attempting to remove adherent deposits in steam circuits by alkaline boil-out alone leads to inadequate cleaning; applying acid chemical cleaning to a contaminant profile dominated by oil and grease wastes reaction capacity on organic foulants and increases project cost.

## 1.1 Terminology

The following terms are used consistently throughout this article:

- **Alkaline boil-out (boil-out):** A boiling operation carried out in the boiler water circuit with a high-pH solution.
- **Acid chemical cleaning (pickling):** The cleaning stage in which an inhibited acid solution is applied via external circulation.
- **Chemical cleaning:** Used only as the umbrella term covering both methods; it is not used as the name of a specific stage.

## 1.2 pH, contaminant profile, and cleaning mechanism


Method selection for internal boiler cleaning is driven primarily by solution pH and the target contaminant profile. The pH scale is defined from 0 to 14; pH 7 denotes a neutral environment, pH < 7 an acidic environment, and pH > 7 an alkaline environment. Typical pH for alkaline boil-out is 10.5–13; oil and grease saponify (emulsify) in this environment. Typical pH for acid chemical cleaning is 1–3; adherent iron oxide, deposits, and mineral scale dissolve in this environment. It is not feasible from an engineering standpoint to remove both contaminant types effectively within a single pH range.

Monitoring pH in the field or under laboratory conditions during cleaning indicates that the selected method is being applied correctly.

## 1.3 VGB-S-513 commissioning cleaning sequence

VGB-S-513 defines commissioning cleaning in a logical sequence:

**Flushing (Section4) → Alkaline boil-out (Section5) → Acid chemical cleaning (Section6) → Passivation → Steam blowing (Section7).**

This article focuses on the alkaline boil-out and acid chemical cleaning stages; flushing and steam blowing are treated as complementary steps. Skipping stages or executing them out of order in project planning adversely affects cleaning quality and the commissioning schedule.

# 2. Alkaline Boil-out Method

## 2.1 Purpose and Scope

The primary purpose of alkaline boil-out is to remove organic contaminants remaining from manufacture and erection (oil, grease, preservative oils, paint) and to establish a clean, operation-ready surface in the water circuit. A secondary purpose is to loosen loose rolling flakes and thin rust layers and to prepare conditions for formation of a protective magnetite layer during operation. Per VGB-S-513 Section 5, alkaline boil-out applies only to water-carrying circuits; steam lines (superheater, reheat, steam piping) are not cleaned in this stage.

Field advantages of the method include minimal temporary piping requirements (the boiler is heated with its own firing system), effective oil/grease removal in the water circuit, and the option to align scheduling with the refractory dry-out programme (VGB Section 5.3).

## 2.2 Chemicals and Dosage

For strong alkaline boil-out per VGB-S-513 Section 5.5.1, sodium hydroxide, trisodium phosphate, ammonia, hydrazine, and an antifoam agent are used. The resulting pH is approximately 12.5. In the mild alkaline method (Section 5.5.2), pH ~10.5 is targeted; the mild alkaline approach is preferred at plants that use demineralised water.

In recent years, organic alternatives (EDTA/NTA, polyacrylates, amine blends, and specialty chemicals that bind heavy metals and lift residues) have also been applied (VGB Section 5.5.3). These products combine degreasing and rust cleaning; however, because the chemicals are organic in nature, they increase wastewater COD (pollution load) and require costly wastewater treatment.

## 2.3 Duration and Procedure

Typical duration is 4–7 days. In the strong alkaline method, pressure is raised, held for approximately 2 hours, then reduced in a controlled manner; the cycle is repeated 1–2 times (VGB Section 5.5.1.5). In the mild alkaline method, pressure is held for at least 8 hours. Organic chemical methods typically use 2 × 24 h applications. **Flushing (VGB Section 4) is mandatory before alkaline boil-out; otherwise loose particles may obstruct circulation.**

## 2.4 Quality Verification

Alkaline boil-out quality is not judged by a single parameter. Sample analysis tracks pH, conductivity, and dissolved iron (Fe). Visual inspection (drum/header interior, endoscopy) confirms surface cleanliness. Reduced solids in blowdown/drain/continuous blowdown samples and improved water clarity indicate cleaning progress. In OEM programmes such as Valmet and Aalborg, magnetite film formation and development of the passive protective layer are assessed at temperature > 200°C, pH > 8, for 24–48 hours.

The image below shows a 24-hour sample series taken during alkaline boil-out. The reader should assess the colour change in the sample bottles from dark to clear tones as evidence of reduced fouling load and approaching completion; pH remaining in the 10.6–11.5 range indicates that alkaline character is maintained.

### 2.5 Limitations and Risks

- Alkaline boil-out does not clean steam lines; steam blowing (VGB Section 7) is required for SH/RH and steam piping. Strong caustic applications also carry stress corrosion risk in crevice regions (VGB Section 5.4).
- Bringing the burner into service requires fuel consumption planning.
- Alkaline wastewater must be neutralised before disposal.

## 3. Acid Chemical Cleaning (Pickling) Method

### 3.1 Purpose and Scope

The purpose of acid chemical cleaning is to obtain a defined clean metal surface on internal pipe walls and to form a protective magnetite layer through passivation (VGB Section 6). In pre-operational acid cleaning, manufacturing residues and protective oil films on internal pipe surfaces are removed in the acid stage; in post-operational acid cleaning, lime, silicate, and iron oxide deposits are targeted for removal. Per VGB-S-513 Section 6, acid chemical cleaning may cover all circuits of the water and steam systems.

Field advantages include combined cleaning of water and steam systems, potential shortening of steam blowing and faster achievement of steam quality, early turbine roll with OEM approval, and preserved heat transfer efficiency with reduced tube overheating risk.

### 3.2 Chemicals and Inhibitors

Degreasing may use an alkaline solution or surfactants. The acid stage employs mineral acids, organic acids, and chelants (EDTA, ammonium citrate) selected according to metallurgy and contaminant profile. **All acid chemical cleaning applications require inhibitor use**; without inhibitor, acid reacts with base metal, causing corrosion and hydrogen evolution (VGB Section 6.4). After cleaning, neutralisation, rinsing, and oxidising passivation (e.g. $H_2O_2$) are applied; alkaline rinsing then mitigates hydrogen risk.

### 3.3 Duration and Procedure

Typical project duration is 5–8 days (including preparation, acid circulation, rinsing, and passivation). Acid contact time is generally 2–6 hours; temperature is limited by inhibitor constraints (upper limit ~70°C for most inhibitors). The chemical cleaning circulation pump, circulation-water heater/steam generator, and temporary piping must be planned through detailed engineering before the chemical cleaning operation begins (VGB Section 6.1).

### 3.4 Quality Verification

Acid chemical cleaning quality is monitored during circulation via acid concentration, dissolved Fe/Cu, redox potential, and conductivity. Metal loss testing (corrosion coupons, VGB Section 10.3) confirms internal metal loss. Residual deposit (residual layer) measurement is performed by tube cross-section analysis (VGB Section

10.4). Visual inspection of the drum, headers, and tube bores confirms a clean metal surface. After passivation, a uniform dark magnetite film is assessed by before/after comparison.

The figure shows a comparison of the drum internal surface before cleaning (right) and after cleaning (left); the reader should focus on the contrast between the sludge/oxide layer on the right and the defined clean metal surface on the left.

## 3.5 Limitations and Risks

In acid chemical cleaning projects, wastewater volume and disposal costs are high. Temporary piping adds material and labour cost. Ventilation is mandatory because of hydrogen embrittlement and $H_2$ explosion risk. Acid residue in horizontal lines that cannot be drained may cause sustained corrosion. For austenitic steels and Ni alloys, metallurgy mismatch makes selection of the acid used in the chemical cleaning process critical (VGB Section 10.8).

## 4. Comparative Analysis of Methods

Alkaline boil-out and acid chemical cleaning are not interchangeable when compared by pH range, target contaminant type, circuit scope, and field infrastructure. The summary table below provides a quick reference for the principal differences.

| Characteristic | Alkaline boil-out | Acid chemical cleaning (pickling) |
|---|---|---|
| Typical pH range | 10.5 – 13 | 1 – 3 (inhibited acid) |
| Contaminants removed | Oil, grease, paint, loose oxide | Oil, grease + mineral deposits (calcium, silica) + oxide surfaces |
| Typical duration | 4–7 days | 5–8 days |
| Circuit scope | Water-carrying sections | Water + steam-wetted circuits |
| Circulation | Natural (boiler firing) | External pump (mandatory) |
| Typical application | New boiler commissioning | New (high pressure) + in-service maintenance |
| Advantages | Less temporary piping and preparation | Shorter steam blowing; faster achievement of steam parameters; degreasing step included; high cleanliness level; uniform protective layer; early turbine roll |
| Disadvantages | Burner must be in service; fuel consumption during boiler operation; steam side not cleaned | Wastewater management; temporary piping cost (material + labour) |

## 5. Selection Criteria and Decision Matrix

*Classic approach for a new boiler: alkaline boil-out (water-circuit degreasing) + steam blowing (SH/RH mill scale) = full commissioning cleaning package. Acid chemical cleaning is added when required by OEM specification or high-pressure plant requirements; it is not mandatory on every new boiler.*

## 5.1 New boiler (pre-operational)

For package boilers, HRSGs, and low- to medium-pressure plants, alkaline boil-out together with steam blowing is usually considered sufficient.

For utility boilers, high-pressure units, and projects with an OEM requirement for acid chemical cleaning, the sequence is planned as: alkaline boil-out (degreasing) → acid chemical cleaning (oxide removal) → passivation → steam blowing. If the contaminant profile is organic only (oil/grease), alkaline boil-out or external degreasing is preferred. For adherent mill scale in SH/RH, steam blowing is applied; if results are insufficient, acid chemical cleaning is evaluated.

## 5.2 In-service boiler (post-operational)

Indicators such as reduced heat transfer, increased pressure drop, and flow loss raise the need for operational acid chemical cleaning. Planned maintenance intervals are typically 3–5 years (depending on water chemistry and OEM requirements). If the contaminant profile contains only oil/fouling, degreasing or mild alkaline cleaning may suffice.

## 5.3 Decision matrix

In power plant and industrial commissioning projects, schedule and cost pressure often pushes teams to shorten cleaning scope. VGB-S-513 defines the contaminant-appropriate, complementary cleaning chain (flushing → alkaline boil-out → acid chemical cleaning → passivation → steam blowing) as the quality baseline. The decision matrix should be used to balance these two requirements for each project; skipping stages for speed or cost can lead to higher lifecycle cost through tube overheating in the boiler, steam quality deviation, or turbine damage.

Alkaline boil-out and acid chemical cleaning (pickling) are not the same process; they differ in pH range, target contaminant type, and circuit scope. Alkaline boil-out removes oil and grease in a high-pH environment, applies to the water circuit, and is executed with boiler firing. Acid chemical cleaning dissolves adherent oxide and deposits with inhibited acid, covers water- and steam-wetted circuits, and requires external circulation.

Cleaning quality is not measured by pH alone; dissolved iron, conductivity, residual layer, visual inspection, and post-passivation magnetite must be evaluated together. On new boilers, alkaline boil-out and steam blowing form the standard commissioning package; acid chemical cleaning is added per OEM requirements and contaminant profile.

A contaminant profile analysis must be performed before every project. Determining the proportions of oil/grease, mill scale, iron oxide, and mineral deposits forms the basis for deciding which stages (flushing, alkaline boil-out, acid chemical cleaning, passivation, steam blowing) are required. Selecting methods without profile analysis is an unacceptable risk to both cost and equipment integrity.

Method selection should be planned holistically within the VGB-S-513 cleaning chain, together with flushing and steam blowing. Schedule and cost pressure in the Turkish market should not mean compromising quality requirements; it should drive early definition of the correct scope.

## 6. References

*This article is based on the following primary sources:*


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