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TECHNICAL ARTICLE

Pre-Chemical Cleaning Flushing: Open Circuit or Filtered Circuit?

Comparative evaluation of pre-operational flushing practices in accordance with VGB-S-513 and field experience

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High-velocity water flushing applied before chemical cleaning in commissioned boilers, Waste Heat boilers and associated pipework is a critical step that determines the technical quality of the remainder of the project. VGB-S-513 defines flushing as the "first unrenouncable step." Similarly, the ASME PWR2004-52033 technical paper emphasises that oil, rust, loose mill scale, welding slag and construction debris must be removed before chemical cleaning.

This article compares open-circuit (open / once-through) flushing and filtered closed-circuit flushing in accordance with VGB-S-513, presenting industry field observations together with Proses Commissioning Tech. Corp.'s own project experiences. The key message is that **flushing is a mandatory preparatory step to ensure the subsequent chemical cleaning phase is completed correctly, economically and in a single pass.**

Flushing removes physically transportable particles from piping — loose rust, sand, dust, welding slag, wire fragments and construction debris. Adherent mill scale, magnetite layers and oil/grease films cannot be removed by flushing; these are cleaned by chemical descaling and alkaline boil-out respectively.

The strategic purpose of flushing is not merely to protect pumps and control valves — the primary objective is to ensure the subsequent chemical cleaning phase is completed correctly and economically. The typical 3–5% inhibited acid solution prepared for pre-operational acid cleaning is calculated to dissolve rust, mill scale and oxide layers adherent to internal pipe surfaces.

> *If free-floating rust, sand and particles circulating in the water are not removed by flushing, acid reaction capacity is consumed on these suspended solids and insufficient acid remains to dissolve adherent rust on pipe surfaces — a second pickling phase, additional chemicals, extra time and therefore additional cost become unavoidable.*

Flushing also protects pump suction sides, strainers and control valves during commissioning. However, chemical cleaning and flushing are not interchangeable; flushing is an essential preparatory step to leave a clean system for the acid phase.

1.1 Contaminant type and method matching

Contaminant type	Preferred method
Loose rust, sand, dust	Flushing
Welding slag, wire fragments	Flushing / blowdown
Oil and grease	Alkaline boil-out
Adherent mill scale, magnetite	Chemical cleaning (acid)
Adherent iron oxide layers	Chemical cleaning (acid)

2.1 Open-circuit flushing (Open / Once-Through)

Clean water passes through the system in a single pass and is discharged to the wastewater line or a temporary holding pond. VGB-S-513 Section 4.1.2: minimum velocity of 0.5 m/s in pipe systems (1 m/s for upward flow); at least 1.5× system volume per flushing cycle. For pre-flushing before chemical cleaning, VGB Section 6.2.4.2 specifies a turbidity target of < 0.2.

2.2 Filtered-circuit flushing (Closed-Loop + Filtration)

VGB-S-513 Section 4.1.4: Water is recirculated in a closed loop via a temporary pump; particles are retained in the filter. In theory water consumption is lower; in practice the outcome depends on filter efficiency, mesh size and recirculation duration. However, when flushing is inadequately completed, the second acid cleaning required, extended recirculation periods and additional filter consumption can practically offset or even exceed the claimed water savings advantage.

2.3 VGB completion criteria

Parameter	Ferritic systems	Austenitic / high-alloy
Conductivity difference (inlet-outlet)	< 20 µS/cm	< 2 µS/cm
Total suspended solids (TSS)	< 5 mg/l	< 1 mg/l
Visual	Clear, colourless, free of solids	Clear, colourless, free of solids
Pre-acid flushing turbidity	< 0.2 (spectral absorption)	< 0,2

The following technical data, shared from a chemical cleaning project completed using the filtered flushing method, is presented to provide a general understanding of how the method performs and the results obtained.

- Method: Filtered (closed-circuit) flushing
- System volume: ~540 m³
- Pump flow rate: ~550 m³/h (approximately one full turnover per hour)
- Filter stages: 100 µm → 40 µm
- Duration: 4–5 days continuous recirculation
- Result: Water remained visibly turbid; conductivity could be reduced to approximately 50 TSS, but clarity and suspended solids targets were not achieved.

Figure 1 — Dirty filter bag after filtered-circuit recirculation. Particle load exceeded filter capacity.

Figure 2 — Stainless steel multi-bag filter housing.

In a 540 m³ volume with one turnover per hour over 5 days of recirculation, this theoretically represents more than 100 full turnovers. Nevertheless, the persistent turbidity indicates that filters could not adequately retain fine particles (colloidal iron oxide, fine rust) and that particles continued to recirculate within the loop.

> *Conductivity (µS/cm) alone is not a sufficient completion criterion. High suspended solids and turbidity indicate that flushing has not been completed.*

3.1 Risk of premature transition to the chemical cleaning phase

When flushing is inadequate and the acid phase follows, field teams frequently encounter the following scenario: the citric acid or boil-out stage begins; however, when iron concentration in the water exceeds a certain threshold (for example 3000 ppm), draining the system and conducting a second acid cleaning comes under consideration. This threshold is technically meaningful — high iron loading disrupts the acid reaction. Yet in a system where adequate pre-flushing has been performed, iron at this level should not be expected at the start of the acid phase; this pattern indicates that pre-acid mechanical cleaning was not completed.

The acid solution is calculated for oxide layers adherent to internal pipe surfaces. When an attempt is made to clean free-floating rust with this acid, insufficient reaction capacity remains for adherent rust; a second cleaning creates additional burden in terms of cost, time and project schedule.

3.2 Defining completion criteria in the Method Statement

In every flushing application, the Method Statement (MoS) should clearly define at which criterion values the phase is considered complete. The turbidity (< 0.2), TSS, conductivity difference and visual clarity targets specified in VGB-S-513 are suitable reference points for this definition.

In practice, companies applying filtered flushing may be reluctant to make measurable commitments regarding cleaning performance; the absence of completion criteria in the MoS increases this uncertainty. It is a technical necessity for the owner or commissioning team to request these criteria before MoS acceptance.

In VGB-S-513 compliant open-circuit flushing, progress is monitored objectively: lightening of water colour in glass beaker samples, opacity/turbidity measurement by spectrophotometer, and conductivity and TSS analysis.

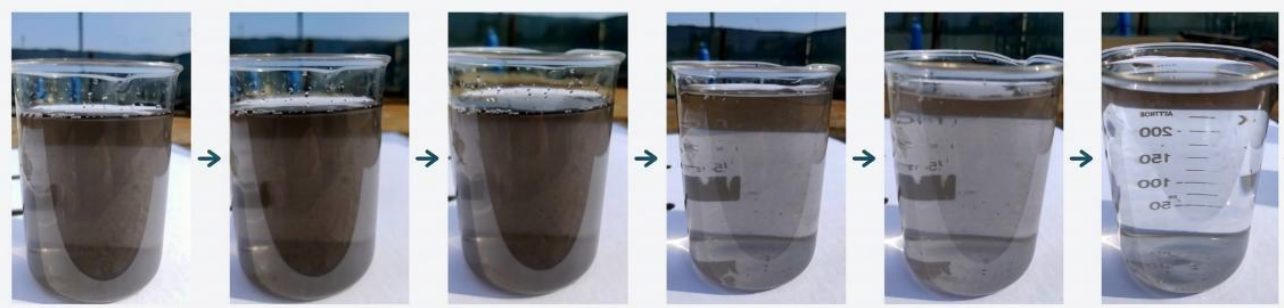

Figure 3 — Open-circuit flushing progress: transition from dark to clear water samples, left to right.

4.1 Field discharge photographs (different projects)

The following two photographs are from different projects and show the start and end points of open-circuit flushing.

Figure 4 — Start of flushing: dirty water discharge to temporary settling pond (high suspended solids).

Figure 5 — Flushing completed: clear water discharge (separate project).

4.2 VGB opacity test — flushing completion verification

Flushing completion verification is performed as a VGB opacity test using a spectrophotometer. Target: spectral absorption coefficient (turbidity) < 0.2.

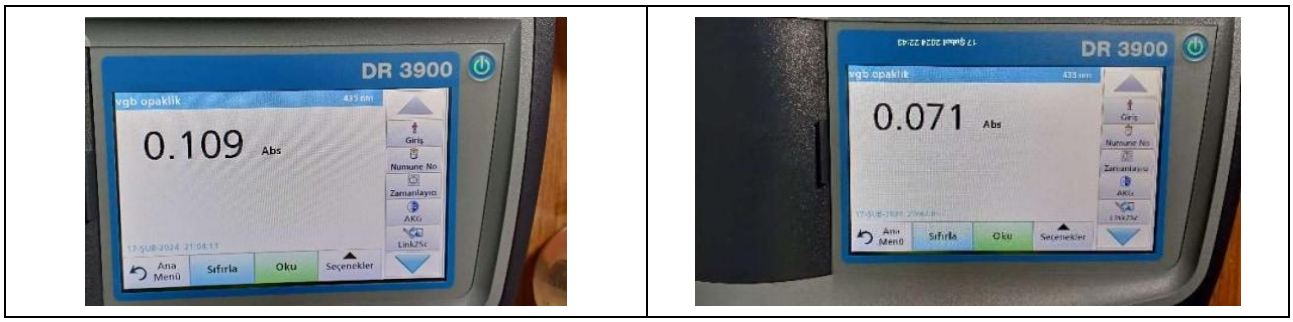

Figure 6 — VGB opacity test: 0.109 Abs and 0.071 Abs — both below the < 0.2 target.

> *While water may remain turbid after days of recirculation in filtered-circuit applications, VGB-compliant open-circuit flushing achieved the completion criterion with opacity of 0.071 Abs. The water savings advantage offered by the filtered method may practically lose its meaning when inadequate flushing leads to a second acid wash and project delays.*

The most frequently cited disadvantage of open-circuit flushing is water consumption — this is correct. However, the second acid cleaning required when flushing is inadequately completed, additional recirculation days and project delays can practically render the claimed water savings advantage of the filtered method meaningless. In commissioned plants, flushing waste additionally contains no chemical

contamination; the contaminants consist of fabrication rust, loose mill scale, sand, dust, welding slag and construction debris.

5.1 Settling pond method

- Flushing water is collected in a temporary waste / settling pond
- It is held for 24 hours — heavy particles settle to the bottom
- The clear upper water (free of suspended solids) may be discharged to sewer or an authorised discharge line
- Bottom sludge is disposed of as inert waste after drying
- Alternative: bottom sludge is collected separately with a submersible pump and upper water is discharged

VGB-S-513 Section 4.4 states that flushing waste is generally not problematic and that settling with flocculant may be applied where necessary.

Criterion	Open-circuit flushing	Filtered-circuit flushing
Adequate water supply	Preferred	Unnecessary complexity
Water-limited (desert, remote site)	Costly	To be considered
Cleaning quality target	Turbidity < 0.2, clear TSS target	Dependent on filter efficiency
Duration	Hours (with proper planning)	Days (risk of blockage)
Acid phase readiness	Low high-iron risk	Inadequate filtration → high iron

1. Flushing must not be rushed to completion. Inadequate flushing to save the chemical cleaning schedule leads to a second acid cleaning and delay costs.

2. The primary purpose of flushing is to prepare the system so that the 3–5% acid solution can dissolve adherent rust on pipe surfaces; attempting to clean free particles with acid consumes acid capacity.

3. Completion criteria must be defined in the MoS. Without turbidity, TSS, conductivity or opacity targets, the flushing phase cannot be measured or accepted.

4. Conductivity alone is not sufficient. Clarity, turbidity (< 0.2), TSS and iron analysis must be evaluated together.

5. Open-circuit flushing is the primary definition in VGB-S-513; it is the most reliable and verifiable method on sites with adequate Demineralised water supply.

6. The water savings advantage of filtered-circuit flushing may practically lose its meaning when inadequate flushing leads to a second cleaning and extended site duration.

7. Flushing waste from new plants Chemical cleaning Project is manageable; solid-liquid separation is achieved by 24-hour holding in a settling pond.

References

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