

Engineering Procedure

SAEP-1026

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Boilers Lay-Up Procedures

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Saudi Aramco DeskTop Standards

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1 Scope

This procedure provides acceptable methods for mothballing and lay-up of fired, water-tube, fire-tube, and waste heat boilers to minimize corrosion when they are off stream longer than five days.

The lay-up of boiler auxiliaries such as deaerators, pumps, motors, piping, valves, etcetera, are covered in the SAER-2365 Saudi Aramco Mothball Manual.

2 References

Saudi Aramco Engineering Procedures

[SAEP-327](#)

Disposal of Wastewater from Cleaning, Flushing, and Dewatering Pipelines and Vessels

[SAEP-1025](#)

Chemical Cleaning of Boilers

Saudi Aramco Engineering Report

SAER-2365

Saudi Aramco Mothball Manual

Saudi Aramco Engineering Standard

[SAES-A-004](#)

General Requirements for Pressure Testing

Saudi Aramco Form

Form 924-4

Confined Space Entry

3 Responsibilities

3.1 Operating Plant Management: responsible for the boiler lay-up.

3.1.1 Operations

Performs the boiler lay-up.

3.1.2 Engineering:

Recommends the procedures to be used for the lay-up. Advises, and assists the foreman of the boiler plant during lay-up activities involving the boiler, and associated equipment.

Inspection:

- Performs inspection before, and after lay-up.

- Monitors lay-up effectiveness.
- Maintains Inspection, Laboratory, and Engineering reports as a part of permanent plant records.

3.1.3 Maintenance

Provides maintenance support.

3.2 Research and Development Center (R&DC)

- Responsible Standardization Agent (RSA), for chemicals.
- Performs QA & QC monitoring of chemicals.

3.3 Boiler and Regional Laboratories

Perform chemical analysis, and log chemical analyses during the lay-up period.

3.4 Consulting Services Department

- Provides advice of specialist/consultant on request.
- Provides technical support to Operations Department upon request.

4 Introduction

4.1 Both the water-side, and the fire-side of boilers are to be protected against corrosion damage during idle periods.

4.2 The following factors contribute to corrosion on the water-side of a boiler system during shut down.

1. Dissolved oxygen, and ingress of oxygen
2. Low pH
3. Deposits inside the tubes
4. Changes in chemistry of the lay-up medium

4.3 The following factors contribute to corrosion on the fire-side during the lay-up.

1. Deposits of sulfur and other hygroscopic deposits on the tubes
 2. Water condensation on the tubes during the lay-up
 3. Other hygroscopic fire-side deposits
 4. Oxygen, and ingress of oxygen
-

4.4 The following design features influence corrosion during the lay-up.

1. Design of superheater with, or without drains.
2. The refractory lining design of the furnace, and bottom header region.
3. Provisions to completely fill, vent, and drain the boiler.

4.5 Three methods are available to protect the water-side of boilers during lay-up.

4.5.1 Wet lay-up

The boiler is completely filled with condensate water that is chemically treated to adjust the pH, and to remove dissolved oxygen.

4.5.2 Dry lay-up

The boiler is dried until no water is visible and the relative humidity inside is below 40%. Corrosion is minimized by humidity control, vapor corrosion inhibitors, displacing air with nitrogen, and maintaining a positive pressure of nitrogen.

4.5.3 Steam lay-up

Steam at 103-413 kPa (15-60 psig), from another source is continuously circulated inside the idle boiler to keep all metal surfaces hot above the dew point.

The fire-side of the boiler is also protected against corrosion, and the boiler can be returned to service quickly (usually within twenty-four hours).

4.6 Fire-side lay-up

The fire-side lay-up procedure as given in Section 10 is used when the water-side is laid up either wet, or dry.

5 Safety Precautions

- 5.1 Protective clothing, respirator, and goggles should be worn during vessel entry to avoid contact of lay-up chemicals with the skin, or eye; inhalation, or oral ingestion.
 - 5.2 Nitrogen gas does not support life. Disconnect all the temporary nitrogen lines before entry is made into the boiler. Do not enter boiler drum until thoroughly vented and tested in accordance with standard CONFINED SPACE ENTRY procedures.
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- 5.3 Ensure that all nitrogen cylinders are in upright position firmly supported, and that they have individual regulators. Also, install a safety relief valve to the manifold to which the nitrogen cylinders are attached.
- 5.4 Obtain Chemical Hazard Bulletins on various chemicals used, for lay-up from the Industrial Hygiene Services, Preventive Medicine Services Division, Dhahran (phone: 877-8527), and keep them within easy reach. These bulletins provide information on storage, handling and protective measures for chemicals.
- 5.5 Blind fuel gas and pilot gas lines. Isolate igniters and do not enter fire-side until CONFINED SPACE ENTRY (Form 924-4), permit is issued.

6 Selection of the Lay-Up Procedure

Commentary Note:

The choice of lay-up procedure may depend on availability of water, steam or nitrogen in a particular facility. Any of the following procedures are acceptable for long term or short term lay-up.

- 6.1 Select steam lay-up if steam is available, and rapid start up (< 24 hours), is required.
- 6.2 Choose wet, or steam lay-up if the boiler is expected to be down for less than four weeks.
- 6.3 Choose dry, wet, or steam lay-up if the boiler is expected to be down for more than 12 weeks.

7 Wet Lay-Up

- 7.1 If this procedure is used for long term lay-up note that occasional firing may be required (see paragraph 7.3.3 below).
- 7.2 Procedure
 - 1. Drain the boiler. Carry out any essential repairs.
 - 2. Connect a nitrogen supply to the highest vent on the boiler
 - 3. Fill the boiler with condensate water and inject approved oxygen scavenger (see Appendix 4), to maintain 200 mg/L to 400 mg/L residual concentration. Use sulfites (sodium or ammonium) only for boilers operating below 5170 kPa (750 psig), that have superheaters with drains. Add morpholine, or morpholine plus cyclohexylamine to adjust the pH between 10.0 and 11.0.

4. Shut off the water supply when it overflows from the steam drum, the superheater inlet, and the outlet header vents, and a pressure of 35 kPa (5 psig) is attained in the boiler steam drum.
5. Maintain a positive pressure of at least 5 psig in the system using nitrogen.

7.3 Boiler maintenance during wet lay-up

1. Install an appropriate calibrated pressure gauge and ensure at least once a day that the boiler pressure gauge reads >35 kPa (5 psig).
2. Take samples from the continuous blowdown line at least once a week. Check the concentration of oxygen scavenger, and the pH.
3. If the pH is not within the range of 10.0 to 11.0, and/or the concentration of oxygen scavenger < 200 mg/L, drain sufficient volume and add required amount of dissolved chemicals. Open the vent and fire the pilot burners until water is heated to 60°C to 70°C.
4. After cooling, introduce water and shut off the water supply when it overflows from the steam drum, the superheater inlet, and the outlet header vents, and a pressure of 35 kPa (5 psig), is attained in the boiler steam drum.
5. Maintain a positive pressure in the system using nitrogen.

7.4 Before placing the boiler back in service after wet lay-up:

1. Relieve pressure.
 2. Open the drum vents.
 3. Remove blinds in blowdown and drain lines.
 4. Drain the boiler.
 5. Drain the superheater section, and rinse with condensate water, until the conductivity of the water out of the superheater is within 10% of the conductivity of the condensate water being introduced to the boiler
 6. Open the steam drum, mud drum, and all water wall headers, including superheaters where installed.
 7. Water flush with condensate and vent the boiler.
 8. Ensure safety relief valve maintenance schedules are up to date, the boiler hydrostatic test is complete, boiler examinations are satisfactory, and the boiler auxiliaries and instrumentation are operable.
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9. Fill the boiler with clean condensate and complete pressure test per [SAES-A-004](#).
10. Drain the boiler to normal operating level.
11. Prepare and fire the boiler.
12. Test boiler safety relief valves under steam pressure before the boiler is placed in service at full operating pressure.
13. Disposal of all wastewater shall be in accordance with [SAEP-327](#).

8 Dry Lay-Up

- 8.1 Consider dry lay-up procedure if the boiler is to be laid up, for more than twelve weeks. For long term lay-up of economizers, neutralize and clean the external fins, and then use the procedure below.
 - 8.2 Procedure
 1. Disconnect the boiler from load and fuel supply.
 2. Drain the boiler under pressure, 138 - 172 kPa (20 - 25 psig).
 3. Remove all water in the low areas of the steam and the mud drums manually. Dry the boiler, economizer and the superheaters using hot air blowers, until there is no water visible and the relative humidity (RH), inside the boiler is below 40%.
 4. Install a suitable (such as Alpha Moisture Systems: Model 200D) hygrometer to monitor from outside, the RH inside the boiler.
 5. Dust, or spray vapor corrosion inhibitors (VCI), inside the tubes, drums and headers. Use dicyclohexyl ammonium nitrate, VPI-260, or VCI-309 (See Appendix 1). Wear personal protection equipment and apply VCI per manufacturer's recommendations.
 6. Close all openings except one small vent. Slowly displace the air inside the boiler, and the economizer, with nitrogen. Monitor oxygen and when it is displaced with nitrogen close the vent, and maintain 35 kPa (5 psig) nitrogen pressure. Post a notice adjacent to each boiler access point stating that the boiler is under nitrogen blanket.
 7. Replace VCI every two years or as per manufacturer's recommendation.
 - 8.3 Boiler Maintenance while in dry lay-up
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1. Keep the nitrogen line connected to the boiler. Maintain pressure using a pressure regulator.
2. Check the RH and the nitrogen pressure daily.
3. Install an appropriate calibrated pressure gauge and ensure that the nitrogen pressure is maintained at 35 kPa (5 psig). Check for leaks, and eliminate them. Introduce nitrogen as required to maintain this pressure.
4. Check the RH during the night, and in the winter months. Ensure that the RH is below 40%. If not open vent, and introduce nitrogen to displace the moisture until RH is below 40%.

8.4 Before placing the boiler back in service after dry lay-up:

1. Disconnect nitrogen supply, and open all boiler vents.
2. Flush to remove all traces of VCI, and inspect the boiler. Chemically clean per [SAEP-1025](#) if necessary.
3. Remove temporary seals used during the lay-up period.
4. Ensure safety relief valve maintenance schedules are up to date, the boiler hydrostatic test is complete, boiler examinations are satisfactory, and the boiler auxiliaries and instrumentation are operable.
5. Fill boiler with clean condensate and perform a pressure test per [SAES-A-004](#).
6. Upon satisfactory pressure test, drain the boiler to normal operating level.
7. Prepare and fire the boiler.
8. Test boiler safety relief valves under steam pressure before the boiler is placed in service at full operating pressure.

9 Steam Lay-Up

- 9.1 Steam lay-up protects both the water-side, and the fire-side of the boiler from corrosion. The boiler can be returned to service very quickly (usually within 24 hours). For long term lay-up of economizers, see Section 8.1.
- 9.2 Procedure
 1. Shut down the boiler.
 2. Inspect the boiler water-side and the fire-side.

3. If any deposit is present on the fire-side, neutralize, clean, and dry per [SAEP-1025](#), Section 11.
 4. Size, and fabricate a suitable condensate collector. (See Appendix 3).
 5. Ensure lower water wall header drains, superheater header drains, and mud drum drains are connected to the condensate collection header.
 6. Ensure the condensate collection header is equipped with a suitable level gauge, a pressure gauge, a sample point, a dial thermometer, and a steam trap; the steam trap is equipped with a by-pass line, and a drain to sewer.
 7. Size, and select steam traps to ensure complete removal of condensate from the boiler. Connect the steam trap to the condensate return system, at a suitable location as close to the boiler as possible.
 8. If a condensate collector is not used, install steam traps, and bypasses at each drain point.
 9. Connect the steam supply line to the superheater outlet header at its connection to the flash drum (knock-out drum).
 10. For boilers not equipped with superheaters, and equipped with more than one safety relief valve, remove one safety relief valve, and introduce the steam supply directly into the steam drum, through a temporary connection.
 11. For boilers not equipped with superheaters, and equipped with only one safety relief valve, install a temporary Tee connection. Install the safety relief valve at the vertical flanged, or screw connection. Introduce the steam into the boiler through the horizontal flanged, or screw connection. Installing a Tee to the boiler steam drum vent to admit steam is also acceptable.
 12. Provide vents at suitable points to remove gases. If the boiler is not equipped with vents to atmosphere from the upper water wall headers, remove one hand hole plug from each header, and install a temporary vent pipe and valve. Provide the upper water wall headers, and the steam drum vents with reducers, and install 0.25", or 0.375" stainless steel tubing for venting.
 13. Provide temporary drains for lower water wall headers with no drains. Remove a hand hole plug (usually a screw plug on the lower part of the header), and weld a suitable diameter pipe into it. Connect the pipe to a steam trap, or condensate collector.
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14. Provide temporary vents and valves for upper water wall headers not provided with vents.
15. Close forced draft/induced draft fan inlet vanes, and seal the exhaust duct.
16. If the boiler is expected to be down for more than 12 weeks, inspect, repair, and clean the inside of all duct work, and the stack. For long term lay-up of economizers, see Section 8.1.
17. Install a heavy duty waterproof cover on the stack, with a suitable ridge arrangement to drain condensed water.
18. After completing all preparations, admit steam into the boiler. To avoid thermal shock, control the entry of steam to raise metal temperature $\leq 38^{\circ}\text{C}$ per hour, until the temperature is stabilized.
19. After all condensate produced is removed from the lowest parts of the boiler, raise the steam pressure to 171 kPa (25 psig). Open the vents, and release pressure to purge all the air from the boiler. Repeat this three times. Close the vents, and increase the steam pressure to 105 - 415 kPa (15 - 60 psig).
20. Examine and repair steam leaks at all temporary, and permanent connections.
21. Regulate the pressure in the boiler, for a minimum temperature of 100°C at the lowest point, i.e., the condensate collector, or steam trap inlets. For boilers which have superheaters without drains to remove water, maintain a minimum temperature of 120°C at the lowest point of the boiler, or at the condensate collector.

9.3 Boiler maintenance during steam lay-up

1. Analyze steam trap discharges periodically, for $\text{pH} \geq 7$, and conductivity ≤ 10 microsiemens, and if acceptable, connect into a collection header to the existing condensate return system. If not acceptable, discard the condensate into the sewer.
2. Ask the laboratory to determine O_2 , and CO_2 content of the condensate samples, daily for seven days. If the O_2 , and CO_2 level are higher than 20 micrograms/liter (ppb), adjust the steam drum, and upper water wall header vents to remove the O_2 and CO_2 . If necessary, add sufficient volatile oxygen scavenger (VOS) to the steam source.
3. If O_2 , and CO_2 levels are at < 20 ppb, reduce sampling of the condensate to once per week.

4. Ensure that a suitable water level is maintained in the condensate collector. When a condensate collector is not used, examine steam traps at regular intervals. Use drains installed to the steam trap system to prove that condensate is not collecting in the lower headers, or mud drum.
5. In the event of a plant, or system failure resulting in the loss of steam supply to the boiler, shut off steam inlet to the boiler. Once the steam supply becomes stable, proceed as outlined in steps 18 to 21 (Section 9.2).
6. During the steam lay-up, keep the relief valve maintenance up to date, to enable quick start up.
7. Inspect the boiler after 6 months, and then after 12 months to confirm that corrosion is under control; thereafter, inspect annually. Inspect the fire-side of the boiler every six months, and ensure that expanded boiler tube joints have not developed leaks.

9.4 Before returning the boiler to service after steam lay-up:

1. Shut off the steam supply to the boiler.
 2. Allow steam pressure to decay to 69 kPa (10 psig).
 3. Open steam drum vents to atmosphere.
 4. Open the valve connecting the superheater to the flash drum (knock-out drum).
 5. Close all lower water wall header drain valves and mud drum drain valves.
 6. When the pressure in the boiler is at zero gauge, isolate and disconnect steam supply.
 7. Remove the temporary safety relief valve connections, and install the permanent safety relief valves.
 8. Remove all temporary upper, and lower water wall header drains, and vents. Replace hand hole plugs previously removed.
 9. Remove cover from stack, and temporary seals used during the lay-up period.
 10. Ensure safety relief valve maintenance is up to date, the boiler hydrostatic test is complete, boiler examinations are satisfactory, and the boiler auxiliaries, and instrumentation are operable.
 11. Fill boiler with clean condensate, and perform a pressure test per [SAES-A-004](#).
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12. Drain the boiler to normal operating level.
13. Prepare the boiler for firing.
14. Test boiler safety relief valves under steam pressure before the boiler is placed in service at full operating pressure.

10 Fire-Side Lay-Up

This procedure is not applicable with steam lay-up. Use only procedure steps 1 to 6 for short term lay-up, and all the steps, for long term lay-up (> 12 weeks).

10.1 Procedure

1. Install necessary blinds in the main fuel lines, pilot gas line, and isolate the boiler igniters.
 2. Inspect the refractory, and the tubes on the fire-side. If any deposit is present, neutralize, clean, and dry per [SAEP-1025](#), Section 11. Seal all refractory, and partially embedded tubes with bitumen.
 3. Install new gaskets on all furnace openings, and manholes. Apply sealing compound on the gaskets of plate type covers.
 4. Close stack blinds, seal the furnace, and cover the forced draft/induced draft fan air inlet with plastic sheeting film, and tape completely, to prevent any ingress of air.
 5. Seal with plastic sheet, and tape, all inlet and exhaust ducts, observation ports, and duct manways, to prevent entry of air.
 6. Seal burner sight glasses tightly.
 7. Dust, or spray vapor corrosion inhibitor (VCI), on all the exposed metal in the fire-side. Use dicyclohexyl ammonium nitrate, VPI-260, or VCI-309 (See Appendix 1). Wear personal protective equipment, and apply VCI per manufacturer's recommendations to get corrosion protection up to 24 months.
 8. Place electric heaters inside the firebox, and flue gas duct. Keep metal surfaces above ambient temperature to reduce moisture in the system. Install ammeters outside the firebox to check the operation of the heaters.
 9. Install a thermometer to check the temperature of the fire-side from outside. Ensure that the thermometer entry location is tightly sealed.
 10. Make all cable entries into the fire-side air tight.
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11. Remove burners, clean, preserve with VPI-260, or VCI-309 (See Appendix 1), and seal them.
12. Inspect, repair, and clean the inside of all duct work, and the stack. Dust, or spray VCI on all the exposed metal. Install a heavy duty waterproof cover on the stack, with a suitable ridge arrangement to drain condensed water.

10.2 Maintenance during the lay-up

1. Ensure that the temperature inside the fire-side is above the ambient.
2. Visually inspect after one month all the sealing used to isolate the fire-side atmosphere. Correct any deficiencies. If conditions are satisfactory, then extend the frequency of inspection to every three months, and then to every six months.

Reapply VCI every two years per manufacturer's recommendations.

11 Corrosion Control, Water and Chemical Treatment Subcommittee

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Olavo Dias	Member
Robin Tems	Member
Abdulatif Abdulhadi	Member
Abdelhak Kermad	Member
Mike Morrow	Member
Robert Palmer	Member
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Revision Summary

28 February 2005

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.

Appendix 1 – SAMS Numbers of Lay-Up Materials

Product Name	SAP MM
Adhesive duct tape for sealing openings, securing plastic protective film, etc.	1000205777
Liquid Ammonia (Ammonium hydroxide)	1000178423
Catalyzed sodium sulfite liquid	1000186446
Cyclohexylamine plus morpholine	1000183543
Dicyclohexyl ammonium nitrate VPI-260	1000183807
Diethyl hydroxyl amine (DEHA)	1000185091
DEHA	1000186446
Electric heaters	1000062846 1000062852 1000062880
Film, plastic 4 mil polyethylene film for protection of equipment	1000216006
Morpholine	1000184683
Nitrogen (cylinder)	1000184763
Soda ash (Sodium Carbonate)	1000186131

Cortec VCI-309 is available through Kanoo Specialty Chemicals, phone 03-857-1265.

Appendix 2 – Definition of Terms

Blend-filling: A method of filling a vessel with chemical solution in which the chemical concentrate (in liquid form) is metered into the filling line to maintain the desired concentration level in the liquid entering the vessel.

Condensate Water: Water having a conductivity of less than 10 microsiemens.

Inhibitor: A compound that retards or stops an undesired chemical reaction such as corrosion or oxidation.

Mothballing/Lay-up: Preservation of a system, or equipment, for later use.

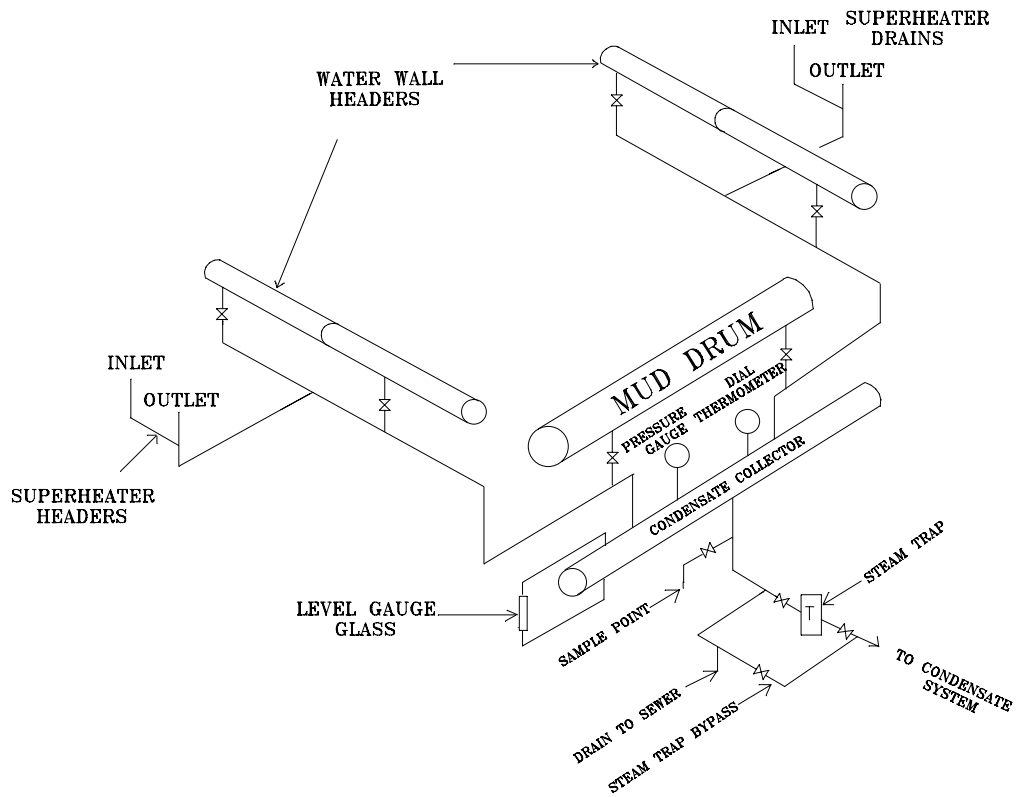
pH: The negative logarithm of hydrogen ion (H^+), concentration in a solution. At a value of 7 the solution is neutral i.e. an equal number of hydrogen (H^+), and hydroxyl ions (OH^-), are present. A value of < 7 is acidic (excess of H^+), and > 7 basic (excess of OH^-).

Water Wedged: Water overflowing vents.

Acronyms:

DEHA	:	Diethyl Hydroxyl Amine
QA & QC	:	Quality Assurance and Quality Control
VOS	:	Volatile Oxygen Scavenger
VCI	:	Vapor Corrosion Inhibitor
VPI	:	Vapor Phase Inhibitor

Appendix 3 – Boiler Drainage Under Steam Lay-Up



Appendix 4 – Approved Oxygen Scavengers

Scavenger Name	Formula	Feed ratio scavenger/O by wt.
Carbohydrazide	$\text{CH}_6\text{N}_4\text{O}$	23
DEHA	$\text{C}_4\text{H}_{11}\text{NO}$	3
Hydroquinone	$\text{C}_6\text{H}_6\text{O}_2$	4
Methy Ethyl Ketoxime	$\text{CH}_3(\text{NOH}) \text{C}_2\text{H}_5$	5.4
Sodium sulfite	Na_2SO_3	8
Catalyzed Sodium sulfite	Na_2SO_3	8
Ammonium bisulfite	NH_4HSO_3	8

Determine first the mass of oxygen scavenger needed by calculating the mass of oxygen in solution and multiplying it by the feed ratio and add 200 mg/L more. To determine the quantity of a supplied chemical needed take into account the concentration of oxygen scavenger in that chemical. For example to treat 10000 L of water with 8 mg/L dissolved oxygen with 45% wt. ammonium bisulfite solution $[(8 \times 10000 \text{ L} \times 8 \text{ mg/L}) + 10000 \text{ L} \times 200 \text{ mg/L}] / 0.45 = 640000 \text{ mg} + 2000000 \text{ mg} / 0.45 \sim 5866666 \text{ mg}$ or approx. 6 kg of 45% wt. ammonium bisulfite solution is required.