



Engineering Procedure

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Chemical Cleaning and Flushing of Lube/Seal Oil and Fluid Power Systems

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1 Scope

This engineering procedure defines the responsibilities of the various departments involved in the cleaning of lube/seal oil and fluid power systems. It outlines methods to determine the need for chemical cleaning, the criteria for selecting specific cleaning procedures and steps, and controls involved in the implementation of the various cleaning procedures.

2 Applicable Documents

The following documents apply as referenced in this procedure:

Saudi Aramco Engineering Standards

[SAES-A-104](#)

Waste Water Treatment, Reuse and Disposal

[SAES-B-069](#)

Emergency Eyewashes and Showers

[SAES-G-116](#)

Cleanliness Standard for Lube/Seal Oil and Fluid Power Systems

3 Purpose

It is necessary to clean a new lube/seal oil or fluid power system initially per [SAES-G-116](#) and to repeat the cleaning periodically thereafter to maintain efficient operation, and to prevent equipment failures. Cleaning is accomplished by a combination of:

- Mechanical cleaning
- Flushing
- Steam cleaning
- Hot alkaline treatment
- Acid/EDTA cleaning
- Neutralization and passivation

For some systems it may not be necessary to use all of the above steps since the degree of contamination will vary from unit to unit. The exact procedure used for cleaning will be determined after consultation with the various departments outlined in Section 4, taking into consideration deposit density and composition, equipment condition and inspection results. Procedures outlined in this document shall not override the cleaning recommendations made by the system manufacturer, particularly where warranty conditions are involved. However, any differences between these procedures and those recommended by the manufacturer shall be questioned and resolved by the proponent.

4 Responsibilities

The Project Construction Agency is responsible to arrange the cleaning to get MCC (Mechanical Completion Certificate) of new or demothballed lube/seal oil and fluid power systems. The facility-operating department is responsible for periodic cleaning of existing systems.

4.1 Project Construction Agency

1. Has the overall responsibility for the cleaning of newly installed systems.
 2. Coordinates and obtains the approval of chemical cleaning procedures and formulations from the Consulting Services Department/Chemical Cleaning Group.
 3. Provides sufficient steam condensate or demineralized water, and nitrogen at site to accomplish the cleaning operations.
 4. Prepares the system mechanically.
 5. Coordinates chemical cleaning and obtains contractor services from Saudi Aramco's approved list of chemical cleaning contractors.
 6. Has the responsibility to arrange with Projects/Operations Inspection and specialist personnel from Consulting Services Department (CSD) for before-cleaning and after-cleaning inspection.
 7. Lay-up the system to protect it against corrosion.
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4.2 Facility Operating Department

4.2.1 Has the overall responsibility for the operational chemical cleaning of lube oil and seal oil systems.

4.2.2 Maintenance

1. Prepares the lube/seal oil and fluid power systems mechanically.
2. Makes provisions to supply sufficient steam condensate or demineralized water, and nitrogen at site to accomplish the cleaning operations.
3. Provides maintenance support during the chemical cleaning operation.
4. Coordinates chemical cleaning and obtains approved contractor services.

4.2.3 Operations Engineering

1. Acts as the technical representative of the proponent for newly installed systems.
2. Advises and assists the project engineer during all cleaning activities involving the system and associated equipment.
3. Advises and assists the foreman of the plant containing the lube/seal oil and fluid power systems and associated equipment during all chemical cleaning activities.
4. Acts as a technical representative to facility operator, during the chemical cleaning of the systems.
5. Ensures adequate safety procedures and precautions are taken.
6. Notifies Loss Prevention Department to review safety during cleaning.
7. Coordinates and obtains the approval of chemical cleaning procedures and formulations from the Materials Engineering and Corrosion Control Division/Consulting Services Department (ME&CCD/CSD).

4.2.4 Projects/Operations Inspection

1. Has the responsibility, in conjunction with Operations Engineering, for inspection and acceptance of before and after cleaning. The presence of chemical cleaning personnel from

ME&CCD/CSD may be requested by Operations Engineering or Inspection if this service is desired.

2. Monitors on-line corrosion rates.
3. Maintains history of lube/seal oil and fluid power systems chemical cleaning and incorporates relevant reports and data into permanent plant records.

4.3 Loss Prevention Department

Audits cleaning operations and permits. Advises on field safety precautions upon request.

4.4 Research and Development Center (R&DC)

- Evaluates and recommends new chemical cleaning procedures, and new corrosion inhibitors.
- Provides specialist/consultant advice on request.

4.5 Regional Laboratories

- Perform deposit chemical analysis, inhibitor effectiveness testing, monitor and log chemical cleaning analyses on-site during cleaning operations.
- Verify the purity of acids and chemicals used for chemical cleaning.
- Verify degree of cleanliness on oil samples.
- Provide LPR probes, on-line corrosion monitoring equipment.

4.6 Chemical Cleaning Contractor

4.6.1 The chemical cleaning contractor shall be selected from the Saudi Aramco's approved list of chemical cleaning contractors. Contractor responsibilities are to be stated in the contract. Contractor responsibilities will normally include:

- Submittal of procedures and documents per Appendix 2
- Supply of all chemicals, including emergency neutralizing agents, inhibitors, and auxiliary pumping and heating equipment
- Provision of personnel necessary to perform the chemical cleaning, including a chemist qualified to conduct the chemical analyses required during the cleaning operation

- Provision of on-line corrosion monitoring and control of corrosion rates per Appendix 5
- Containment, neutralization and clean up of chemical/oil spills
- Disposal of all waste water per [SAES-A-104](#), spent oil and chemical solutions as approved by Saudi Aramco Chief Environmental Engineer, Environmental Engineering Division, Environmental Protection Department

4.6.2 Responsible for cleaning the lube/seal oil and fluid power systems to meet or exceed the cleanliness acceptance criteria as outlined here and in Section 7 of [SAES-G-116](#).

4.7 Consulting Services Department/ME&CCD

- Review and approve the cleaning procedures and subsequent changes necessitated by the field conditions.
- Provide specialist/consultant advice on request.

5 Determining the Need for Chemical Cleaning

5.1 Visual Inspection

5.1.1 During every T & I, inspect lube/seal oil and fluid power systems to determine the need for chemical cleaning. Visual inspection will indicate the condition of the systems and will be one of the primary factors in determining the need for chemical cleaning.

5.1.2 Inspect bearings for signs of wear and blockage of lube oil orifices.

5.1.3 Check the internal surface of the oil storage tanks for corrosion and sludge. Record the location and amount of sludge buildup and check tanks for pits, and corrosion product. Scrape off sludge and corrosion products to determine their depth. Obtain samples of all types of sludge or corrosion product observed for compositional analysis. Take a sample or samples carefully to be representative of the contaminants in the lube/seal oil and fluid power systems.

5.2 Chemical Analysis of Deposits (Sludge or Corrosion Product)

Determine the composition of the deposits and the composition of a suitable acid/EDTA solution that may be used to remove them before initiating any chemical cleaning. The tests listed below will aid in that assessment.

- 5.2.1 Solubility in Dilute HCl - This is the weight percent of the dry deposit that will dissolve in boiling 7.5% wt. inhibited hydrochloric acid. This provides some indication of the degree of difficulty that may be encountered in removing the deposit.
- 5.2.2 Loss on Ignition - This is the weight percentage of the dry deposit that can be removed by heating the insoluble residue from 8.2.1.1 to 315°C in a laboratory furnace. The result is indicative of the organic content of the deposit in the forms of oil, grease, degraded polymers and carbon. If the figure is high (greater than 10.0%) a further definition of the organic content shall be made by refluxing the sample with a suitable organic solvent that will indicate the relative proportions of (i) oil and grease, and (ii) carbon. These proportions will aid in the selection of a suitable hot alkaline treatment.
- 5.2.3 Silica - The percentage of SiO₂ is determined by evaporating the silica as SiF₄ by the addition of hydrofluoric acid to the residue from 8.2.1.2 above.
- 5.2.4 Insoluble Residue - This figure represents the insoluble complexes of other cations and, if the quantity is significant (i.e., greater than 2.0%), additional treatments with more concentrated hydrochloric acid may be required to render the material soluble.

6 Introduction to Chemical Cleaning

The cleaning process for lube/seal oil and fluid power systems may involve a combination of several stages. The cleaning stages required for any given system will be decided on before the cleaning is started.

6.1 Mechanical Cleaning

This is to mechanically remove, using power brushes, tube scrapers or high pressure (55.16 MPa gauge or 8000 psig) water, as much oil and grease as possible from heat exchangers and piping before alkaline cleaning. Most new systems have all welded piping construction, so that access is not possible with mechanical tools.

- 6.2 Flushing with oil can remove only loose material. Adherent contaminants cannot be removed through this process and therefore, faster and more effective measures than flushing with oil may be required.
 - 6.3 Steam Cleaning with or without chemicals at flow velocities of up to 15 m/s shall be used to remove all deposits and oil.
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- 6.4 Hot Alkaline Treatment or water with surfactant shall be used to remove oil and grease.
- 6.5 Acid/EDTA Cleaning shall be used to chemically remove mill scale, and corrosion products.
- 6.6 Neutralization and Passivation shall be used to neutralize acids and to form a strongly adherent protective oxide layer on the wetted surfaces.

7 Safety Precautions

The following precautions shall be observed by all parties to ensure the protection of equipment and personnel during the chemical cleaning.

- 7.1 Prior to initiation of chemical cleaning, permanent or temporary eye wash fountains and safety showers that are located within 15 meters of the work site and accessible in 10 to 15 seconds shall be assembled, tested, and maintained in operational condition. If no eye wash or safety shower facilities exist in the area where the cleaning will be conducted suitable temporary facilities must be installed per [SAES-B-069](#).
- 7.2 Adhere to all work permit procedures. When flammable chemicals are used in the cleaning operation, any flammable gases evolved shall be vented to a safe location. A "Release of Flammable Gas" Work Permit will be required. Welding, burning and running of welding machines or generator sets shall not be permitted within a 5 meter radius of vents from the system being cleaned. A hot work permit will be required to operate pumps.
- 7.3 Maintain on hand and readily available, all the equipment necessary for the containment and clean up of small chemical spills. If necessary, equipment shall be maintained for each chemical in use. Where more than one set of equipment is provided, the chemical(s) for which it may be used shall be clearly labeled on each set of equipment. Material collected from the clean up of such spills shall be disposed of in an approved manner.
- 7.4 To deal with spills that cannot be contained or absorbed, hoses connected to an operable water supply shall be provided adjacent to the equipment and systems being cleaned. The number of hoses required will depend on the severity of the chemical being used, the volume of chemical in use, and the capacity of the water delivery system. Prior to initiation of any cleaning every effort should be made to route any runoff from the cleaning area to a segregated containment pit. If this is not possible and runoff must be routed to the plant general slops system, a suitable disposal plan must be adopted.

- 7.5 Cordon off the area where the blending and heating of chemical solutions is to be performed and post with "DANGER" and "NO ENTRY TO UNAUTHORIZED PERSONNEL" signs. Unauthorized personnel shall not be allowed to enter the cordoned area. Ensure all personnel within the cordoned area, and any other associated work areas wear the required personal protective equipment.
- 7.6 Obtain Chemical Hazard bulletins on various chemicals or materials to be used from the Industrial Hygiene Services, Preventive Medicine Services Division. If Chemical Hazard bulletins are not available for a chemical to be used, obtain or have the chemical cleaning contractor obtain, the appropriate Materials Safety Data Sheet (MSDS) from the chemical manufacturer. These bulletins and MSDS provide information on, first aid and fire fighting measures, stability and reactivity, storage and handling, spill and leak control, and the personal protective equipment require for dealing with the chemicals. Copies of the Chemical Hazard bulletins or MSDS for all the chemicals being used shall be continuously available on site for consultation and review.
- 7.7 Ensure all individual nitrogen cylinders are secure. If the bottles are connected to a common manifold, fit each bottle with a check valve and install a regulator on the manifold. Ensure the manifold is equipped with a relief valve, and that valve is vented to a safe location.
- 7.8 All personnel handling chemicals shall wear the personal protective equipment specified by the Chemical Hazard Bulletin or MSDS for the materials involved.
- 7.9 Nitrogen is a non-toxic gas; however, it will not support respiration. During draining of systems, adequate ventilation must be provided.
- 7.10 Disconnect or isolate all instruments to protect them from exposure to corrosive solutions.
- 7.11 When inhibited hydrochloric acid is the selected cleaning solution, remove all permanent stainless steel, brass, and bronze components from the system and replace them with temporary bypasses, e.g., chemical resistant flexible rubber hose or steel pipe. When inhibited sulfuric or citric acids are to be used, stainless steel components may be left in the system however, brass and bronze components shall be removed.

8 General Preparation

- 8.1 Notify ME&CCD/CSD and the Regional Laboratories of intention to chemically clean lube/seal oil and fluid power systems. Contact ME&CCD/CSD personnel during any stage of chemical cleaning for consultations as necessary.

8.2 Lube and Seal Oil System

- 8.2.1 Drain the existing oil if any from the system. Dispose the spent oil in an approved manner.
 - 8.2.2 Remove filter elements and bypass all connections to the oil reservoir, bearings, seals, flow meters, servo motors, regulators, gauges, etc. and fit with temporary connections between supply and return lines. If the system cooler has mild steel turbulators, remove them. If the system cooler is fabricated from stainless steel and has been factory cleaned removal of turbulators will not be necessary. Inspect all the turbulators for contamination. If on inspection they do not meet [SAES-G-116](#) Section 7.1.3, mechanically or chemically clean them. Store clean or cleaned turbulators to prevent any contamination prior to their re-installation in the cooler. Replace all gaskets by chemical resistant gaskets prior to chemical cleaning.
 - 8.2.3 Replace all permanent valves that will come in contact with acid, with "sacrificial" valves or protect them by blinds. If "sacrificial" valves are not available, keep new valves on hand for replacing all valves contacted by acid during the cleaning procedure.
 - 8.2.4 Install all necessary temporary piping or chemically resistant flexible hoses with cross sectional area equal to or greater than the downstream piping, valves, and instruments. Do not use copper or copper alloys in the system.
 - 8.2.5 Install fittings for liquid sampling, flow elements, temperature probes, and pipe spools with access fittings for on-line corrosion monitoring probes. Make provision for the installation of corrosion monitoring equipment per Appendix 5.
 - 8.2.6 If ammonium bifluoride is to be added to the acid solution, remove all original site glasses and install temporary site glasses. Do not add ammonium bifluoride to the acid solution when cleaning austenitic stainless steels as they are incompatible.
 - 8.2.7 Prior to commencing erection of field fabricated piping and components of lube/seal oil and fluid power systems, remove foreign objects such as weld slag, metal shavings, spatter, insoluble preservatives and compounds, icicles, and burnt residue by mechanical cleaning at grade level.
 - 8.2.8 Inspect all system piping, removable covers, filters, coolers, temporary bypass piping, etc. for cleanliness prior to installation and bolting.
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- 8.2.9 Clean as described in Sections 9 to 13, prior to flushing with oil all internal surfaces of component parts of field fabricated lube or seal oil systems.
 - 8.2.10 Clean in accordance with Sections 9 to 13 before flushing with oil if the internal surfaces of any component parts of a shop-fabricated lube or seal oil system do not meet the requirements of paragraph [SAES-G-116](#), Section 7.
 - 8.2.11 Isolate and clean field fabricated tie-in piping independently of shop-fabricated lube or seal oil systems, which comply with [SAES-G-116](#) Section 7.
 - 8.2.12 To remove solids, install absolute filters, or 100 x 100 mesh steel wire strainers or screens (9CAT 1000284291) at different locations in the system prior to the water and oil circulation steps. Install at least one strainer on the pump discharge. Use 4 x 4 mesh (9CAT 1000284291) backup screens to prevent collapse at high flow rates.
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- 8.3 Cleaning and Ancillary Equipment and Supplies
- 8.3.1 Ensure required amount of nitrogen, supplied at 550 kPa gauge (80 psig), is available in the cleaning area. Provide adequate nitrogen supply to drain the system at least three times.
 - 8.3.2 Ensure that an adequate supply of steam condensate or demineralized water is available at the required temperature. Do not use raw water to flush or hose down the lube/seal oil and fluid power systems.
 - 8.3.3 Ensure the inhibitor to be used is selected from Appendix 3, List of Approved Inhibitors.
 - 8.3.4 Store all chemicals, including emergency neutralizing agents, needed for the procedure on-site prior to commencing cleaning. Determine chemical compatibility from the reactivity sections of the Chemical Hazard Bulletins or MSDS and ensure that incompatible chemicals are segregated during storage. Store emergency neutralizing agents, clean up and containment equipment in such a manner that they are easily recognizable and readily accessible at all times.
 - 8.3.5 Provide adequate lighting at all operating points.
 - 8.3.6 Ensure that sufficient plywood sheets, tarps or other suitable materials are available to cover all coolers for heat retention during any acid cleaning steps.
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- 8.3.7 Ensure that a heat exchanger is available to maintain the fluid temperature, within the limits specified under Sections 10 through 13. A steam coil inside the mixing tank and a supply of low-pressure (<400 kPa gauge or 60 psig) steam is generally adequate for this purpose.
 - 8.3.8 Ensure spare pumps are available in case of circulating pump failure, and that there is sufficient pumping capacity to drain the acid solution within fifteen minutes in case of an emergency. Ensure sufficient holding tank capacity is available for draining and neutralizing cleaning solutions if necessary.
 - 8.4 Cleaning Operations
 - 8.4.1 Steam clean and chemically degrease stainless steel components. Under no circumstances expose stainless steel components to solutions containing more than 50 mg/L chlorides.
 - 8.4.2 Measure the volume required to establish circulation of the lube/seal oil and fluid power systems by filling the system with water from a metered tank or by using a flow meter with a totalizer.
 - 8.4.3 Test systems hydrostatically at 690 kPa gauge (100 psig) or 1.5 times the pump discharge pressure whichever is lower, after installation of all temporary piping and connections.
 - 8.4.4 Calculate the cross sectional area of the lube and seal oil system piping to determine the required volume flow rate of the circulating pumps to achieve the minimum required flushing velocity of 3 m/s in all piping. Identify sections of large diameter piping for flushing separately if MAOP limits the maximum achievable flow velocity. Check and ensure that the flow design includes flow reversal manifold and valves, control valves to control circulation within specified limits. Perform velocity checks for each major flush and circulation path.
 - 8.4.5 Determine maximum volume flow rate for acid cleaning so that the fluid velocity in the smallest piping will not exceed 1 m/second.
 - 8.4.6 Flush the system using steam condensate or demineralized water at a velocity of at least 3 m/s (or at the highest velocity limited by MAOP) for a minimum two hours, and drain rapidly under air pressure to remove as much mobile debris as possible. If necessary, isolate sections of the system to achieve this velocity.
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- 8.4.7 If the chemical cleaning parameters are being monitored both by the contractor and in-house laboratories, the agreement between the two sets of results should be within 20%.
- 8.4.8 Ensure that the chemical cleaning contractor has planned for the disposal of wastewater and chemical solutions per paragraph 4.6.1 and has the approval of the Environmental Engineering Division/Environmental Protection Department, Dhahran. If necessary, also check that the approval of the proper Governmental Environmental Agency or Agencies has been obtained.

9 Cleaning Log Sheets

- 9.1 An accurate log of cleaning activities shall be maintained continuously throughout the operation. The following represent the minimum information that must be recorded on the log sheets: time and date of cleaning process, temperatures, corrosion rates, chemical additions, results of screen inspections, and results of chemical cleaning analyses. The person making the entry shall initial all log entries. The chemical cleaning contractor's shift supervisor will start a new log sheet when he comes on shift and will sign all log sheets filled out during his shift. A typical log sheet is shown in Appendix 4.
- 9.2 The contractor shall also maintain on-line corrosion monitoring charts indicating corrosion rates verses time. The contractor may maintain other supplemental log sheets, as he believes necessary.
- 9.3 All log sheets and charts shall be kept as permanent plant records on completion of the cleaning operation. Copies of any contractor supplemental log sheets shall also be kept in the permanent plant records.

10 Chemical Cleaning Treatment Selection

10.1 General Criteria

Deposit composition, quantity, and distribution, may vary considerably between one lube/seal oil and fluid power system to another, or even within the same lube and seal oil system at various time periods during its life. Therefore, it is necessary in each case, to select a specific treatment or series of treatments, which will be most effective in achieving thorough and safe cleaning. This Section provides a guide to the selection of cleaning treatments.

- 10.1.1 The following criteria must all be satisfied:
 - 10.1.1.1 The treatment(s) must be safe to use and compatible with the materials of construction of the equipment to be

cleaned; and

10.1.1.2 The system deposit must show sufficient solubility (>70% wt.) in the treatment solution(s) selected so that, the soluble components and any insoluble matter may reasonably be expected to dissolve or detach fully during the flushing process, and

10.1.1.3 The treatment will achieve the desired degree of cleanliness.

10.1.2 With those criteria satisfied, the final selection between suitable alternatives may be made, with consideration of other constraints including cost, disposal problems, and the cleaning time available. Responsibility for the final specification of the treatment(s) is defined in Section 4.

10.1.3 Chemical cleaning will normally involve one or more of the following steps: Degreasing, acid cleaning, followed by neutralization and passivation treatment. Laboratory evaluation of deposit samples will be required to determine which of the above steps are necessary. In addition, the deposit analysis will be required to complete the treatment selection process as described in Sections 10.2.

10.2 Hot Alkaline Treatment Selection

10.2.1 If deposit solubility is 70% or greater in the acid/EDTA solution chosen and LOI testing shows the presence of organics, a separate alkaline treatment should be performed in-line with the guidelines detailed in section 10.2.3.

10.2.2 If deposit solubility is < 70 % and LOI testing shows that organics are not present, then the choice of acid/EDTA solvent is not suitable, so further testing of alternative solvents needs to be performed

10.2.3 If carbon or other organic compounds are present, these must be removed. Selection of a removal treatment depends on the degree of contamination.

10.2.2.1 Hot steam or condensate or demineralized water at 95°C, with or without surfactant, will remove light oil and grease, indicated by an organic contamination of less than 5 wt%.

10.2.2.2 Soda ash is used when organic contamination is 5 wt% to 10 wt%.

- 10.2.2.3 Caustic degreasing (NaOH) is used when organic contamination is 10% to 25%.
- 10.2.2.4 Permanganate (KMnO₄) degreasing is used when organic contamination is greater than 25% and carbonized. This treatment should only be employed where deposit type and quantity render it necessary, since costs, disposal problems and complication of subsequent acid/EDTA cleaning, are greater than in the case of the alternatives.

10.3 Acid/EDTA Selection

10.3.1 Hydrochloric Acid

Inhibited hydrochloric acid is frequently used in chemical cleaning operations since it dissolves a wide variety of deposits, is economic, and easy to handle. It exhibits good corrosion characteristics when correctly inhibited and the process is controlled within the accepted limits. The process is flexible and can be modified to enhance silica removal by the addition of ammonium bifluoride, or to remove organics by addition of surfactants. It is not compatible with stainless steels.

10.3.2 Citric Acid

Citric acid is compatible with alloy steels requiring low chloride acids, and presents good handling, safety, and corrosion characteristics, in comparison to hydrochloric acid. It is less aggressive in its attack of some iron oxide deposits and therefore usually requires higher temperatures or longer contact times. In general it is more expensive than hydrochloric acid treatment. The normal reasons for its selection are a) presence of austenitic materials, and b) to reduce cleaning time by using a single solution and eliminating the need to drain, flush, and refill the systems between the iron oxide removal and the neutralization/passivation stages.

10.3.3 EDTA

Ammonium and di-ammonium EDTA salts, are generally expensive in comparison with citric and hydrochloric acids. It is compatible with alloy steels requiring low chloride acids, and presents good handling, safety, and corrosion characteristics. Higher temperatures are required to achieve satisfactory cleaning. Corrosion rates are low under properly controlled conditions. Iron oxide removal, neutralization and passivation can be carried out sequentially with the single solution.

10.4 Neutralization and Passivation

- 10.4.1 Following acidization of a lube and seal oil system, it is essential that the equipment be thoroughly neutralized. Neutralization can be accomplished either by circulating a solution of 0.5% sodium carbonate, or during the passivation treatment, where the process requires pH values of 7 or greater.
- 10.4.2 The selection of passivation treatment is governed by the acid selection and the materials of construction of the system to be cleaned. Where citric acid or EDTA processes have been used, these are normally extended to effect neutralization and passivation through pH adjustment and the addition of an oxidizing agent. To accomplish this, the citric acid, ammonia and nitrite are added. If ambient temperature is all that can be achieved, the nitrite/phosphate treatment will give some protection to the metal surfaces. If internal surfaces have been allowed to rust following acidization, this rusting is removed by citric acid with ammonia, then sodium nitrite is added later to achieve a high degree of passivation.

11 Hot Alkaline Treatment

The selection of a hot alkaline treatment shall be made on the basis of the organic content of the deposit as detailed in section 10.2.3

11.1 General Preparation

1. Ensure all preparations listed in Sections 6 and 7 have been completed.
2. Ensure all lube/seal oil and fluid power system instrument leads are isolated for protection, unless required for the cleaning operation.
3. Carefully inspect all pressure parts for obstructions. Check all lines, drains and vents to be certain that they are clear.
4. Commercial grade quality chemicals will be adequate for use as described in this Section, except where austenitic materials are present in the system to be cleaned. In this case the total chlorides from all the chemicals in the mixture must not yield a final solution with a chloride concentration greater than 50 mg/L.

11.2 Alkaline Degreasing with Soda Ash

11.2.1 Control Parameters

Chemical	Concentration
Sodium carbonate	0.5 to 1.0% by weight
Sodium metasilicate	0.5 to 1.0% by weight
Trisodium phosphate	0.5 to 1.0% by weight
Surfactant	0.1 to 0.2% by volume
Anti foam (if required)	0.05 to 0.1% by volume
Temperature Limit	95°C maximum
Circulation rate	150 to 250 L/minute
Residence Time	4 to 6 hours
Corrosion Rates	< 2 mpy

11.2.2 Safety Hazards

The solution can react violently with acids.

11.2.3 Procedure

1. Dissolve the chemicals externally and blend fill through the chemical feed connection. Fill the lube/seal oil and fluid power systems to ensure adequate alkaline solution contact with the contaminated metal surfaces. Vent air, as required, from high point vents to allow complete liquid filling of the system.
2. Heat the solution with steam to 95°C and circulate for 4 to 6 hours after the required temperature is reached.
3. Drain the system into a holding tank.
4. Following complete draining of alkaline solution, fill the system with steam condensate or demineralized water heated to 77°C for a rinse.
5. Drain the system and the repeat rinse.
6. The lube and seal oil system will be inspected by Operations and Operations Engineering. If the inspection indicates unsatisfactory removal of oil and grease, repeat the entire procedure.

11.2.4 Testing

Immediately after the system has been filled and once each hour thereafter during circulation, determine the phosphate values. If the phosphate concentrations drop to half the original values, add additional chemicals to restore the original concentrations.

11.3 Caustic Degreasing

11.3.1 Control Parameters

Chemical	Concentration
Sodium hydroxide	1.0 to 2.0% by weight
Trisodium phosphate	0.5 to 1.0% by weight
Surfactant	0.1 to 0.3% by volume
Anti foam (if required)	0.05 to 0.1% by volume
Temperature Limit	95°C maximum
Circulation Rate	150 to 250 L/minute
Residence Time	4 to 6 hours
Corrosion Rates	< 2 mpy

11.3.2 Safety Hazards

Sodium hydroxide reacts exothermically with water and must never be added to hot water. All dilution of sodium hydroxide, either liquid or solid, should be carried out slowly with constant stirring.

11.3.3 Caustic Degreasing Procedure

The procedure steps are same as in Section 11.2.4 (alkaline degreasing with soda ash).

11.3.4 Testing

Immediately after the system has been filled and once each hour thereafter during circulation, determine the phosphate values. If the phosphate concentrations drop to half the original value, add additional chemicals to restore the original concentration.

11.4 Permanganate Degreasing

11.4.1 Control Parameters

Chemical	Concentration
Sodium hydroxide	1.0 to 3.0% by weight
Potassium permanganate	1.0 to 3.0% by weight
Temperature Limit	95°C maximum
Circulation Rate	120 to 150 L/minute
Residence Time	4 to 6 hours
Corrosion Rates	< 2 mpy

11.4.2 Safety Hazards

Handle potassium permanganate with care, as it is a strong oxidizing agent. Add slowly with constant stirring to dilute sodium hydroxide in water.

11.4.3 Precautions

Do not use any antifoam or surfactant as they will react with permanganate and deplete its strength. This treatment frequently results in the deposition of manganese dioxide. If this treatment is to be followed by hydrochloric acid stage, chlorine may well be liberated with a consequent increase in corrosion rates and safety hazards (see Section 12.3.4.2).

11.4.4 Permanganate Degreasing Procedure

1. Dissolve the chemicals externally and fill the lube/seal oil and fluid power systems to contact with contaminated metal surfaces.
2. Heat the solution with steam to bring to desired temperature range. Circulate, using chemical cleaning pumps for 4 to 6 hours. Monitor permanganate concentration until concentration stabilizes.
3. Drain the solution into a holding tank.
4. Following complete draining of alkaline solution, fill the system with steam condensate or demineralized water heated to 77°C to rinse.
5. Drain the system and repeat rinse.
6. The lube and seal oil system will be inspected by Operations and Operations Engineering. If the inspection indicates unsatisfactory removal of oil and grease, repeat the entire procedure.

11.4.5 Testing

Immediately after the system has been filled and once each hour thereafter during circulation, determine the permanganate concentration. If permanganate strength drops below 1.0% do not add permanganate to increase its concentration. Drain the system into a holding tank, add fresh degreasing solution and continue circulation.

12 Acid/EDTA Cleaning

- 12.1 Following removal of organic material if required, by hot alkaline treatment, Acid/EDTA Cleaning is carried out to remove iron oxides, mill scale, weld spatter, remaining hard deposits and silica. The acid solutions are selected as noted in Section 10.3. Although the acid concentrations listed encompass most cleaning situations, there may be instances where higher acid, inhibitor and ammonium bifluoride concentrations may be beneficial. Extended contact times, longer than those specified, may be required for certain heavy and hard to remove deposits. Changes to the specified procedures below require prior approval from CSD/ME&CCD.
- 12.2 Commercial grade quality chemicals will be adequate for use as described in this Section, except where austenitic materials are present in the system to be cleaned. In this case the total chlorides from all the chemicals in the mixture must not yield a final solution with a chloride concentration greater than 50 mg/L. The acid solutions must not contain greater than 100 mg/L of iron in the concentrated form.
- 12.3 Hydrochloric Acid
- 12.3.1 Control Parameters

Chemical	Concentration
Hydrochloric acid	3.5 to 5% by weight
Inhibitor	0.2 to 0.3% by volume or as recommended by manufacturer
Surfactant	0.0 to 0.2% by volume
Ammonium bifluoride	0.0 to 1.0% by weight
Oxalic acid (See 12.3.4.2)	1.0% by weight
Temperature Limits	65°C to 75°C
Circulation Rate	120 L/minute to 250 L/minute
Maximum Fluid velocity	1 m/s
Residence Time	2 to 6 hours
Corrosion Rates	<600 mpy
Total dissolved Iron	10,000 mg/L max.
<u>Passivation phase</u>	
Sodium nitrite	0.5% by weight
Monosodium phosphate	0.25% by weight
Disodium phosphate	0.25% by weight
Sodium hydroxide	To adjust pH to 7
Temperature Limit	50°C to 65°C
Circulation Rate	120 L/minute to 250 L/minute
Residence Time	2 to 4 hours
Corrosion Rates	< 2 mpy

12.3.2 Testing

Immediately after mixing, test the solution for inhibitor effectiveness. (See Appendix 5.) During circulation monitor the solution for acid concentration, total iron concentration, corrosion rate, and temperature. Maintain these parameters within the limits specified. Take samples at one-hour intervals. Perform analyses as rapidly as possible and preferably on-site.

12.3.3 Safety Hazards

Hydrochloric acid is a strong mineral acid and must be handled with suitable precautions, particularly in the concentrated state. Oxalic acid is highly toxic.

12.3.4 Precautions

12.3.4.1 Review materials used in system construction to ensure that all are compatible with high chloride solutions. Austenitic stainless steels are prone to stress corrosion cracking in such environments and must be removed from any system to be cleaned by hydrochloric acid. Corrosion rates are controlled by the addition of inhibitor. The effectiveness of the inhibitor, in turn, controlled by a number of variables. These include inhibitor concentration, acid concentration, temperature, circulation velocity, residence time, and concentration of dissolved iron. Great care must be taken to control these variables within the stated limits, unless approved by CSD/ME&CCD.

12.3.4.2 When a permanganate degreasing has been conducted, the residual deposit will probably be contaminated with manganese dioxide. This will liberate chlorine in contact with hydrochloric acid. To prevent this and severe pitting attack, add 1.0% of oxalic acid to the hydrochloric acid.

12.3.5 Hydrochloric Acid Procedure

1. Fill the lube/seal oil and fluid power systems with steam condensate or demineralized water, completely venting all air in the system. If the condensate or demineralized water is sufficiently hot, circulate with the chemical cleaning pumps to achieve uniform metal temperatures throughout system, and adjust to 65-75°C. For condensate or demineralized water at a lower

- temperature, use an external heat exchanger, or inject steam, to obtain the required temperature and adjust by circulation. All air-cooled exchangers shall be covered to retain the heat.
2. Blend mix in the external acid tanks the required acid, inhibitor, and surfactant volumes. Oxalic acid must be added to the solution if permanganate degreasing has been performed on the system.
 3. Using a PVC pipe, bubble nitrogen into the acid tanks for at least 1 hour, at a minimum flow rate of 1 m³/hr to strip the oxygen from the solution, and thoroughly mix the acid and inhibitor in the tank.
 4. Check inhibitor effectiveness (see Appendix 5) in the acid on-site. As quickly as possible, blend fill the lube and seal oil system with inhibited acid solution. Blend a slightly higher acid concentration during the beginning of the fill than at the end because the initial acid entering the system is consumed to some degree during the fill. Ammonium bifluoride may be added in concentrations up to 1.0% by weight to assist in the removal of iron oxide and silica.
 5. Circulate the blended acid solution using the chemical cleaning pumps for a period of 2 to 6 hours. Reverse flow direction every hour using the flow reversal manifold. Continue circulation and ensure that the various sections of the lube and seal oil system are circulated in turn, using valves and by pass connections. Take samples from the various locations and monitor temperature, acid concentration, iron concentration, and inhibitor effectiveness. (See Appendix 5.)
 6. If the acid concentration falls below 3.0%, or if the total iron exceeds 10,000 mg/L, or if the measured corrosion rates exceed 600 mpy for a period of 15 minutes and action by the cleaning crew fails to reduce the corrosion rate below this level, drain the system immediately into a holding tank under nitrogen pressure of 550 kPa gauge (80 psig) and go to step 12.3.5.11.
 7. During circulation, temperatures will gradually decay from 75°C. This is acceptable to a minimum of 65°C. If it becomes necessary to increase the solution temperature, use steam coils, or other means, to apply heat in the temporary circulating tank.
 8. Continue circulation, taking test samples every hour. Continue cleaning until the acid and total iron concentration approach equilibrium. Normally, this will be accomplished in 2 to 6 hours.

9. Check for acid leaks in the circulation system and if the leaks can not be contained drain to an acceptable holding tank. Neutralize this solution as soon as possible; do not hold for later reuse following repair of the leaks.
10. Drain the acid into a holding tank under a positive nitrogen pressure of 550 kPa gauge (80 psig). Drain in as short a time as possible, using the maximum number of drain valves consistent with maintaining a positive nitrogen pressure. Introduce nitrogen into the system through the vent line. Adequately size the pressure regulator and delivery piping to introduce nitrogen at a volumetric rate capable of displacing all of the acid in the lube and seal oil system within a period of 30 minutes.
11. Fill the system with hot steam condensate or demineralized water mixed with 0.5% wt. of soda ash. Drain the lube and seal oil system under nitrogen as before and refill with the same solution, for a second rinse. Drain the second rinse under a positive nitrogen pressure. Monitor the pH of the two rinses as they are being drained. If the pH is less than 7 add Soda ash directly to the solution being drained into the sewer. When the procedure selected for passivation is per Section 13.2 add about 0.1% by weight of citric acid to the second rinse to assure more thorough iron removal.

12.3.6 Neutralization

Immediately after Acid Cleaning and rinsing of the lube/seal oil and fluid power systems, the final step is neutralization and passivation of the freshly cleaned surfaces. Commercial grade quality chemicals will be adequate for use as described in this Section, except where austenitic materials are present in the system to be cleaned. In this case the total chlorides from all the chemicals in the mixture must not yield a final solution with a chloride concentration greater than 50 mg/L.

12.3.6.1 Testing

Monitor and maintain pH by adding caustic (sodium hydroxide) if necessary.

12.3.6.2 Safety Hazards

Sodium nitrite is a strong oxidizing agent. It must be handled with care.

12.3.6.3 Procedure

Commentary Note:

Other passivation procedures may be employed. The passivation shown here is an example. CSD chemical cleaning experts will review and comment on other passivation procedures on request. For mild steel systems it is common to employ an HCl stage followed by a complete citric acid treatment stage (Section 12.4), the only difference being shorter contact times during the iron removal stage.

1. Circulate at 50°C to 65°C for 2 to 4 hours. Insert a 100 x 100 mesh screen into the return line at the chemical circulating tank, and circulate for another 30 minutes to check cleanliness of the system. Continue circulating the chemicals until screens contain no observable particles. When the screens are acceptable, the flushing with the water-based solution is assumed to be completed.
2. Drain the passivation solution using 35 kPa gauge clean nitrogen assist.

12.3.7 Drying

Dry the system by flowing dry nitrogen at flow rate of at least, 1 m³/minute. Monitor the dew point with a calibrated portable dew point tester at several vent locations and at the final vent location most distant from the inlet point. During drying stroke all valves to assist with the removal of any water trapped in valve cavities. Continue the drying operation until a dew point of -1°C or lower is achieved at all test locations.

12.4 Citric Acid

12.4.1 Control Parameters

Chemical	Concentration
<u>Iron removal phase</u>	
Citric acid	2.5 to 5% by weight
Inhibitor	0.2 to 0.3 % by volume or as recommended by manufacturer
Ammonia/Caustic	To pH 4.0 to 4.5
Temperature Limits	70°C to 82°C

Chemical	Concentration
Total dissolved Iron	10,000 mg/L max.
Maximum Fluid velocity	1 m/s
Circulation Rate	120 L/minute to 250 L/minute
Corrosion Rates	<600 mpy
Total dissolved Iron	10,000 mg/L max.
Residence Time	4 to 6 hours
<u>Passivation phase</u>	
Free Citric acid	1.0% by weight
Sodium nitrite	0.5% by weight
Ammonia/Caustic	To pH 9.5
Residence Time	2 to 4 hours

12.4.2 Testing

Immediately after mixing, test the solution for inhibitor effectiveness. (See Appendix 5). During iron removal circulation, monitor the solution for free citric acid concentration, total iron concentration, corrosion rate, and temperature. Maintain these parameters within the limits specified. Take samples at one-hour intervals. Perform analyses as rapidly as possible and on-site.

12.4.3 Safety Hazards

Ammonia is a strong respiratory irritant in low concentrations and toxic at higher concentrations. Explosive limits are 16% to 24% in air. Sodium nitrite is a strong oxidizing agent.

12.4.4 Precautions

Corrosion rates are controlled by the addition of inhibitor. The effectiveness of the inhibitor, in turn, controlled by a number of variables. These include inhibitor concentration, acid concentration, temperature, circulation velocity, residence time, and concentration of dissolved iron. Great care must be taken to control these variables within the stated limits, unless approved by CSD/ME&CCD.

12.4.5 Procedure

12.4.5.1 Iron Removal Phase

1. Fill the lube and seal oil system with steam condensate or demineralized water eliminating all air in the system. If the condensate or demineralized water is

sufficiently hot, circulate with chemical cleaning pumps to achieve uniform metal temperatures throughout the system, and adjust to 82°C. If the condensate or demineralized water is not hot enough, use an external heat exchanger or inject steam. All air-cooled exchangers must be covered to retain the heat.

2. Check inhibitor effectiveness in the acid on-site. (See Appendix 5). As quickly as possible, blend fill the system with inhibited citric acid with sufficient ammonia or caustic to adjust pH between 4 and 4.5.
 3. Circulate the blended acid solution using the chemical cleaning pumps for a period of 4 to 6 hours. Reverse flow direction every hour using flow reversal manifold. Continue circulation to ensure that the various sections of the system are circulated in turn using valves and by pass connections. Take samples from the various locations and monitor temperature; free citric acid concentration, iron concentration, inhibitor effectiveness, and pH. Maintain free citric acid strength above 1% wt. and the pH between 4 and 4.5 by adding the appropriate chemicals.
 4. During circulation, temperatures will gradually decay from the original levels. This is acceptable to a minimum of 70°C at the completion of this phase. If, however, it becomes necessary to increase the temperature, use steam coils, or other means, to apply heat in the temporary-circulating tank.
 5. Continue circulation, taking test samples every one hour, and until the acid and total iron concentration approach equilibrium. Normally this will be accomplished in two to six hours.
 6. Check for acid leaks in the circulation system and if the leaks can not be contained, drain to an acceptable holding tank. Neutralize this solution as soon as possible; do not hold for later reuse following repair of the leaks.
 7. If the total iron exceeds 10,000 mg/L, or if the measured corrosion rates exceed 600 mpy for a period of 15 minutes and action by the cleaning crew fails to reduce the corrosion rate below this level, drain the
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system immediately into a holding tank under nitrogen pressure of 70 to 350 kPa gauge (10 to 50 psig). Rinse the system with condensate or demineralized water and repeat from 11.5.5.2 above.

12.4.5.2 Passivation Phase

Commentary Note:

Other passivation procedures may be employed. The passivation shown here is an example. CSD chemical cleaning experts will review and comment on other passivation procedures on request.

1. Ensure that free citric acid concentration is >0.5% wt. If not, add further citric acid to achieve this level. Add ammonia or caustic to adjust the solution pH to 9.5.
2. Add sodium nitrite and circulate for a period of 2 to 4 hours.
3. Drain the system under air as before and refill with steam condensate or demineralized water, for a final rinse. At this point the system is both neutralized and passivated.
4. Open lube/seal oil and fluid power system and inspect.

12.4.5.3 Drying

Dry the system by flowing dry nitrogen at flow rate of at least, 1 m³/minute. Monitor the dew point with a calibrated portable dew point tester at several vent locations and at the final vent location most distant from the inlet point. During drying stroke all valves to assist with the removal of any water trapped in valve cavities. Continue the drying operation until a dew point of -1°C or lower is achieved at all test locations.

12.5 Ammonium or Di-ammonium Ethylene Diamine Tetra Acetic Acid (EDTA)

12.5.1 Control Parameters

Chemical	Concentration
<u>Iron removal phase</u>	
EDTA	3 to 10.0% by weight
Inhibitor	0.2 to 0.3 % by volume or as recommended by manufacturer
Ammonia	to pH 9.2 (for ammonium EDTA), to pH of 6.2 (for di-ammonium EDTA)
Iron removal phase	4 to 8 hours
Temperature	85°C to 93°C
<u>Passivation phase</u>	
Free EDTA	3 to 10.0% by weight
Sodium nitrite	0.5% by weight
Ammonia/Caustic	To pH 9.5(during passivation)
Maximum Fluid velocity	1 m/s
Circulation Rate	120 L/minute to 250 L/minute
Residence Time	4 to 6 hours

12.5.2 Testing

Immediately after mixing, test the solution for inhibitor effectiveness. (See Appendix 5). During iron removal circulation monitor the solution for EDTA concentration, total iron concentration, corrosion rate, and temperature. Maintain these parameters within the limits specified. Take samples at one-hour intervals. Perform analyses as rapidly as possible and on-site.

12.5.3 Procedure

12.5.3.1 Iron removal Phase

1. Fill the system with steam condensate or demineralized water and heat to 93°C inject inhibitor and circulate for 1 to 2 hours to uniformly coat the metal surface with inhibitor. Inject concentrated EDTA solution to a concentration of up to 10.0% solution in the lube/seal oil and fluid power systems.
2. Do not allow the temperature to drop below 85°C. Apply heat as necessary to maintain the circulation temperature as close as possible to 93°C. Continue circulation until iron concentration stabilizes. This may require 4 to 8 hours.

3. Monitor iron and EDTA concentrations and maintain the pH specified. If free EDTA concentration drops below 3.0% inject more EDTA to restore the concentration to 3.0%.
4. If the total iron exceeds 10,000 mg/L, or if the measured corrosion rates exceed 600 mpy for a period of 15 minutes and action by the cleaning crew fails to reduce the corrosion rate below this level, drain the system immediately into a holding tank under nitrogen pressure of 550 kPa gauge (80 psig). Rinse the system with condensate or demineralized water, and repeat steps from 12.5.3.1 above.

12.5.3.2 Passivation Phase

Commentary Note:

Other passivation procedures may be employed. The passivation shown here is an example. CSD chemical cleaning experts will review and comment on other passivation procedures on request.

1. If free EDTA concentration drops below 3.0% inject more EDTA to restore the concentration to 3.0%.
2. Add ammonia to adjust the solution pH to 9.5.
3. Add sodium nitrite and circulate for a period of 4 to 6 hours.
4. Drain the lube/seal oil and fluid power systems under air as before and refill with steam condensate or demineralized water, for a final rinse. At this point the system is both neutralized and passivated.
5. Open lube/seal oil and fluid power system and inspect.

12.5.3.3 Drying

Dry the system by flowing dry nitrogen at flow rate of at least, 1 m³/minute. Monitor the dew point with a calibrated portable dew point tester at several vent locations and at the final vent location most distant from the inlet point. During drying stroke all valves to assist with the removal of any water trapped in valve cavities. Continue the drying

operation until a dew point of -1°C or lower is achieved at all test locations.

13 Oil Flushing

- 13.1 After cleaning and drying the system, remove any temporary bypass connections other than those bypassing bearings, seals and gearboxes, and leave them in place until flushing is completed. Hand clean the areas that remain bypassed with lint-free cloths prior to system start-up.
- 13.2 Place 100 x 100 wire mesh stainless steel (9CAT 1000284291) screens between a pair of rubber gaskets (not asbestos), and installed flanges. Use 4 x 4 wire mesh backup screens (9CAT 1000284291) to prevent collapse at high flow rates. Remove and install new inspection screens in the lube and seal oil return piping at the reservoir flanges every 8 hours. Monitor flushing of solids by inspecting these screens. Keep the old screens tagged sequentially and with their location and removal time. If absolute filters are installed, instead of screens examine oil samples on a glass plate every 8 hours under microscope.
- 13.3 After drying, within 2 hours start flushing the lube/seal oil and fluid power systems with oil specified for the operating system for a period of approximately 48 hours to remove loose material in system. Flush the system at a velocity of at least 3 m/s, or at the maximum velocity limited by the MAOP in the larger lines. If the existing oil pumps cannot provide adequate circulation either in series, parallel, or high-speed operation, temporary circulation pumps shall be installed for the flushing operation. Monitor oil flushing velocity by (1) flow meters, (2) comparing the differential pressure to the pump's head capacity curve, or (3) ammeters on the motors.
- 13.4 When many parallel flow paths are present in the flushing circuit, selectively close off paths to force enough flow in each path to achieve 3 m/s minimum velocity.
- 13.5 If the presence of water is detected due to incomplete drying of the system, add 5% solution of Diethylene Glycol to scavenge the water. After circulating for 2 hours, drain the system at the reservoir flanges.
- 13.6 When system flush is near completion, stop flushing, drain the system at the reservoir flanges remove all valves, including block, CVs, self actuated CVs, etc., clean manually with lint-free cloths and replace.
- 13.7 Inspect and verify cleanliness of all temporary flushing equipment such as pumps, heat exchangers, piping, hoses and filters, in order not to add dirt to the system. Install at the outlet additional screens of each item of temporary flushing equipment.

- 13.8 If the system is segmented conducted the flush in a systematic manner to clean it sequentially from inlet to outlet, preventing re-contamination a section of the system that has already been flushed.
- 13.9 Periodically blow down drains, instrument connections and vents to remove accumulated water in low points in each shift during the flushing.
- 13.10 Slowly and repeatedly stroke valves between the nearly closed and fully open positions to create turbulence in the valve bonnet cavities, to flush them.
- 13.11 During flushing apply thermal, mechanical and hydraulic shock to dislodge foreign material.
- 13.12 Thermal Shock

During flushing vary the oil temperature from 38°C to about 80°C, alternately using the lube oil cooler and the heating coil.
- 13.13 Mechanical shock

Use a small plastic or copper hammer at weld joints, fittings and other areas that trap material frequently during flushing cycles.
- 13.14 Hydraulic Shock

Shock the system occasionally by interrupting the flow. Shut down the pump completely and wait for five minutes to allow for complete draining of lines. Restart the pump and restore full flushing velocity.
- 13.15 After 24 hours of flushing, install the equipment manufacturer's specified or 10 micron filter cartridges, whichever has the lower pore rating. Change filter cartridges if the differential pressure approaches by-pass pressure. Where heavy fouling of particular components is observed, install temporary 50 microns filters on the outlet piping of such components before installing the 10-micron equipment filters. Flush the system for 24 hours. Inspect the 50-micron filters and continue flushing with clean filters if necessary, until the heavily fouled components are considered sufficiently clean to allow installation of the 10-micron equipment system filters.

14 Acceptance

- 14.1 After approximately two days of flushing, perform an acceptance check to verify whether it meets the cleanliness requirements specified in [SAES-G-116](#), Section 7. If it does not, continue flushing for another 48 hours and repeat the cleanliness check. If the system is not clean after 7 days with slag, scale, paint, rust or other abrasive or adherent material continuing to appear on the inspection
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screens, circulation shall be stopped. Steps shall be taken to identify and isolate contaminated sections of the system. The contaminated parts of the system shall be mechanically or chemically cleaned again.

14.2 If chemical cleaning is required:

1. Drain the flushing oil.
2. Degrease with steam or surfactants to remove the flushing oil from the system, and then proceed as in Section 12.

15 Preparation for Service

- 15.1 After flushing is completed, drain the flushing oil from the oil reservoir, overhead tank, filters, coolers and piping. Hand clean the oil reservoir and overhead tank internally using lint free cloth.
- 15.2 Discard and safely dispose the drain flushing oil.
- 15.3 Install the turbulators after thoroughly solvent washing and hand drying each piece independently.
- 15.4 Remove all remaining bypasses and screens, install bearing seals and new filter elements. Restore the oil system to the operating configuration.
- 15.5 Re-fill the lube and seal system with the service oil specified.

16 Lay-Up

If the start up is delayed by more than five days (120 hours) after flushing of the system, protect it against corrosion by completely filling the system with inhibited service oil.

Revision Summary

12 January 2009	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.
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Appendix 1 – Definition of Terms

Austenitic Stainless Steels: Steels containing both chromium and nickel, e.g., 300-series stainless steels. These alloys are essentially nonmagnetic and corrosion resistant in many environments.

Blend filling: A method of filling a vessel with acid in which the concentrated acid (in liquid form) is metered into the filling line at such a rate as to maintain the desired concentration level in the liquid entering the vessel.

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

Mill Scale: A layer of iron oxide consisting of magnetite (Fe_3O_4) on the surface of hot rolled steel.

Mils per Year (mpy): A measurement of corrosion penetration in one thousandths (0.001) inch per year.

Neutralization and Passivation: A treatment for steel surfaces to give greater resistance to corrosion by shifting the normal electrochemical potential of the metal with a thin film of oxide.

pH: A value between 0 and 14 taken to represent the acidity or basicity of an aqueous solution.

Sacrificial Valve: A substitute valve used in a chemical cleaning operation in place of the regular valve equipment to prevent corrosion damage to that equipment.

Surfactant: A compound that reduces surface tension when dissolved in water or water solutions or that reduces interfacial tension between a liquid and a solid.

Water (steam condensate or demineralized water): Good quality water having a conductivity of less than 50 micro mhos.

Water Flushing: Cleaning a metal surface by copious supplies of water at 3 m/s.

Appendix 2 – Contractor Submittals

For review and approval, contractor submittals shall include the following. (See paragraph 4.4.)

Lube oil System details

1. Location, fill volume, materials of construction
2. Components isolated, blinded, plugged, or removed, instruments, filters, tanks
3. Contaminant composition and solubility in the proposed acid solution.

Selected treatments for cleaning

4. Hot alkaline treatment
5. Acid solution
6. Neutralization and passivation

Materials and Quantities

7. Steam condensate or demineralized water volume for each stage of cleaning
8. Nitrogen volume for each stage of cleaning
9. Chemicals and quantities
10. Emergency chemicals, equipment and quantities
11. Inhibitor name and quantity

Equipment details

12. Pumps and capacities
13. Size, pressure rating of Piping, Fittings, and Valves
14. Tanks and holding capacities
15. Power source

Control parameters

16. Circulation rate, temperature limits, chemical concentrations, pH, Fe, corrosion rate
 17. Sketch of circulation path, showing locations of: pumps, control valves, chemical injection, flow and temperature instruments, corrosion probes, vents, drains, blinds, plugs
 18. Waste disposal plan and approvals, Chemical Hazard bulletins/MSDS
 19. Chemical analysis procedures
 20. Contractor safety manual
 21. Contingency plans to handle piping leaks, pump failures
 22. Corrosion control methodology
 23. Corrosion monitoring methodology
 24. Quality assurance and control procedures
 25. Schedule of activities, start and end dates
 26. Personnel assigned and their qualifications
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Appendix 3 – List of Approved Inhibitors

Saudi Aramco Approved Commercial Corrosion Inhibitors for Chemical Cleaning

Acid, max. conc.	Max. Corr. Rate ⁽¹⁾	Max. Temp °C	MANUFACTURER or DISTRIBUTOR			
			Amchem ⁽³⁾ Chemical, suggested conc. % ⁽²⁾	Akzo ⁽⁴⁾ Chemical, suggested conc. % ⁽²⁾	Halliburton ⁽⁵⁾ Chemical, suggested conc. % ⁽²⁾	Navdeep ⁽⁶⁾ Chemical, suggested conc. % ⁽²⁾
HCl, 6% v/v	300 mpy	82	Rodine 213 or 214 , 0.2 v/v	Armohib 28 , 0.2 v/v	HAI 50 , ** 0.2 v/v	Nevamine CP 20 , 0.2 v/v
Citric, 3.5% w/w	200 mpy	92	Rodine 31A , 0.2 w/w of citric acid	Armohib 31 , 0.2 w/w of citric acid	OSI-1A , 0.2 w/w of citric acid	none
EDTA, 10% w/w	200 mpy	95	Rodine 241 , 0.2 w/w of EDTA	none	OSI-1A , 0.2 w/w of EDTA	none

Notes:

- 1) The corrosion rate is measured at the pump discharge upstream of the four way flow reversal manifold per Appendix 5. The flow velocity and the inhibitor concentrations are adjusted such that the maximum corrosion rate is not exceeded.
- 2) Suggested concentrations are shown. The actual concentration shall be adjusted such that the maximum corrosion rate is not exceeded.
- 3) Henkel Surface Technologies Madison Heights, MI, U.S.A.; phone: 248-583-9300, Fax: 248-583-2976
- 4) Akzo Chemicals Inc., Chicago, Ill. U.S.A.; phone: 312 906-7500
- 5) Halliburton Services, Dhahran, Saudi Arabia, 31932, phone: 03 856-1616/-1544, Fax: 03-856-1591
- 6) Navdeep Chemicals, Bombay, India, phone: 009122-261-3855/-7715/-2804, Fax: 009122-286-2735

** Surfactant must also be added

Appendix 4 – Chemical Cleaning Log Sheet

Plant Location	Acid(s) Used
System No.	Date Started
System Type	Date Finished

Date	Time	Temp. °C	Acid % wt.	Total Iron mg/L	PO ₄ mg/L	KMnO ₄ mg/L	Corr. mpy	pH	Notes
Date:					Shift Supervisor				

Appendix 5 – Corrosion Monitoring and Control

Electrochemical Instrumentation

- Use electrochemical instrumentation for acid/EDTA inhibitor effectiveness testing and to provide on-line, real time corrosion monitoring and control during the acid /EDTA stage of the cleaning process.
- A suitable instrument would comprise a computer-controlled potentiostat, and probes capable of making repeated linear polarization resistance measurements.
- Verify inhibitor effectiveness (see Appendix 3 for maximum allowable corrosion rate) in static solution at the temperature specified.
- Perform corrosion measurements using two or three electrode probes installed on the access fittings located in the temporary pipe work. At least use two monitoring points as noted below.
- In the pump outlet line, upstream of the flow reversal manifold.
- In the pump inlet line, downstream of the flow reversal manifold.
- Monitor as soon as acid is introduced into the lube/seal oil and fluid power systems and continue until drain down.
- If the measured corrosion rates exceed 600 mpy for a period of 15 minutes, and action by the cleaning crew fails to reduce the corrosion rate below this level, drain the lube/seal oil and fluid power systems as soon as possible under nitrogen pressure.