

Engineering Procedure

SAEP-317

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Testing and Inspection (T&I)
of Shell and Tube Heat Exchangers

Document Responsibility: Inspection Dept.

Saudi Aramco DeskTop Standards

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1 Scope

This Saudi Aramco Engineering Procedure (SAEP) describes the procedures and requirements for the inspection, testing, repairing and re-rating of In-service Shell and Tube (S&T) Heat Exchangers.

2 Purpose

This SAEP is intended to be used by Plant and Equipment (P&E) Inspectors from both the Operation Engineering Inspection Units and shop inspectors when inspecting shell and tube heat exchanger equipment that is removed from service for T&I. It also defines the responsibilities of the organizations involved in inspecting, testing, repairing, altering, and maintaining records on heat exchangers.

3 References

References shall be the latest issued revision or edition.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

<u>SAEP-20</u>	<i>Equipment Inspection Schedule</i>
<u>SAEP-1140</u>	<i>Qualification of Saudi Aramco NDT Personnel</i>
<u>SAEP-1142</u>	<i>Qualification of Non-Saudi Aramco NDT Personnel</i>
<u>SAEP-1144</u>	<i>Magnetic Particle Examination</i>
<u>SAEP-1145</u>	<i>Liquid Penetrant Examination</i>

Saudi Aramco Engineering Standards

<u>SAES-A-004</u>	<i>Pressure Testing</i>
<u>SAES-A-005</u>	<i>Safety Instruction Sheet</i>
<u>SAES-E-004</u>	<i>Design Criteria for Shell and Tube Heat Exchangers</i>
<u>SAES-H-100</u>	<i>Painting Requirements for Industrial Facilities</i>
<u>SAES-H-101</u>	<i>Approved Protective Coating Systems</i>
<u>SAES-H-102</u>	<i>Safety Requirements for Painting</i>
<u>SAES-W-010</u>	<i>Welding Requirements For Pressure Vessels</i>

Saudi Aramco Materials System Specifications

<u>32-SAMSS-004</u>	<i>Manufacture of Pressure Vessels</i>
<u>32-SAMSS-007</u>	<i>Manufacture of Shell and Tube Heat Exchangers</i>

Saudi Aramco Forms & Data Sheets

<i>Form SA 2173-ENG</i>	<i>Data and Operating Limits – Heat Exchangers</i>
<i>Form SA 2714-ENG</i>	<i>Shell and Tube Heat Exchanger Data Sheet</i>

Saudi Aramco General Instructions

<i>GI-0002.100</i>	<i>Work Permit System</i>
<i>GI-0002.102</i>	<i>Pressure Testing Safety</i>
<i>GI-0006.102</i>	<i>Isolation, Lockout and Use of Hold Tags</i>

Saudi Aramco Standard Drawing

<i>AE-036250</i>	<i>Ferrules for 0.750" Outside Diameter Condenser Tubes</i>
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3.2 Industry Codes and Standards

American Society of Mechanical Engineers

<i>ASME SEC II</i>	<i>Material Specifications</i>
<i>ASME SEC VIII D1 & D2</i>	<i>Boiler and Pressure Vessel Code</i>

American National Standards Institute

<i>ANSI NB-23</i>	<i>National Board Inspection Code</i>
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American Petroleum Institute

<i>API STD 510</i>	<i>Pressure Vessel Inspection Code</i>
<i>API RP 572</i>	<i>Inspection of Pressure Vessels</i>
<i>API STD 660</i>	<i>Shell and Tube Heat Exchangers for General Refinery Services</i>

Tubular Exchanger Manufacturers Association (TEMA)

4 Safety

- 4.1 All inspection and testing shall be in full compliance with GI-0002.100, "Work Permit System".

- 4.2 All inspection and testing shall be in full compliance with GI-0006.102, "Isolation, Lockout and Use of Hold Tags".
- 4.3 All pressure testing shall be in compliance with GI-0002.102, "Pressure Testing Safety".
- 4.4 All blasting and painting operations shall be in compliance with [SAES-H-102](#), "Safety Requirements for Painting".

5 Definitions

Exchanger: Denotes shell and tube type heat exchangers, condensers, re-boilers, coolers, pre-heaters, unfired heaters, heating coils, chillers, steam generators, vaporizers, and evaporators, all with either fixed or removable tube bundles.

Inspector: is any of the following:

- A Saudi Aramco employee qualified to the criteria specified in the Company's Plant & Equipment (P&E) Inspector Job Descriptions recognized by the Organization and Industrial Engineering Department (O&IE), and a member of a business line Operations Engineering/Inspection Unit,
- A qualified contract P&E Inspector, or
- An assigned Shops Inspector.

Shop: Any Company Maintenance or ASME approved vendor shop qualified to engage in repair, test or alter heat exchangers.

Field: Any location where heat exchanger repair work is performed, other than in a Shop.

Repair, Alteration and Rerating: For definition of these terms refer to ANSI NB-23, National Board Inspection Code and API STD 510, Pressure Vessel Inspection Code and SAES-D-008, Inspection, Repairs, Alteration, Rerating and Testing of Existing Pressured Equipment.

Manufacturer's Data Report: A Code document completed and furnished by the Manufacturer, certifying all materials, construction and workmanship conform to Code requirements.

Safety Instruction Sheet (SIS): A SIS (Saudi Aramco Form 2713-ENG) shows the minimum required thickness and test pressure of each exchanger component based on the design pressure and temperature in accordance with [SAES-A-005](#).

Minimum Required Thickness: Minimum thickness t_m is equal to the design thickness as calculated by the applicable ASME SEC VIII D1 or D2 to the temperature, pressure and/or vacuum limits as specified by the Company. The calculated $t_m(s)$ exclude corrosion allowance and apply to all components except tubes which are covered by a separate definition. When t_m design thickness is reached by loss of the corrosion allowance through service related corrosion/erosion, action must be taken to repair, replace, retire, or de-rate the equipment.

Corrosion Allowance (C): The corrosion allowance is any metal thickness in excess of the calculated minimum required thickness. If an exchanger is clad, the cladding must be considered as corrosion allowance.

Corrosion Rate: Corrosion rate is the rate of metal loss due to corrosion over a period of time. The corrosion rate is usually measured in mils per year (mpy).

Lamiflex Seal: Multiple layers of a flexible thin gage metal bolted to the side edges of the horizontal baffle to seal between the baffle and the shell. It directs the flow longitudinally in the shell to ensure circulation through the upper and lower halves of the bundle.

Ligament: The metal between adjacent tube holes in a tubesheet.

Ding: This term define mechanical damage, such as dents and gouges.

Knife Edging: Refers to the erosion and corrosion of the channel and floating head cover baffle edges. This is usually associated with bypassing of a liquid or gas between the tubesheet gasket grooves and corrosion of the channel/floating head baffle(s).

Baffle Grooving: Refers to erosion and corrosion which grooves either the bottom portion of a heat exchanger shell (due to bypassing of a liquid) at the junction of the vertical baffles of a tube bundle and the shell, or results in horizontal grooves at the junction of the lamiflex seal and shell.

Wire Drawing: Describes the results from the abrasive cutting action of a liquid or steam across a gasket seating surface creating a hairline groove which allows leakage.

Tube Minimum Wall Thickness (TMS): Tube minimum wall thickness shall be the greater of the calculated minimum thickness (t_m) or one third ($\frac{1}{3}$) the original tube design thickness (structural minimum). In most instances, the calculated minimum tube wall thickness required to contain the pressure would be so small that the tube would have insufficient structural strength to be self supporting and withstand other imposed operational stresses.

6 Responsibilities

- 6.1 The Responsible Operation Engineering Division/Inspection Unit (OED/IU) shall:
 - 6.1.1 Establish and revise inspection intervals, in accordance with [SAEP-20](#) limits, based on the conditions found during Testing and Inspection (T&I). The initial internal inspection or T&I of the exchanger is between one and two years after the initial start-up. The next T&I shall not exceed $\frac{1}{2}$ the calculated remaining life of any component or 10 years whichever is less. The inspection interval shall be assigned for each exchanger and listed in an Equipment Inspection Schedule (EIS).
 - 6.1.2 Provide the Responsible Operations Maintenance Division (OMD) with recommended repair procedures for damaged exchangers including tube plugging or replacement.
 - 6.1.3 Perform all inspections and specify the degree of cleanliness and what tests are required on the exchangers in accordance with Sec. 7 "Detailed Inspection of Heat Exchangers" of this SAEP.
 - 6.1.4 Witness and evaluate all required tests performed on the exchanger. The inspection unit supervisor may authorize others to witness certain tests at his discretion but shell test and test to identify leaking tubes shall be witnessed and accepted by the inspector.
 - 6.1.5 Verify all repair work on the exchanger is in compliance with the scope of work and with the requirements of this SAEP. Inspector shall also verify that the exchanger is acceptable to return to service for continued operation.
 - 6.1.6 Perform On Stream Inspection (OSI) on all exchanger components accessible during operations.
 - 6.1.7 Maintain a permanent and progressive set of records for each exchanger per Sec. 10 of this SAEP.
- 6.2 The Responsible Operations Engineering Division/Operation Engineering Unit (OED/OEU) shall:
 - 6.2.1 Issue/review T&I packages identifying anticipated work on exchangers. T&I packages should contain the scope of the inspection, the required testing and the blinding list.

- 6.2.2 Review and approve the recommended repair procedures submitted by OED/IU for repairs of a routine nature. Prepare and issue alteration procedure for alteration/repair of a none routine nature.
 - 6.2.3 When needed, OEU will provide special repair procedures for damaged exchangers. The repair procedures should include methods of repair/replacement, approved welding procedures, material and coating specifications, etc.
 - 6.2.4 The proponent OED/OEU shall prepare and issue chemical cleaning and/or neutralization procedures as needed for properly cleaning and neutralizing exchangers for T&I work.
 - 6.2.5 Prepare and issue a new/revised Safety Instruction Sheet per [SAES-A-005](#) any time an exchanger is rerated.
 - 6.3 The Responsible Operations Maintenance Division (OMD) shall:
 - 6.3.1 Determine whether specified exchanger T&I work will be performed in the shop or in the field. Notify inspection Unit regarding planned T&I action to facilitate their pre-shutdown inspection.
 - 6.3.2 Provide positive isolation, purge and drain the exchanger and certify that it is safe for T&I work to begin. When T&I is to be performed in the field, Operations, Maintenance and Engineering (OME) shall proceed with work per paragraphs 6.4.1 through 6.4.6.
 - 6.3.3 When T&I is to be performed in the shop, OMD shall remove applicable exchangers from the plant and transport them to the Shop for inspection, testing and/or repair per section 6.4 below.
 - 6.3.4 When shop T&I work is completed and accepted by inspection, transport exchanger from the shop and install in the plant.
 - 6.3.5 A tube bundle, that has been removed from the shell for maintenance, shall be subjected to all the required pressure tests in situ as per the SIS and be inspected for tube, roll and gasket leaks.
 - 6.3.6 After the exchanger is accepted for service by inspection, OMD shall remove the isolation blinds and reconnect all piping.
 - 6.3.7 Fabricate and install new name plate for re-rated exchanger as authorized by OED per paragraph 9.7 below.
 - 6.4 The Responsible Mechanical Services Shop Department/ Northern Shops Division (MSSD/NSD) shall:
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- 6.4.1 Notify the responsible OED/IU at least 4 hours prior to start of any disassembly, cleaning, testing or repair work on any exchanger. One calendar day notice will be required for offshore and remote areas.
- 6.4.2 Disassemble and clean all components of the exchanger for inspection.
- 6.4.3 Perform all repair work in accordance with the approved repair procedures.
- 6.4.4 To ensure cooperation and a team effort, the Shop Foreman or his designated representative can provide information regarding their assessment and repairs recommended to the inspector while he is at the shop performing the initial or detailed inspection. This will provide for development of the most cost effective plan for repair/reconditioning of exchangers. The scope of work decision remains the responsibility of OED/IU.
- 6.4.5 Remove representative tubes, as designated by the inspector, for sectioning and inspection, or prepare tubes for in place non-destructive evaluation when specified.
- 6.4.6 Perform all pressure tests described in Section 8, "Pressure Testing".
- 6.4.7 Notify the responsible OME when T&I is complete and the exchanger is ready for return to plant.

7 Detailed Inspection Procedure

7.1 Initial Inspection

- 7.1.1 Review inspection, operating history and maintenance records including OSI survey findings to note any trends and prepare initial recommendations. If tube leaks are suspected based on history, request a pretest as defined in paragraph 8.5 of this procedure.
 - 7.1.2 Perform pre-shutdown inspection to note leaks and other components that require further evaluation when the exchanger is removed from service. Remove plugs from insulation, check for both external corrosion and the integrity of insulation to determine if more insulation removal is required to inspect for under insulation corrosion.
 - 7.1.3 Make an initial inspection immediately after the tube bundle has been pulled from the shell and before cleaning to check for patterns and types of fouling and evidence of plugged tubes. In case of fixed tubesheet heat exchangers, the initial inspection must be done through the shell nozzles.
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If necessary, collect sample of sludge material and send for laboratory analysis to determine the type of corrosive materials present. Extra caution should be taken when handling pyrophoric material that can spontaneously ignite.

- 7.1.4 Record the number and location of tubes already plugged, update inspection data and compare with existing inspection records.
 - 7.1.5 Ensure that each component of the heat exchanger is properly cleaned before it is inspected. Recommend further cleaning when required for inspection purposes.
 - 7.1.6 Ensure that 300 series stainless steel tube bundles are cleaned/tested with fresh water, condensate or boiler feed water that contains less than 50 PPM chlorides. Provide soda ash neutralization of such bundles as specified by OED prior to opening the exchanger.
 - 7.1.7 When skim cut machining is required for gasket surfaces, measurements must be taken before and after the machining to ensure minimum flange thickness is maintained.
- 7.2 Inspection of the Stationary Head (Channel/Bonnet)
- 7.2.1 Perform a visual inspection on the entire body/baffle of the channel/bonnet and channel cover. If component has cladding or overlay visually check 100% and perform NDE as needed. Inspect all welds and their Heat Affected Zone (HAZ) for corrosion and defects. Perform Wet Fluorescent Magnetic Particle Test in accordance with SAEP-325 on all welds of magnetic material when material/environment is susceptible to cracking. Penetrant Testing (PT) or UT shear wave must be used to test for cracking suspected on non-magnetic material. Inspect baffles for deformation that would indicate need for additional support. Inspect the bosses, short nipples and valves on the channel/bonnet inlet and outlet nozzles.
 - 7.2.2 Inspect channel/bonnet flange gasket surface(s), the channel cover gasket surface, the inlet and outlet nozzle flange gasket surfaces, and the horizontal baffle gasket surfaces. Look for corrosion, wire drawing and dings. Inspect the horizontal baffle gasket surfaces for knife edging which indicates possible bypassing.
 - 7.2.3 Ultrasonically gage the thickness of the channel/bonnet, the channel cover and the channel/bonnet nozzles. Calculate the corrosion rate as defined in API STD 510 and check the remaining thickness against the

Minimum Required Thickness (TM). Evaluate integrity of welds by using the appropriate NDE procedure. Measure and record depth of pits.

- 7.2.4 Visually inspect all short nipples for corrosion/deposits and use Nondestructive Examination (NDE) as needed to verify condition of nipples.
- 7.2.5 Check the percent depletion of sacrificial anodes and replace as applicable. Visually inspect the internal coating/lining system and repair/replace if needed.
- 7.2.6 Recommend repairs of the stationary head as needed.

7.3 Inspection of the Shell and Shell Cover

- 7.3.1 Visually inspect the entire shell surface for internal corrosion, particularly for baffle grooving where cross baffles of the tube bundle contact the shell. If coated, inspect the internal coating of the shell. Measure and record depth of pits by using a pit gauge.

Internal inspection of shell for exchangers with 2 fixed tubesheets is done through the nozzles and might be limited by nozzle size. However, such design is normally selected for very clean shell side services.

- 7.3.2 Visually inspect the internal surface of the shell cover for general corrosion especially along the bottom surface where corrosive products can accumulate. Measure and record depth of pits.
- 7.3.3 Inspect all welds and their Heat Affected Zone (HAZ) for corrosion and defects. Perform Wet Fluorescent Magnetic Particle Test in accordance with SAEP-325 on all welds of magnetic (ferritic) material when material/environment is susceptible to cracking. Penetrant Testing (PT) or UT shear wave must be used to test for cracking suspected on non-magnetic (non-ferritic) material. Perform PT in accordance with [SAEP-1145](#).
- 7.3.4 Inspect the (G-3) & (G-4) shell and shell cover flange gasket surfaces and the shell inlet and outlet nozzle flange gasket surfaces for general corrosion, wire drawing, dings and other mechanical damage.
- 7.3.5 Inspect all nozzles and their attachment welds for corrosion. Recommend repair or replace the corroded nozzle or nozzle attachment welds as required.

- 7.3.6 Inspect all reinforcement pad weep holes for signs of leakage. If leakage is suspected, an air/soap test should be conducted on the applicable internal surface per [SAES-A-004](#).
 - 7.3.7 UT measure the shell and shell cover and document the readings. Calculate the corrosion rates as defined in API STD 510 and check the remaining life. Determine what repairs are needed to ensure thickness remains above tm during the next service period.
 - 7.3.8 Recommend shell and shell cover repairs as needed.
 - 7.4 Inspection of the Floating Head Cover
 - 7.4.1 Visually inspect the floating head cover and including the partition plates for corrosion and cracking.
 - 7.4.2 Inspect gasket surfaces for dings, wire drawing, other mechanical damage and general corrosion.
 - 7.4.3 Ultrasonically gage the floating head cover. Calculate corrosion rates as defined in API STD 510 and compare the remaining thickness against the tm.
 - 7.4.4 Check the floating head cover bolts for thinning and corrosion. For bolting exposed to caustic, amine or sour services, a sample of the bolts (10%) should be inspected for stress corrosion cracking using Wet Fluorescent Magnetic Particle Testing (WFMPT) per [SAEP-1144](#), Appendix III or an approved UT procedure. If any bolt cracking is found, all the remaining bolts should be inspected. Also, stamping on ends of bolts should be checked to ensure the specified bolts are used.

Commentary Note:

If floating head bolts are found to be broken in caustic, amine or sour service check bolt stamping, use B7M bolts.
 - 7.4.5 Recommend repairs of floating head cover and bolting replacement as necessary.
 - 7.5 Inspection of the Tube Bundle
 - 7.5.1 Inspect tubesheets, especially the gasket surfaces, after the tube bundle has been cleaned. Look for general corrosion, pitting corrosion, wire drawing, mechanical damage, erosion, tube seal weld cracks, cracked ligaments, and galled threads in the bundle stud pulling holes. Suspected cracking should be verified by using either PT or WFMPT.
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- 7.5.2 Inspect the tube bundle exterior; that is the tube O.D., impingement plate, vertical baffles, tie rods and spacers and the horizontal baffle with lamiflex seals if so equipped. Look for general corrosion, pitting, high velocity erosion, environmental attack, tube grooving at baffles resulting from vibration and mechanical damage. Document tube I.D./O.D. and wall thickness and compare to original measurements. Inspection of fixed tubesheets exchangers can be done through shell nozzles.
- 7.5.3 Inspect the tube ends and tube I.D. for tube end impingement, high velocity erosion, general corrosion and pitting. For this inspection use no less than 25 foot-candles of light, a tube scratcher, boroscope and NDE as deemed necessary by the inspector.
- 7.5.4 Mark sample/specimen tubes to be removed for inspection. Have them split full length and sandblasted before evaluation. An alternative is to utilize an appropriate nondestructive technique, such as MFL, UT, ET, or RFET to evaluate thickness of tubes in place.
- 7.5.5 Leaking tubes and tubes approaching and/or below minimum wall thickness (tm) shall either be plugged or replaced (match tube metallurgy when selecting plugs). Such tubes are the best specimens to pull for inspection. Calculate corrosion erosion rate as defined in API STD 510 and determine remaining life. A guideline for retubing decisions should be based on the greater of the calculated minimum thickness (tm) or one third ($\frac{1}{3}$) the original tube thickness. Selection of $\frac{1}{3}$ the original tube thickness provides for structural integrity of tubes.

Commentary Note:

Prior to installing any tube plug in any tube either cut the tube behind the tubesheet or drill a hole in the tube. The venting of the tube will keep the pressure from building up inside the tube and blowing out the tube plug or plugs.

- 7.5.6 Inspect all ferrules for deterioration, cracking, and looseness. Ensure that all tubes on inlet passes are protected with properly inserted ferrules that fit snugly, if specified.
- 7.5.7 Consult with the Responsible Operation Engineering Unit regarding bundle retubing when 10% of tubes in any one pass or a total of 10% of the tubes in the bundle have been plugged. When bundle re-tubing is required, the Responsible Operations Engineering Unit, Corrosion Engineer or CSD shall approve that the tube material specified by the Inspection Unit is adequate for the process conditions or shall specify alternative tube material.

7.5.8 Recommend tube bundle repair/re tubing as necessary. Prior to issuing a re-tube worksheet, consult the responsible Operating Engineering Unit to confirm the findings.

7.6 Inspection of the Foundations, Supports and Anchor Bolts.

7.6.1 Visually inspect the concrete piers for cracks, spalling, general deterioration, and settlement. Check for rust and stains on the concrete. This will indicate either the reinforcing bars or the steel piling are corroding.

7.6.2 Visually inspect for crevice corrosion between the exchanger shell and cradle support, especially if the two components have not been completely seal welded. Trapped moisture can cause corrosion on carbon steel shells. Recommend seal welding the exchanger shell to the cradle support.

7.6.3 Verify that the slots for the hold-down-bolts on the floating-head-end of the cradle footings will accommodate thermal movement. Ensure that the nuts are not tightened against the cradle footing or that the slots are not filled with grout or concrete.

7.6.4 Tap the anchor bolts with a hammer to determine soundness. The bolts may be corroded just beneath the concrete surface.

7.6.5 Check the ground cable connection.

7.6.6 Recommend foundation and support repair as necessary.

8 Pressure Testing

8.1 The number, type and sequence of pressure tests required for a heat exchanger depends on the type of inspection required, the exchanger design, the presence of leaks, the extent of repair and whether the exchanger is field or shop repaired.

8.2 Testing a heat exchanger with the tubesheet design, based on differential pressure, requires caution not to exceed the differential design pressure during testing.

8.3 Pressure tests shall be performed in accordance with [SAES-A-004](#) and the applicable safety instruction sheet (SIS).

8.4 New gaskets shall be used on final closure of all flanges and nozzle joints.

8.5 Preliminary Test (All Exchangers)

This test is performed when required to determine which exchanger (or bank of exchangers) is leaking. Begin every plant site job by obtaining a work permit per GI-0002.100 and by observing the safety requirements of GI-0002.102 during the testing. This test is applicable to all exchanger designs and it is performed by the following steps:

1. Isolate the exchanger per GI-0006.102 and approved blind list.
2. Drain the shell side of the exchanger.
3. Open the instrument connection (bleeder) or bottom shell nozzle flange.
4. Apply and maintain a hydrostatic pressure test, through the channel/bonnet nozzle, on the tube side of the bundle.
5. Look for leakage at the open connection per step 3 above.
6. Monitor pressure gauge and evaluate pressure drop for leak indication.

Warning:

During hydrostatic testing, never exceed the differential pressure rating when such a rating is given.

Never stand directly in front of any installed tube plugs while an exchanger bundle is being tested. There exists the possibility that a tube plug could be loose.

8.6 Initial Tube Test (Floating Tubesheet Exchangers)

8.6.1 When a leak is detected on the preliminary test, an initial tube test will be needed to determine if the leak is from the (G-5) floating head gasket, roll joints or damaged tubes. This test is performed by the following steps:

1. Remove the shell cover.
2. Apply and maintain a hydrostatic pressure test, through the channel nozzle, on the tube side of the bundle.
3. Check the (G-5) floating head gasket for leakage. If no leak is detected, then the bundle is leaking from a roll joint(s) or damaged tube(s). A ring test will be needed to positively identify the leak location(s).

8.6.2 If a test ring is unavailable, leak location(s) can usually be identified by the following steps:

1. With the shell cover removed and with pressure on the tube side, look for roll leaks from the back side of the floating tubesheet.

2. Drain the tube bundle. Remove the channel cover and reinstall the shell cover.
3. Dry the tubes by air blowing beginning at top row of tubes.
4. Apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
5. Slightly raise/elevate the floating head end of the exchanger to ensure leakage into any tube runs to the channel end.
6. Look for water leaking from tubes or roll joints at the stationary head-channel end tubesheet.
7. As a last resort, individual tube test may be required to positively identify which tube(s) are leaking.

8.7 Ring Test (Floating Tubesheet Exchangers)

This test is performed after the Initial Tube Test to determine which tubes in the bundle are leaking and to check for roll leaks. A ring test shall be performed to check for roll leaks on bundles reinstalled after they were removed for maintenance. This is a requirement of [SAES-A-004](#). This test is performed by the following steps:

1. Remove the channel cover.
2. Remove floating head cover from the floating tubesheet and install a specially fabricated packing gland type steel "Test Ring". When bolted in place, the test ring is designed to seal around floating tubesheet and at the (G-4) shell flange.
3. Apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
4. Look for leaks at both tubesheets of the tube bundle. Leaks can be from damaged tubes or tube to tubesheet roll joints.

8.8 Shell Test (U-Tube Heat Exchangers)

When leakage is detected on the preliminary test, a shell test will be needed to positively identify the location of the leak. This test can also be conducted without the preliminary test such as during normal T&I. The test is performed by the following steps:

1. Remove channel cover.

2. Apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
3. Look for water leaking from damaged tubes or roll joints at the stationary tubesheet.

8.9 Shell Test (Fixed Tubesheets Heat Exchangers)

When a leak is detected on the preliminary test, a shell test will be needed to positively identify the location of the leak. This test can also be conducted without the preliminary test such as during normal T&I. The test is performed by the following steps:

1. Remove both stationary heads (channels/bonnets).
2. Apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
3. Look for water leaking from damaged tubes or roll joints at both exposed tubesheets of the bundle.

8.10 Shell Test (Kettle Type Reboiler)

When a leak is detected on the preliminary test, a shell test will be needed to positively identify the location of the leak. This test can also be conducted without the preliminary test such as during normal T&I. The test is performed by the following steps:

1. Remove channel cover.
2. Apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
3. Look for water leaking from tubes or roll joints at the stationary tubesheet.
4. For re-boilers equipped with floating tubesheet, water leaking from the bottom row of tubes may indicate either leaking roll joints at the floating tubesheet or a (G-5) floating head gasket leak. To positively identify the location in such a case will require a tube test and entering the shell, if there is access, for floating head gasket inspection. A confined space entry requires special approval.

8.11 Final Tube Test

This test is performed to verify that the repaired tube bundle is still leak free after reinstallation in the shell. This test also verifies leak free connections as detailed below. The test is performed by the following steps:

1. Open the instrument connection on the bottom shell nozzle.
2. Apply and maintain a hydrostatic pressure test in the stationary head channel/bonnet on the tube side of the bundle.
3. Look for leaks at the shell side open bottom drain connection.
4. On U-tube exchanger, verify leak free gasket connections at the (G-1) channel to channel cover and (G-2) channel to fixed tubesheet gasket surfaces.
5. On exchanger with floating tubesheet, the test is done with the shell cover removed to check for (G-5) floating head cover gasket leakage.
6. On exchangers with 2 fixed tubesheets, verify leak free flanged gasket connections at both stationary heads (channels/bonnets). Channels on each end of these exchangers may have both G-1 and G-2 gaskets while bonnets will only have a G-2 connection.
7. On kettle type exchangers, such as re-boilers, verify leak free connections at the (G-1) channel to channel cover and (G-2) channel to fixed tubesheet gasket surfaces. Re-boilers with floating tubesheet require entering the shell, if there is access, to check for leaks from the floating head cover gasket. A confined space entry requires special approval.

8.12 Final Shell Test

This is usually the last test performed on the exchanger prior to returning it to service. This test verifies that there are no gasket leaks at the (G-3) fixed tubesheet to shell flange and (G-4) shell to the shell cover flange. This test is not required for exchangers with fixed tubesheets integral with the shell. The test is performed by the following steps:

1. Open the drain connection on channel/bonnet bottom nozzle.
 2. With the shell cover installed, apply and maintain a hydrostatic pressure test on the shell side of the exchanger.
 3. Look for leaks at the (G-3) and (G-4) shell flange gasket connections and at the channel drain connection.
 4. The pressure test duration shall be in accordance with [SAES-A-004](#).
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9 Repair, Modifications and Rerating

- 9.1 All applicable repair work shall be done in accordance with the applicable repair procedure and in compliance with the original design, SAES-D-008, API STD 510, ANSI NB-23, as supplemented by [SAES-E-004](#) and [32-SAMSS-007](#).
- 9.2 Alteration and rerating of the exchangers shall be as defined by the SAES-D-008, ANSI NB-23, National Board Inspection Code, or API STD 510, Pressure Vessel Inspection Code and shall be approved by the Responsible OED and concurred by the Consulting Services Department (CSD). A new SIS, Form 2713-ENG, and Shell and Tube Heat Exchanger Data Sheet, Form 2714-ENG, shall be completed, approved and issued by OED to document these changes. The old forms shall be voided and kept for record only. Do not modify the Manufacturer's Data Report. Make new drawings to reflect any changes. Appendix A of SAES-D-008 shall be used for recording of repairs and alterations.
- 9.3 Material selection for repairing or alterations of heat exchangers shall be in compliance with the original design data sheets, ASME SEC II or as approved by the Responsible OED. Material used in repairing exchangers shall be specified on the applicable repair procedure and must be verified by the inspector.
- 9.4 Welding on an exchanger shall be in accordance with [SAES-W-010](#), Welding Requirements For Pressure Vessels.
- 9.5 Welding on an exchanger shall be performed by certified welders, in accordance with an approved Welding Procedure Specifications (WPS).
- 9.6 A hydrostatic pressure test shall be performed as part of a heat exchanger rerating. The test pressure shall be as per the heat exchanger revised SIS.
- 9.7 Rerated exchangers shall be furnished with new name plates, showing rerated conditions as required by SAES-D-008 and API STD 510. An additional nameplate bracket may have to be installed. The original nameplate shall not be removed but should be voided and the date specified.

10 Records

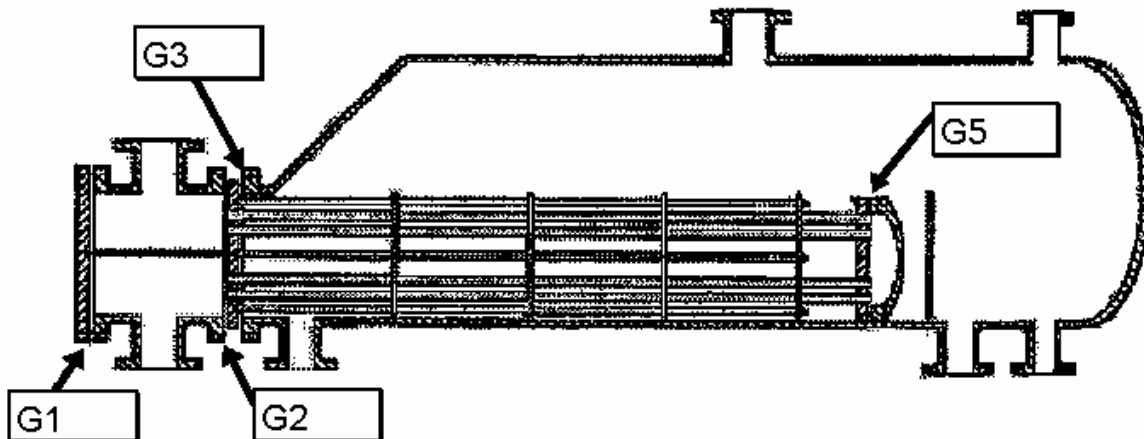
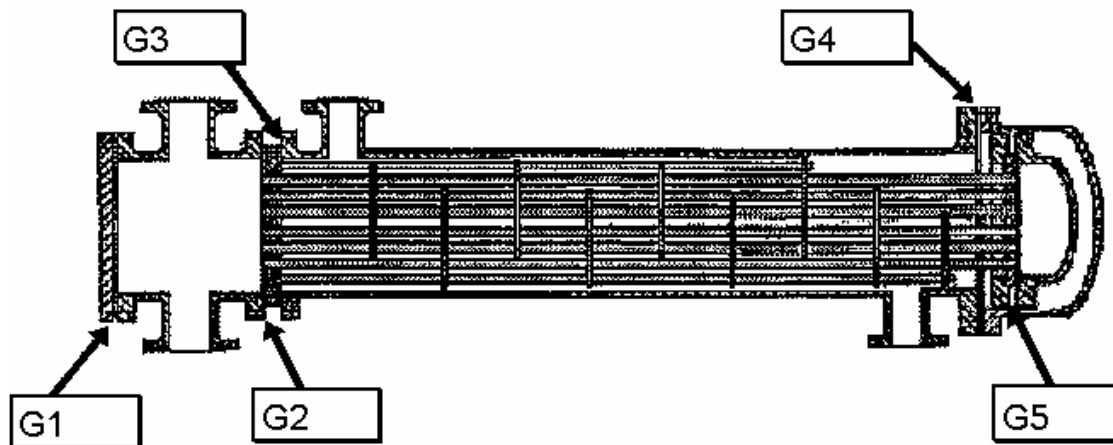
- 10.1 A permanent and continuous set of records shall be maintained by the proponent Inspection Unit on each heat exchanger. The records shall include but are not limited to the following:
 - a. Current Safety Instruction Sheet, Saudi Aramco Form 2713-ENG.

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- b. Current Shell and Tube Heat Exchanger Data Sheet, Saudi Aramco Form 2714-ENG.
 - c. Manufacturer's Data Report.
 - d. Past T&I and OSI reports (including corrosion rates, test results, cleaning procedures used, repairs, replaced components, number and location of plugged tubes, alterations, etc.).
 - e. Drawings and sketches reflecting any alterations including the number of plugged tubes and their location.
 - f. Condition and remaining service life of each component, including the bundle.
 - g. Final location of the tube bundle removed from shell; reinstalled in same shell, installed in another shell, sent to reclamation, etc.
 - h. Spare bundles available for each exchanger.
 - i. List of interchangeable bundles.
- 10.2 Inspection, maintenance/repair information should be recorded on heat exchanger inspection report/worksheet form similar to format shown in Appendix-B.

Revision Summary

30 July, 2003	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with editorial change in Commentary Note to paragraph 7.5.5.
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Appendix A – Exchanger Gasket Designation



Legend: Gasket Locations Identified by "G" Number

- G1 Represents Channel to Channel Cover Gasket
- G2 Represents Channel to Fixed Tubesheet Gasket
- G3 Represents Fixed Tubesheet to Shell Gasket
- G1 Represents Shell Cover to Shell Gasket
- G1 Represents Floating Head Cover to Floating Tubesheet Gasket

Appendix B - Inspection Report/Worksheet Form

SHELL / TUBE HEAT EXCHANGER INSPECTION REPORT/WORKSHEET		[] PARTIAL REPORT [] FINAL REPORT		WORKSHEET NO. DATE:	
PLANT No.	EXCHANGER No.	BUNDLE No.	CAUSE OF OUTAGE		
SHELL SIDE SERVICE	TUBE SIDE SERVICE		NUMBER OF TUBES		
SHELL & COMPONENT REPAIRS					
FUTURE RECOMMENDATIONS					
BUNDLE REPAIRS FOR (BUNDLE NO. _____)					
FUTURE RECOMMENDATIONS					
PRESSURE TESTING TEST PRESS FROM SIS: SHELL SIDE ___ PSIG, TUBE SIDE ___ PSIG		No. OF PLUGGED TUBES			
☐ TUBES LEAKED DURING RING/SHELL TEST ☐ ROLL LEAKS FIXED TUBESHEET DURING TEST ☐ ROLL LEAKS FLOATING TUBESHEET DURING TEST		PASS #	BEFORE	NOW	TOTAL
RING TEST AT ___ PSIG WITNESSED BY:	DATE:	AREA INSPECTOR		DATE:	
TUBE TEST AT ___ PSIG WITNESSED BY:	DATE:	FIELD SUPERVISOR		DATE:	
SHELL TEST AT ___ PSIG WITNESSED BY:	DATE:	UNIT SUPERVISOR		DATE:	

Appendix B – Inspection Report/Worksheet Form (Cont'd)

SHELL / TUBE HEAT EXCHANGER		DATE: _____ WORKSHEET NO. _____ PLANT NO. _____ EXCHANGER NO. _____			
INSPECTION REPORT/WORKSHEET					
CONDITION OF THE SHELL AND COMPONENTS					
COMPONENT	VISUAL INSPECTION FINDINGS (DESCRIBE)	ULTRASONIC SURVEY			
SHELL		to	ta	tm	R/L
SHELL COVER					
CHANNEL					
CHANNEL COVER					
FLOATING HEAD COVER					
SPLIT RINGS					
NOZZLES					
CONDITION OF BUNDLE					
TUBE MATERIAL:		TUBESHEET MATERIAL:			
	FIXED TUBESHEET (CHANNEL SIDE)	FLOATING TUBESHEET			
GENERAL CONDITION					
CLADDING CONDITION					
GASKET SURFACES					
TUBE ENDS CONDITION					
INTERNAL TUBE CORROSION					
EXTERNAL TUBE CORROSION					
INTERNAL TUBE FOULING					
EXTERNAL TUBE FOULING					
BAFFLES CONDITION					
TIE RODS CONDITION					
ADDITIONAL COMMENTS/SPECIAL TEST:					