Engineering Standard

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Design Criteria of Shell
and Tube Heat Exchangers

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Saudi Aramco DeskTop Standards

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1 Scope

1.1 This standard covers the minimum mandatory requirements for the thermal and mechanical design of new shell and tube heat exchangers (hereinafter referred to as exchangers). It does not cover exchangers that undergo repairs or alterations.

1.2 This standard is intended to establish a standard for thermal and mechanical design and to assist the Design Engineer in the selection and specification of exchangers.

1.3 The requirements in this standard shall be used by the Design Engineer for the completion of the Saudi Aramco's shell and tube heat exchanger data sheet (hereinafter referred to as data sheet).

1.4 This standard shall not be attached to or made a part of purchase orders.

1.5 This standard may not be applied to the design of non-TEMA exchangers that are used with or as parts of packaged equipment like motors, compressors, pumps and turbines oil coolers.

Commentary Note:

These exchangers have small heat transfer surface with a typical shell diameter of up to 6 inch and tube length of up to 4 feet.

1.6 Where a licensor's specification requirement is more stringent than that of this specification, this licensor's specific requirement shall govern.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design and construction of exchangers covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-005	*Safety Instruction Sheet*
SAES-A-112	*Meteorological and Seismic Design Data*
SAES-A-301	*Materials Resistant to Sulfide Stress Corrosion Cracking*
SAES-B-006	*Fireproofing in Onshore Facilities*
SAES-H-001	*Selection Requirements for Industrial Coatings*
SAES-H-101	*Approved Protective Coating Systems*
SAES-H-101V	*Approved Saudi Aramco Data Sheets - Paints and Coatings*
SAES-J-600	*Pressure Relief Devices*
SAES-L-109	*Selection of Flanges, Stud Bolts and Gaskets*
SAES-N-001	*Basic Criteria, External Insulation*
SAES-N-100	*Refractory Systems*
SAES-X-500	*Cathodic Protection Vessels and Tank Internals*

Saudi Aramco Materials System Specifications

32-SAMSS-007	*Manufacture of Shell and Tube Heat Exchangers*
32-SAMSS-031	*Manufacture of Clad Vessels and Heat Exchangers*

Saudi Aramco Forms and Data Sheets

Form SA 2713-ENG	*Safety Instruction Sheet - Shell and Tube Heat Exchangers*
Form SA 2714-ENG	*Shell and Tube Heat Exchanger Data Sheet*

3.2 Industry Codes and Standards

American Society of Civil Engineers

ASCE 7	*Minimum Design Loads for Buildings and Other Structures*

American Society of Mechanical Engineers

ASME SEC II	*Material Specifications Parts A, B and D*
ASME SEC VIII D1	*Rules for Construction of Pressure Vessels*
ASME SEC VIII D2	*Rules for Construction of Pressure Vessels, Alternative Rules*
ASME B16.11	*Forged Steel Fittings, Socket-welded and Threaded*
ASME B16.5	*Pipe Flanges and Flanged Fittings*
ASME B16.20	*Metallic Gaskets for Pipe Flanges - Ring-Joint, Spiral-Wound, and Jacketed*
ASME B16.21	*Non-Metallic Gaskets for Pipe Flanges*
ASME B16.47	*Large-Diameter Steel Flanges NPS 26 inch through NPS 60 inch*

American Petroleum Institute

API STD 660	*Shell and Tube Heat Exchangers for General Refinery Services*

Tubular Exchangers Manufacturers Association

TEMA	*Standards of the Tubular Exchanger Manufacturers Association*

Process Industry Practices

VEFV1100	*Vessels/S&T Heat Exchanger Standard Details*

4 Definitions

Amine Services: All amine solutions including MEA, DGA & ADIP.

Auto-Refrigeration Temperature: Auto-refrigeration temperature is the adiabatic vaporization temperature of the process fluid coincident with any pressure equal to 25% of the maximum operating pressure.

Caustic Services: All sodium hydroxide solutions at all temperatures and concentrations.

Cyclic Services: Services that require fatigue analysis per AD-160 of ASME SEC VIII

D2. This applies to Division 1 and Division 2 of ASME SEC VIII.

Design Engineer: The Engineering Company responsible for specifying the thermal and mechanical design requirements for exchangers.

Exchanger Manufacturer: The company responsible for the manufacture of exchangers.

High Alloy Steels: Steels with a total alloying content more than 5%.

Hydrogen Services: Process streams containing relatively pure hydrogen and component streams containing hydrogen with a partial pressure of 350 kPa abs (50 psia) and higher.

Lethal Services: Process streams containing a concentration of hydrogen sulfide in excess of 20% by volume shall be considered as lethal service.

LODMAT: The lowest one-day mean ambient temperature at a site or location.

Low - Alloy Steels: Steels with nominal chromium content up to 5% chrome or nominal nickel content up to 3%.

Nominal Thickness: The value of the design thickness required to withstand all primary loads, and includes allowance for corrosion.

Saudi Aramco Engineer: Supervisor of the Piping & Mechanical Unit of the Consulting Services Department, Dhahran.

Shock Chilling Effect: The rapid decrease in temperature of a component caused by a sudden flow of fluid colder than -20°C and at a temperature lower than the initial temperature of the component by 40°C, regardless of pressure.

Thick Wall Exchanger: An exchanger or part of it with nominal thickness greater than 50 mm.

Utility Services: Water, steam, air and nitrogen services

Wet Sour Service: Following process streams containing water and hydrogen sulfide:

1) Sour water service with a hydrogen sulfide (H_2S) concentration above 2 mg/L (2 ppm) and a total pressure of 450 KPa absolute (65 psia) or greater.

2) Hydrocarbon services meeting the definition of sour environments in SAES-A-301, where the H_2S concentration of 2 mg/L (2 ppm) or more in the water phase is equivalent to H_2S partial pressure of 0.05 psia. Sour crude systems upstream of a stabilization facility and sour gas upstream of a sweetening or dehydration plant are examples of such environments.

Wet Sour HIC Services: Hydrogen Induced Cracking (HIC) resistant steel qualified in accordance with 01-SAMSS-016 shall be specified for the following environments with normal operating temperatures between 0°C (32°F) and 150°C (302°F):

1) Sour water service with a hydrogen sulfide (H_2S) concentration above 2 mg/L (2 ppm) and a total pressure of 450 KPa absolute (65 psia) or greater.

2) Hydrocarbon services meeting the definition of sour environments in SAES-A-301, where the H_2S concentration of 2 mg/L (2 ppm) or more in the water phase is equivalent to H_2S partial pressure of 0.05 psia.

3) A hydrocarbon system exposed to an environment with a H_2S concentration above 50 mg/L (50 ppm) in the water phase, regardless of H_2S partial pressure.

Commentary Note:

HIC resistant steel is not required in caustic services, lean amine systems and rich amine DGA systems.

5 Responsibilities

5.1 The Design Engineer is responsible for specifying the thermal and mechanical design requirements and completing the data sheet in accordance with this standard. The Design Engineer may also carry out the thermal design.

5.2 The Exchanger Manufacturer is responsible for the thermal design (rating) and verification of the Design Engineer's thermal design, if applicable. The Exchanger Manufacturer is also responsible for the manufacture of exchangers, which includes the complete mechanical design, Code and structural calculations, supply of all materials, fabrication, nondestructive examination, inspection, testing, surface preparation, and preparation for shipment, in accordance with the completed data sheet and the requirements of 32-SAMSS-007 and 32-SAMSS-031.

6 Basis for Thermal Design

6.1 General

6.1.1 This section covers the basic design considerations which shall be used when selecting, sizing and specifying exchangers.

6.1.2 The exchanger nomenclature in TEMA shall be used when specifying exchangers, including sizes and types.

6.1.3 The Design Engineer shall utilize API STD 660, Annex B "Shell and Tube Heat Exchanger Checklist" when completing the exchanger data sheet.

6.2 Thermal Design

6.2.1 The exchanger size shall be based with due consideration for maintenance requirements. Following are the recommended maximum limits for removable bundles. Larger bundles may be used with prior agreement from the individual plant.

1) Bundle weight: 10200 kg (22400 lb)

2) Bundle diameter: 1524 mm (60 inch)

3) Straight tube length 6096 mm (20 feet)

Commentary Note:

Longer tube lengths and larger bundle diameters can reduce the number of shells for the same duty. However, this will require availability of lifting equipment capable of removing heavy tube bundles for maintenance.

6.2.2 Tube-side fluid shall generally be the higher ranking of the following:

1) Cooling water.

2) Fouling, erosive, corrosive or less viscous fluid.

3) The higher pressure fluid.

4) The smaller flow rate.

6.2.3 The log mean temperature difference (LMTD) correction factor shall not be less than 0.8.

6.2.4 The LMTD for kettle reboilers and the recirculating thermosyphon reboilers shall be based upon isothermal boiling at the outlet temperature.

6.2.5 The LMTD calculation for vertical thermosyphon reboilers shall take into account the suppression of the boiling point along the tube length due to the effect of static head.

6.2.6 The surface area in the 'U' bends shall be excluded from the heat transfer calculations except for tubes in kettle reboilers and stab-in type bundles.

6.2.7 Triangular pitch shall be limited to those services that are clean such that they do not require mechanical cleaning. Tube pitches shall generally be specified as follows:

1) Triangular pitch (30 degree) for all services with shell-side fouling resistance up to and including:

0.000176 m² °K/W (0.001 hr °F ft²/Btu)

2) Square pitch (90 degree) for shell side reboilers and for all services with shell-side fouling resistance above:

0.000176 m² °K/W (0.001 hr °F ft²/Btu)

3) Rotated square pitch (45 degree) for shell-side laminar flow regimes, in preference to square pitch.

6.2.8 For square and rotated square pitches, a minimum of 6.3 mm shall be provided between adjacent tubes. Cleaning lanes shall be continuous through the bundle.

6.2.9 For strength welded tube to tubesheet joint, a minimum of 6.3 mm shall be provided between adjacent tubes.

6.2.10 Fouling resistances shall be in line with the individual plant's operating experience in similar service and as per process licensor's recommendations/specifications, where applicable. In the absence of such information, the fouling resistance shall be selected from the values recommended by TEMA. The following are the exceptions to this:

1) Fouling resistance for sea water shall be 0.000352 m² °K/W (0.002 ft² hr °F/Btu).

2) Fouling resistance for untreated well water for water temperature up to 52°C shall be 0.000528 m² °K/W (0.003 ft² hr °F/Btu) and 0.00088 m² °K/W (0.005 ft² hr °F/Btu) for water above this temperature.

3) Cooling water outlet temperature not to exceed 49°C.

6.2.11 The Design Engineer shall consider providing spare exchangers for critical services where severe fouling can be expected and which would result in un-scheduled shutdowns.

6.2.12 The Design Engineer shall include provisions for blocking and bypassing streams where required by the process design. For example, the effect of bypassing heat transfer streams in a crude preheat exchanger train shall be fully investigated on the downstream exchangers.

6.2.13 For single phase shell-side services, the baffle cut shall be horizontal. Vertically cut baffles shall generally be specified for shell-side condensing and vaporizing services and for fluids containing suspended solids.

6.2.14 The value for the calculated pressure drop in the clean condition is to be specified on the data sheet.

6.2.15 When minimum wall tubes are specified, the tube-side pressure drop shall be based on 110% of the selected tube wall thickness.

6.2.16 Design inlet cooling water temperature to be used in the design of heat exchangers utilizing seawater shall as follows:

	Design Inlet Cooling Water Temperature	
Conditions	**East Coast**	**West Coast**
Summer	35°C	33°C
Winter	9°C	9°C

The maximum cooling water outlet temperature shall not exceed 49°C.

6.2.17 Where untreated well water is used as the cooling fluid, the design cooling water inlet temperature shall be based on actual water reservoir data.

6.2.18 Exchangers utilizing sea or untreated well water or cooling tower water as cooling medium shall have a minimum water velocity of 1.2 m/s. The maximum permissible water velocity varies with the tube material as shown below:

Materials	m/s
Admiralty Brass (inhibited)	1.5
Carbon Steel (only with fresh water)	1.8
Aluminum Brass or Aluminum Bronze	1.8
70/30 Cupro-nickel	3.0
90/10 Cupro-nickel	3.0
Nickel - Copper Alloy (Monel)	3.7
AISI 316 Stainless Steel (fresh water only)	4.6
Titanium	unlimited

6.2.19 Kettle reboilers shall be sized such that no more than 0.5 weight percent liquid is entrained in the outlet vapor. A minimum of 450 mm shall be provided as the height above the highest liquid level. Design engineer to provide vapor velocity at the vapor space in reboilers for review to Saudi Aramco Engineer.

6.2.20 The Design Engineer shall ensure that the exchanger design is free of any damaging flow induced tube vibration including the effect of acoustic vibration.

6.2.21 The Design Engineer shall provide the completed data sheet, and thermal design calculations (including tube vibration) for review by the Saudi Aramco Engineer. If the design is done using computer programs, the relevant input and output data shall be submitted.

The data sheet shall contain fluid physical properties used in the design, including non-linear condensing and boiling heat release profiles and weight fraction vapor curves, where applicable. For vaporizing services, critical pressure of the boiling fluid and the relevant vapor liquid equilibrium data shall also be provided.

The Design Engineer shall include a sketch on the data sheet, showing both the shell and the tube side flow arrangements. For stacked exchangers, it shall also show the stacking arrangement.

6.3 Selection of TEMA Types

6.3.1 The service is considered clean when fouling resistance of the stream is not greater than 0.000176 m^2 °K/W (0.001 hr °F ft^2/Btu). Fouling resistance in excess of this means that the service is fouling.

6.3.2 Generally, exchangers shall either be a floating head type (TEMA type SAES or AET) or 'U' tube type.

Floating head type is required when both the shell and the tube sides are considered fouling, and require mechanical cleaning. 'T' type (pull through) is preferred due to easier maintenance.

'U' tube bundles shall only be specified for use in clean tube-side services, or when tube-side can be chemically cleaned or when specified by the process licensor.

6.3.3 Fixed tubesheet type shall only be specified in shell- side clean and non-fouling services or when specified by the process licensor. However, fixed tubesheet type is not acceptable in shell-side wet sour services.

6.3.4 Fixed tubesheet exchangers without the expansion joints are acceptable up to a maximum differential temperature of 28°C between tube wall temperature in any one tube pass and average shell temperature. However, when shell and tube materials have different thermal expansion coefficients, the differential stresses shall be analyzed even

when the temperature difference is less than 28°C. Designs with shell expansion joint require approval by Saudi Aramco engineer.

6.3.5 For fixed tubesheet exchangers, the Design Engineer shall analyze and specify (on the data sheet) the mean shell and tube wall temperatures which give the maximum temperature differential. The conditions of normal operating, start-up, shut-down, process upset, emergency, and steam-out shall be investigated to determine the maximum differential.

6.3.6 Shells with two passes (TEMA 'F' type) shall not be used unless approved by the Saudi Aramco Engineer.

For shells with two passes, the shell-side fouling resistance shall not exceed:

$$0.000176\ m^2\ °K/W\ (0.001\ hr\ °F\ ft^2/Btu)$$

'F' type shells shall be limited to a maximum shell-side pressure drop of 70 kPa (10 psi).

6.3.7 Packed floating heads are not permitted, except where approved by the Saudi Aramco Engineer.

6.3.8 Preferred channel covers are TEMA type 'A' (removable flat cover). Type 'B' (integral bonnet) covers may be used when tube-side fluid is non-fouling, and frequent access to the tubesheet is not anticipated.

6.4 Tubes

6.4.1 The minimum tube outside diameter shall be 19.05 mm (0.75 inch) unless otherwise approved by the Saudi Aramco Engineer. Preferred tube diameters are 19.05 mm (0.75 inch) and 25.4 mm (1 inch).

6.4.2 The tube wall thickness shall be specified in accordance with the requirements of API STD 660.

6.4.3 Preferred tube lengths are the commonly used standard Imperial lengths as given in TEMA. Standard metric lengths such as 5 meters and 6 meters shall not be used as these give decimal values of Imperial lengths.

6.4.4 Low fin tubes may be used for shell-side non-fouling and low surface tension fluids where their use is justified. Their specification requires prior approval by the Saudi Aramco Engineer.

7 Basis for Mechanical Design

7.1 General

7.1.1 All exchangers shall be mechanically designed in accordance with the rules of the ASME SEC VIII D1 or ASME SEC VIII D2 (herein referred to as the Codes), API STD 660, TEMA and the requirements of 32-SAMSS-007 and, if applicable, 32-SAMSS-031.

7.1.2 The applicable Division and the edition of the Code to be used for the design of exchangers shall be specified on the data sheet.

7.1.3 ASME SEC VIII D2, shall be specified when economically justified. The following guideline shall be used to determine when Division 2 should be considered:

1) When the thickness of exchanger shell/channel/ heads exceeds 50 mm, irrespective of design pressure, materials, or service.

2) When the erected weight of exchanger exceeds 90 Tonnes (100 Tons).

3) For exchangers with design pressures 13.8 MPa (2000 psi) and larger, irrespective of service and materials of construction.

7.1.4 It is the responsibility of the design engineer, as defined in this standard, to prepare a detailed User Specification for ASME SEC VIII D2 in accordance with paragraph AG-301 of Division 2.

7.1.5 The application of ASME Code Cases to the design of exchangers requires prior approval of the Saudi Aramco Engineer.

7.2 Design Pressure

7.2.1 Exchangers shall be designed to withstand the maximum internal and/or external pressure conditions, which can occur during normal operation, including startup, shutdown or any unusual operation as shown on the Process Flow Diagram (PFD).

7.2.2 The internal design pressure shall not be less than the larger of: the maximum operating pressure plus 100 kPa (15 psi) or 110% of the maximum operating pressure.

7.2.3 The internal design pressure of exchangers with maximum operating pressure 6.9 MPa (1000 psi) and above shall be a minimum of 105% of the maximum operating pressure.

7.2.4 Exchangers in vacuum service shall be designed for a maximum external pressure of 100 KPa (15 psi).

7.2.5 Exchangers that are subject to steam out conditions shall be designed for an external pressure of 100 KPa (15 psi) at 149°C (300°F).

7.2.6 Exchangers in steam services shall be designed, on the steam side, for an external pressure of 100 KPa (15 psi) at design temperature.

7.2.7 Tube bundles are designed for a minimum differential pressure of 2.1 MPa (300 psi) when the design pressure of either heat exchanger sides (shell or tubes) is above 4.1 MPa (600 psi) and service conditions make it impossible to pressurize one side of the exchanger without simultaneously pressurizing the other side. The system process design shall determine the correct minimum differential design pressure, which may be higher than 2.1 MPa (300 psi).

7.2.8 The values of normal operating pressure, maximum operating pressure, and design pressure shall be specified on the data sheet.

7.2.9 In exchangers with tube side as the high-pressure side, design pressure of the shell side should be at least two-thirds of the tube side design pressure.

Commentary Note:

This is to prevent any unexpected catastrophic failure in case of tube leak in exchangers.

7.3 Design Temperature

Design temperature shall not be less than the maximum operating temperature plus 28°C (50°F).

7.4 Minimum Design Metal Temperature

The minimum design metal temperature (MDMT) shall be specified on the data sheet and shall be equal to the lowest of the following conditions:

1) The LODMAT at the site location, unless a higher start-up temperature is specified and approved by operations, and a suitable warm-up start-up procedure has been developed.

2) The temperature of a process stream causing shock-chilling condition as defined in Section 4 of this standard.

3) Auto-refrigeration condition as defined in Section 4 of this standard.

4) The minimum operating temperature at an operating pressure greater than 25% of the design pressure.

7.5 TEMA Class

The TEMA mechanical class corresponding to the type of service shall be specified on the data sheet in accordance with the following:

1) For utility (non-hydrocarbon) plants and for exchangers that are part of packaged units such as pumps and compressors, TEMA class C may be specified.

2) For all other services, TEMA class R shall be specified.

7.6 Service Type

Services falling under the categories of: wet sour, lethal, hydrogen, caustic and cyclic shall be specified as such on the data sheets.

7.7 Joint Efficiency

A joint efficiency of 85% or higher shall be specified for the design of all pressure containing components of ASME Code Div.1 heat exchangers.

7.8 Corrosion Allowance

7.8.1 The minimum corrosion allowances of pressure components shall be in accordance with TEMA and the following.

7.8.2 Corrosion allowance shall be based on achieving a minimum service life of twenty years.

7.8.3 The maximum corrosion allowance shall be 6.4 mm (0.25 inch). Should a higher corrosion allowance be required in order to obtain a twenty year service life, the exchanger shall be integrally clad or weld overlaid with a corrosion resistant metallic lining or as an alternative solid corrosion resistant material shall be specified for the exchanger. Selection of any of the alternatives shall be based on cost effectiveness and a proven history of satisfactory service in similar service environments.

7.8.4 The minimum corrosion allowance shall be specified on the data sheet as follows:

1) For all carbon and low alloy steels in all services, except wet sour services, the minimum corrosion allowance shall be specified as 3.2 mm (0.125 inch) for TEMA class R exchangers. Corrosion

allowance of 1.6 mm (0.0625 inch) may be used for TEMA class C exchangers.

2) For carbon and low-chrome alloy steel exchangers in wet sour services, the minimum corrosion allowance shall be specified as 3.2 mm (0.125 inch) irrespective of TEMA class.

3) Corrosion allowance for integrally clad and/or weld overlayed surfaces shall be nil. Minimum required cladding and weld overlay thicknesses are given in 32-SAMSS-031.

7.9 Heads

7.9.1 The types of heads shall be specified on the data sheet.

7.9.2 The type of heads for exchangers shall be specified as ASME 2:1-ellipsoidal or ASME hemispherical. ASME flanged and dished heads (torispherical) may only be used for utility services up to a design pressure of 690 KPa (100 psi).

7.9.3 For thick wall exchangers, heads shall be specified as hemispherical unless 2:1 ellipsoidal heads are deemed economical. Torispherical heads shall not be used.

7.10 Loads

7.10.1 Wind and Earthquake Loads

1) Wind and earthquake loads shall be determined by the Exchanger Manufacturer in accordance with the procedures detailed in ASCE 7.

2) The Design Engineer shall determine the basic wind speed corresponding to the Saudi Aramco site in accordance with SAES-A-112. The basic wind speed shall be specified on the data sheet.

3) The Design Engineer shall determine the earthquake zone, soil coefficient and effective peak acceleration ratio (Av) corresponding to the Saudi Aramco site in accordance with SAES-A-112. The earthquake zone and site soil coefficient shall be specified on the data sheet.

7.10.2 Weight of Liquid Contents

The Design Engineer shall specify on the exchanger data sheet the maximum operating liquid level and density of liquid as well as full hydrostatic test load for the exchanger in the erected position.

7.10.3 Piping and Equipment Loads

1) Nozzles shall be designed for external piping loads, such as may be produced from thermal expansion/contraction and weight.

2) Where such conditions exist, the Design Engineer shall specify these loads on the data sheet.

3) For exchanger supporting equipment (e.g., stab-in type heat exchanger, reboilers, etc.), the equipment loads imposed on the exchanger are to be determined and specified on the data sheet by the Design Engineer.

7.10.4 Refractory Linings

1) For exchangers which are refractory lined, the extent and design density of the refractory lining shall be specified on the data sheet.

2) The value of the design density of the refractory shall be determined in accordance with SAES-N-100.

7.11 Stress Analysis

7.11.1 Where applicable, the requirements for Division 2-Alternate rules and fatigue stress analysis are to be specified by the Design Engineer in accordance with this standard. When a thermal or fatigue analysis is required per this standard for a Division 1 exchanger, the analysis methods and stress combination limits presented in Division 2, Appendix 4, may be used. However, the basic design stress intensity value, S_m, shall be taken from the Division 1 tables of ASME SEC II for the corresponding material and temperature.

7.11.2 The Design Engineer is responsible for specifying the heat transfer coefficients to be used for all thermal stress analysis.

7.11.3 Thermal Analysis

1) A thermal stress analysis is required for ASME SEC VIII D1 exchanger if a thermal gradient along the circumferential or longitudinal axes, under steady state operating conditions, exceeds 65°C in a distance measured as the square root of R times T, where:

- R is the radius of the exchanger component under consideration and,
- T is the thickness of the component under consideration

- R and T are measured in the same units.

2) Thermal gradients may be reduced to within allowable limits with the addition of thermal sleeves.

7.11.4 Exchangers Designed in accordance with Division 2

1) The scope of the required stress analysis shall be specified by the Design Engineer in accordance with the rules of Division 2.

2) As a minimum, the scope of the stress analysis (in the steady state condition) shall be as follows:

- Head to shell weld
- Nozzle to shell welds including external piping loads

7.11.5 Fatigue Analysis

1) A fatigue analysis, if required, shall be based on the calculated number of cycles for a minimum 20-year life, as determined in accordance with the rules of Division 2, paragraph AD-160.

2) The number of cycles shall include the number of start-ups, shutdowns, emergency shut-downs and upset conditions.

7.12 Tube to Tubesheet Connection

7.12.1 Tubes are normally expanded into the tubesheet. However, for the following services, the tubes shall be strength welded to the tubesheet.

1) When the difference in the shell and tube side design pressures is greater than 10.3 MPa (1500 psi).

2) When steam at 540°C or above is one of the fluids.

7.12.2 Tubes shall be seal welded to the tubesheet for exchangers in sea water service and when inter-mixing of the streams must be avoided (in the event of a tube leak).

8 Nozzles and Gaskets

8.1 General

8.1.1 The quantity, types, sizes and pressure classes of all nozzles shall be specified on the data sheet.

8.1.2 The Design Engineer is responsible for ensuring that the facings, bolt centers, number and size of bolts of exchanger nozzles match the mating piping flanges.

8.1.3 NPS 2½, 3½, and 5 nozzles shall not be used.

8.1.4 Nozzles NPS 1½ and larger shall be flanged.

8.1.5 Threaded or socket-welded.

Threaded or socket-welded connections are prohibited in hydrogen, lethal, wet sour and caustic services. However, for other services, smaller than NPS 1½ threaded or socket welded connections with 6000-lb rating conforming to ASME B16.11 may be used.

Commentary Note:

This requirement is intended for vents, drains and instrument connections that may be attached to the shell or nozzles.

8.1.6 In total condensing services, a minimum of NPS 1½ connection shall be provided as a vent. The vent shall be located near the condensate outlet.

8.1.7 The use of distributor belts on the shell-side shall be considered in lieu of normal nozzle arrangement when the shell nozzles are large.

Commentary Note:

Large shell side nozzles result in long unsupported tube span in the shell inlet and outlet areas. The use of distributor belts will help in better utilization of the heat transfer surface and reduce the tendency for tube vibration in these critical areas.

8.2 Ratings (ASME Pressure Classes) and Facings

8.2.1 The ASME pressure classes shall be specified on the data sheet.

8.2.2 ASME pressure class 400 shall not be used.

8.2.3 Pressure ratings shall be in accordance with the following:

1) Pressure ratings of flanges 24 inch NPS and smaller shall be specified in accordance with ASME B16.5.

2) Pressure ratings of flanges larger than 24 inch NPS shall be specified in accordance with ASME B16.47, Series A.

8.2.4 The facings of flanges shall be raised face or ring-type joint in accordance with SAES-L-109. Flat face flanges may be used in utility services only.

8.2.5 Bolted joints specified with non-ASME flanges shall be designed to meet all anticipated loading conditions of the exchanger.

8.3 Chemical Cleaning and Instrument Connections

8.3.1 Chemical cleaning connections, if required, shall be preferably located on exchanger nozzles.

8.3.2 Connections for the measurement of temperature, pressure and flow shall be preferably located in the adjoining piping, except when required in intermediate nozzles of stacked exchangers.

8.4 Gaskets

8.4.1 The type of gasket shall be specified on the data sheet in accordance with SAES-L-109.

8.4.2 All gaskets shall be in accordance with API STD 660 and ASME B16.20.

8.4.3 The design of spiral wound gaskets shall be as follows:

1) For all services and design temperatures, spiral wound gaskets shall be specified with solid outer centering rings.

2) For design temperatures above 450°C, spiral wound gaskets shall be specified with solid outer centering rings and inner confining rings.

3) For exchangers in continuous vacuum service, irrespective of design temperature or design pressure, spiral wound gaskets shall be specified with solid outer centering rings and inner confining rings.

8.4.4 Materials of gaskets shall be specified in accordance with 32-SAMSS-007.

8.4.5 Gaskets for nozzle connections in utility services may be specified as non-asbestos conforming to ASME B16.21, and must be chemically resistant and mechanically suitable for the service conditions.

9 Exchanger Supports

9.1 General

The type of support required shall be specified by the Design Engineer in the data sheet.

9.2 Supports for Vertical Exchangers

Where lugs are used as a support for vertical exchangers, minimum number of four lugs shall be specified for exchangers above 24 inches in diameter. The locations and orientations of lugs shall be specified on the data sheet.

9.3 Supports for Horizontal Exchangers

9.3.1 Horizontal exchangers shall be supported by at least two saddles. The exchanger shall be fixed at one saddle and free to move in the longitudinal direction, due to thermal and pressure differentials, at the other saddle.

9.3.2 The data sheet shall specify locations of the fixed and sliding saddles and dimension from exchanger's centerline to underside of saddle base plate.

10 Material Selection

10.1 General

The materials of construction for pressure and non-pressure components shall be based on the design temperature; minimum design metal temperature; and service in accordance with 32-SAMSS-007, Table 1, Acceptable Materials for Carbon and Low-Chrome Alloy Steels. Use of materials other than those listed in the materials section of 32-SAMSS-007 requires approval of shall be specified by the Saudi Aramco Engineer.

10.2 Impact Testing

The impact testing of exchanger components shall be determined by the Exchanger Manufacturer based on the material minimum design metal temperature (MDMT), in accordance with the requirements specified in 32-SAMSS-007.

10.3 Postweld Heat Treatment (PWHT)

10.3.1 For carbon and low alloy steels, the following process services require PWHT. Other process conditions may also require PWHT, as determined during the project design or as specified by the Saudi Aramco Engineer.

1) All caustic soda (NaOH) solutions at all temperatures.

2) All mono-ethanol amine (MEA) solutions at all temperatures.

3) All di-glycol amine (DGA) solutions above 140°C design temperature.

4) All rich amino di-isopropanol (ADIP) solutions above 90°C design temperature.

5) All lean ADIP solutions above 60°C design temperature.

6) Exchangers in hydrogen service at all temperatures manufactured from P-No.3, 4 and 5A/B/C base materials.

7) All methyldiethanolamine (MEDA) solutions, at all temperatures.

10.3.2 Code exemptions for PWHT are not permitted if PWHT is specified for process conditions in accordance with this standard.

11 Insulation and Surface Coating

11.1 The extent and thickness of external insulation shall be specified on the data sheet in accordance with SAES-N-001.

11.2 The selection of the type of coating shall be in accordance with SAES-H-001.

11.3 The Approved Protective Coating Systems (APCS) shall be selected from SAES-H-101 and specified on the data sheet together with the applicable Class 09 specification for the surface preparation and painting systems.

12 Fireproofing

The extent of fireproofing required on exchanger supports shall be determined in accordance with the requirements of SAES-B-006 and specified on the data sheet.

13 Cathodic Protection

Exchangers shall be cathodically protected when specifically required by SAES-X-500.

14 Drawings and Calculations

14.1 The data sheet and any relevant forms shall be completed by the Design Engineer to the extent as detailed in this standard. The data sheets shall include all information necessary for the Exchanger Manufacturer to carry out the mechanical design and verify the thermal design.

14.2 When completing the data sheets using the SI system of measurement, the following units shall be used:

Flow rate: kg/h Length: m or mm

Temperature: °C	Density: kg/m³
Heat Capacity: kJ/kg K	Thermal Conductivity: W/m K
Pressure: kPa	Heat Transfer Rate: W/m² K
Latent Heat: kJ/kg	Heat Duty: W

14.3 The Design Engineer is responsible for the completion of the Safety Instruction Sheet (Form 2713-ENG) for the exchanger in accordance with SAES-A-005 and the data on the Exchanger Manufacturer's drawings.

14.4 As built thickness of all pressure components shall be specified by the Design Engineer on the Safety Instruction Sheet (SIS) after the completion of fabrication.

14.5 All approved data sheets, drawings and forms are to be submitted to Engineering Drawings Services Division (EDSD) for inclusion into Corporate Drawings Management System.

Revision Summary

30 March 2005 Major revision.