Engineering Standard

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Design Criteria of Double Pipe 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 double pipe and multitube hairpin 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 of thermal and mechanical design and to assist Design Engineers 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 data sheet (hereinafter referred to as data sheet).

1.4 This standard shall not be attached to nor made a part of purchase orders.

This standard may not be applied to exchangers that are used with or as parts of package equipment like compressors, pumps and turbine oil coolers.

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-B-006	*Fireproofing in Onshore Facilities*
SAES-H-001	*Selection Requirements for Industrial Coatings*
SAES-H-100	*Painting Requirements for Industrial Facilities*
SAES-H-101	*Approved Protective Coating Systems*
SAES-H-101V	*Approved Saudi Aramco Data Sheets - Paints and Coatings*
SAES-N-001	*Basic Criteria, External Insulation*
SAES-W-010	*Welding Requirements for Pressure Vessels*
SAES-X-500	*Cathodic Protection Vessels and Tank Internals*

Saudi Aramco Materials System Specification

32-SAMSS-028	*Manufacture of Double Pipe Heat Exchangers*

Saudi Aramco Forms and Data Sheets

Form 2713-ENG	*Safety Instruction Sheet*
Form 2714-ENG	*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 V	*Nondestructive Examination*
ASME SEC VIII D1	*Rules for Construction of Pressure Vessels*
ASME SEC VIII D2	*Rules for Construction of Pressure Vessels, Alternative Rules*
ASME B16.5	*Pipe Flanges and Flanged Fittings*
ASME B16.11	*Forged Steel Fittings, Socketwelded and Threaded*

ASME B16.20	*Metallic Gaskets for Pipe Flanges - Ring-Joint, Spiral-Wound, and Jacketed*
ASME B16.21	*Non-Metallic Gaskets for Pipe Flanges*

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*

4 Definitions

Amine Services: All amine solutions including MEA, DGA, MDEA and 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.

Double Pipe Exchanger: Consists of a single tube or multitubes enclosed within a U-shaped pipe shell.

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

Hydrogen Services: Process streams containing relatively pure hydrogen and component streams containing hydrogen with a partial pressure of 350 kPa (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. Other services as determined by the project design may also be designated as lethal services.

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

Low-Alloy Steels: Alloy materials with nominal chromium content of 1.25%, 2.25% or 5%.

Multitube Exchanger: Consists of multitubes within a U shaped shell.

Nominal Thickness: Thickness required for withstanding all primary loads, including allowance for corrosion.

Saudi Aramco Engineer: The Supervisor of the Process Equipment Unit, Consulting Services Department, Dhahran.

Shock Chilling Effect: Shock chilling is defined as 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.

Utility Services: Water, air and nitrogen services.

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

1) Sour water with a hydrogen sulfide concentration above 2 milligrams per liter.

2) Crude containing hydrogen sulfide when transported or processed prior to completion of stabilization.

3) Gas or hydrocarbon condensate containing hydrogen sulfide when transported or processed prior to completion of sweetening or hydrogen sulfide stripping.

4) Multiphase services when the partial pressure of hydrogen sulfide is above 0.34 kPa abs (0.05 psia) in the gas phase or a concentration of hydrogen sulfide above 2 milligrams per liter in the water phase.

Wet Sour HIC Services: All of the above Wet Sour Services where the H_2S concentration in the water phase is above 50 milligrams per liter.

Exception:

lean and rich DGA services, other lean amine services, and caustic services are not included.

5 Responsibilities

5.1 The Design Engineer is responsible for specifying the thermal and mechanical design requirements and completing the Saudi Aramco 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-028.

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

6.2 Thermal Design

6.2.1 The sizing of heat exchangers, including overall length, tube size, number of tubes, tube pitch, fins, number and arrangement of hair pins, shall be determined by the Exchanger Manufacturer in accordance with the required operating and performance data supplied by the Design Engineer.

6.2.2 In general, tube-side fluid shall be the higher ranking of the following:

1) Cooling water
2) Fouling, erosive, corrosive or less viscous material
3) The higher pressure fluid
4) The smaller flow rate

6.2.3 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:

Exceptions:

1) Fouling resistance for sea water shall be 0.000352 m² °K/W (0.002 ft² h °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 h °F/Btu) and 0.00088 m² °K/W (0.005 ft² h °F/Btu) for water above this temperature.

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

6.2.5 The value for the maximum allowable pressure drop and calculated pressure drop in the clean condition shall be specified on the data sheet. When minimum wall tubes are specified, the tube-side pressure drop shall be based on 110% of the selected tube wall thickness.

6.2.6 Design inlet cooling water temperature to be used in the design of heat exchangers utilizing seawater shall be 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 be 49°C.

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

6.2.8 Exchangers utilizing seawater, 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 in Table 1.

Table 1 – Maximum Water Velocity

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

6.2.9 Fins are not recommended in high fouling services where tube outside fouling factor is greater than 0.0007 m^2 °K/W(0.004 ft^2 hr °F/Btu).

6.3 Tube Dimensions

6.3.1 The inner tube outside diameter shall be a minimum of 19.05 mm.

6.3.2 Tube diameters and wall thicknesses shall be specified in accordance with API STD 660 corresponding to the materials of construction of the tube. Pipe specification is acceptable in lieu of tubes.

6.3.3 The tube wall thickness for exchangers in hydrocarbon, wet sour, and steam services shall be specified as minimum.

6.3.4 Tube wall thicknesses for exchangers in utility services may be specified as average.

6.3.5 Where pipe is used for the tubeside, the minimum allowable thickness shall be Schedule 40 for carbon and low-alloy steels, and Schedule 10 for non-ferrous and austenitic stainless steels.

6.3.6 The length of the unit shall not exceed 6 meters unless otherwise approved by the Saudi Aramco Engineer.

6.3.7 Fins, if provided, shall be a minimum of 0.5 mm thick.

7 Mechanical Design

7.1 General

7.1.1 If economical, exchangers of the same material, type and size shall have all similar parts made completely interchangeable.

7.1.2 All exchangers shall be mechanically designed in accordance with the rules of the ASME SEC VIII D1 (herein referred to as the Code), API STD 660, TEMA, and the requirements of 32-SAMSS-028.

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

7.2 Design Pressure

7.2.1 Exchangers shall be designed to withstand the maximum internal and/or external pressure which can occur during normal operation, including startup, shutdown or any unusual operation on either side as shown on the PFD. For the tube side, the internal pressure is the tube side pressure and the external pressure is the shell side pressure. For the shell side, the internal pressure is the shell side pressure and the external pressure is the atmospheric pressure.

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 gage (1000 psig) 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 All exchangers that are subject to steamout conditions shall be designed for an external pressure of 50 KPa abs (7.5 psia) 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 may be designed for a minimum differential pressure of 2.1 MPa (300 psi) when the design pressure is above 4.1 MPa gage (600 psig) 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.

7.3 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 Services Type

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

7.6 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.

7.7 Corrosion Allowance

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

7.7.2 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 manufactured with a corrosion resistant material.

7.7.3 For all carbon and low-alloy steels in all services, the minimum corrosion allowance shall be specified as 3.2 mm (0.125 inch).

7.8 Loads

7.8.1 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.

7.8.2 Piping and Equipment Loads

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

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

8 Nozzles and Gaskets

8.1 General

8.1.1 The quantity, types, sizes and pressure classes of all connecting piping shall be specified on the data sheet by the Design Engineer.

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 Nozzles with NPS of 2½ , 3½ , and 5 shall not be used.

8.1.4 All nozzles shall be flanged. 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.

8.2 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 of flanges shall be in accordance with ASME B16.5.

8.2.4 The facings of flanges shall be raised face or ring-type joint. 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.

8.4 Gaskets

8.4.1 The type of gasket shall be specified on the data sheet.

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.

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 The materials of all gaskets shall be specified in accordance with 32-SAMSS-028.

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

9 Material Selection

9.1 General

9.1.1 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-028, Table 1, Acceptable Materials for Carbon and Low-Alloy Steels.

9.1.2 Use of materials other than those specified in 32-SAMSS-028 shall require a prior approval from the Saudi Aramco Engineer.

9.2 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-028.

9.3 Postweld Heat Treatment

9.3.1 For carbon and low-alloy steels, the following services require postweld heat treatment (PWHT). Other services 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

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

10 Insulation and Surface Coating

10.1 The extent and thickness of external insulation shall be specified on the data sheets SAES-H-001V in accordance with SAES-N-001.

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

10.3 The Approved Protective Coating Systems (APCS) shall be selected from SAES-H-101 and specified on the data sheets together with the applicable Class 09 Saudi Aramco Materials System Specification for the surface preparation and painting systems.

11 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.

12 Cathodic Protection

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

13 Drawings and Calculations

13.1 The data sheet and any Relevant forms are to 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.

13.2 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

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

13.4 The as built thicknesses of pressure components shall be specified by the Design Engineer on the Safety Instruction Sheet (SIS) after the completion of fabrication.

13.5 All data sheets, drawings and forms are to be provided in electronic format

Revision Summary

30 July, 2003 Major revision.