

# Engineering Standard

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SAES-E-015

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## Design Criteria of Electric 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 thermal and mechanical design of new immersion-type electric heat exchangers (hereinafter referred to as exchangers). It does not cover exchangers that undergo repairs or alterations.
- 1.2 This standard establishes a standard for thermal and mechanical design and to assist the 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 Saudi Aramco's Electric 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.

## 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*

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<a href="#"><u>SAES-A-112</u></a>	<i>Meteorological and Seismic Design Data</i>
<a href="#"><u>SAES-B-006</u></a>	<i>Fireproofing in Onshore Facilities</i>
<a href="#"><u>SAES-H-001</u></a>	<i>Selection Requirements for Industrial Coatings</i>
<a href="#"><u>SAES-H-101</u></a>	<i>Approved Protective Coating Systems</i>

#### Saudi Aramco Material Systems Specification

<a href="#"><u>32-SAMSS-027</u></a>	<i>Manufacture of Electric Heat Exchangers</i>
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#### Saudi Aramco Forms and Data Sheets

<i>Form SA 2713-ENG</i>	<i>Safety Instruction Sheet – Shell and Tube Heat Exchanger</i>
<i>Form SA 9541-ENG</i>	<i>Electric Heat Exchanger Specification Sheet</i>

### 3.2 Industry Codes and Standards

#### American Society of Civil Engineers

<i>ASCE 7</i>	<i>Minimum Design Loads for Buildings and Other Structures</i>
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#### American Society of Mechanical Engineers (Boiler and Pressure Vessel Codes)

<i>ASME SEC II</i>	<i>Material Specifications Parts A, B and D</i>
<i>ASME SEC V</i>	<i>Nondestructive Examination</i>
<i>ASME SEC VIII</i>	<i>Rules for Construction of Pressure Vessels</i>
<i>ASME B16.11</i>	<i>Forged Steel Fittings, Socket-welded and Threaded</i>
<i>ASME B16.5</i>	<i>Pipe Flanges and Flanged Fittings</i>
<i>ASME B16.20</i>	<i>Metallic Gaskets for Pipe Flanges, Ring-Joint, Spiral-Wound, and Jacketed</i>
<i>ASME B16.21</i>	<i>Non-Metallic Gaskets for Pipe Flanges</i>
<i>ASME B16.25</i>	<i>Butt-weld Ends</i>

#### Tubular Exchanger Manufacturers Association

## 4 Definitions

**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.

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**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 electric heat exchangers.

**Effective Surface:** Heated surface of each element.

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

**Exchanger Unit:** One or more exchangers for a specific service.

**Heater:** Addition of heat for a specific service without a phase change.

**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.

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

**MDMT:** Minimum design metal temperature, determined in accordance with this standard.

**Pressure Drop:** Measured between inlet and outlet nozzles, including interconnecting piping of multi-shell exchangers.

**Saudi Aramco Engineer:** Supervisor of the Piping & Valves 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  $-20^{\circ}\text{C}$  and at a temperature lower than the initial temperature of the component by  $40^{\circ}\text{C}$ , 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 with a total partial pressure of 400 kPa absolute (65 psia) or greater.
- (2) Crude containing hydrogen sulfide when transported or processed prior to completion of stabilization.

- (3) Gas or hydrocarbon condensate containing hydrogen sulfide with a total partial pressure of 400 kPa absolute (65 psia) or greater, 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 absolute (0.05 psia) in the gas phase or a concentration of hydrogen sulfide above 2 milligrams per liter in the water phase.

## 5 Responsibilities

- 5.1 The Design Engineer is responsible for specifying the electrical 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 electrical design, mechanical design, code and structural calculations, supply of all materials, fabrication, non-destructive examination, inspection, testing, surface preparation, and preparation for shipment, in accordance with the completed data sheet and the requirements of [32-SAMSS-027](#).

## 6 Thermal Design

- 6.1 The Design Engineer shall specify the process design, heater construction and shell design on the data sheet, including the quantity of exchanger units required, effective surface area and allowable pressure drop for the specific service.
  - 6.2 Exchangers may be installed in the horizontal or vertical positions, the Design Engineer shall specify the position on the data sheet.
  - 6.3 Exchangers shall only be specified for use in the following services and design conditions:
    - (1) Hydrocarbon, hydrogen and utility services up to and including 700°C design temperature
    - (2) Clean, non-erosive services
  - 6.4 Exchangers shall not be used in cyclic service.
  - 6.5 Fouling resistance 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
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information, the fouling resistance shall be selected from the values recommended by TEMA.

- 6.6 Exchangers shall be designed for single pass shells only.
- 6.7 The value of the maximum allowable pressure drop in the clean condition shall be specified on the data sheet.
- 6.8 The Design Engineer shall ensure that the exchanger design is free of any damaging flow induced element vibration including the effect of acoustic vibration.
- 6.9 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, all relevant input and output data shall be submitted.

The data sheet shall contain fluid physical properties used in the design, including non-linear boiling heat release profile and weight fraction vapor curve, 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. For stacked exchangers, it shall also show the stacking arrangement.

## **7 Mechanical Design**

- 7.1 General
    - 7.1.1 Exchangers shall be mechanically designed in accordance with the rules of the ASME SEC VIII D1 (hereinafter referred to as the Code), [32-SAMSS-027](#) and the requirements of this standard.
    - 7.1.2 The applicable edition of the Code to be used for the design of exchangers, shall be specified on the data sheet.
    - 7.1.3 The application of ASME Code Cases to the design of exchangers requires the prior approval of the Saudi Aramco Engineer.
  - 7.2 Design Pressure
    - 7.2.1 Exchangers shall be designed to withstand the maximum internal pressure and/or vacuum which can occur during normal operation, including startup, shutdown or any unusual operation.
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- 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 All Exchangers that are subject to steam-out conditions shall be designed for an external pressure of 50 kPa (7.5 psi) at 149°C (300°F).

### 7.3 Design Temperature

The design temperature shall not be less than the maximum operating temperature plus 28°C (50°F), and must include consideration for any upset conditions.

### 7.4 Minimum Design Metal Temperature (MDMT)

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 Service and Description

The exchanger description, (examples: air heater, regeneration heater) shall be specified on the data sheet.

### 7.6 Joint Efficiency

A joint efficiency of 85% or higher shall be specified on the data sheet for all pressure containing components of the 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).
- 7.7.3 As a minimum, a corrosion allowance of 1.6 mm (.0625 inch) shall be specified on the data sheet.
- 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 ( $A_v$ ) 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/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 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 Nozzle sizes NPS 2½, 3½, and 5 shall not be used.
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- 8.1.4 Nozzles shall be flanged or prepared for butt-welding according to ASME B16.25.
  - 8.1.5 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 fittings rating conforming to ASME B16.11 may be used.
  - 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 The ASME Class 400 shall not be used.
    - 8.2.3 Pressure ratings shall be in accordance with ASME B16.5.
    - 8.2.4 Facing 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, except when required in intermediate nozzles of stacked exchangers.
  - 8.4 Gaskets
    - 8.4.1 Type of gaskets shall be specified on the data sheet.
    - 8.4.2 All gaskets shall be in accordance with 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.
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- (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 The material of all gaskets shall be in accordance with [32-SAMSS-027](#).

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 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.

9.3.3 Sliding end support shall allow twice the theoretical expansion movement and shall be equipped with 6 mm (0.25 inch) minimum thickness sliding plates. Stacked exchangers shall have a shim allowance of 6 mm (0.25 inch) at the intermediate supports.

## 10 Clips and Attachments

The orientations, elevations and details of any clips shall be specified by the Design Engineer.

## 11 Materials

### 11.1 General

11.1.1 The materials of construction for pressure components shall be based on the design temperature; minimum design metal temperature; and service in accordance with [32-SAMSS-027](#), Table 1, Basic Materials Specifications.

11.1.2 Use of materials other than those listed in the materials section of [32-SAMSS-027](#) require approval of the Saudi Aramco Engineer.

### 11.2 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-027](#).

### 11.3 Postweld Heat Treatment (PWHT)

11.3.1 Exchangers in hydrogen service at all temperatures manufactured from P-No.3, 4, and 5A/B/C base materials shall be postweld heat-treated.

11.3.2 Other process conditions may also require PWHT, as determined during the project design or as specified by the Saudi Aramco Engineer.

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

## 12 Coatings and Painting

12.1 The selection for the type of coating to be applied on exchangers shall be in accordance with [SAES-H-001](#).

12.2 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.

## 13 Fireproofing

The extent of fireproofing required shall be determined in accordance with the requirements of [SAES-B-006](#) and specified on the data sheet.

## 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/m <sup>3</sup>             |
| Heat Capacity: kJ/kg K | Thermal Conductivity: W/m K            |
| Pressure: kPa          | Heat Transfer Rate: W/m <sup>2</sup> K |
| Latent Heat: kJ/kg     | Heat Duty: W                           |
- 14.3 The Design Engineer is responsible for the completion of the Safety Instruction Sheet (SIS) for the exchanger using Form 2713-ENG in accordance with [SAES-A-005](#) and the data on the Exchanger Manufacturer's drawings.
- 14.4 As- built thickness of 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 (EDSD) for inclusion into Corporate Drawings management System.

### Revision Summary

30 September, 2002	Major revision.
31 May, 2003	Editorial revision to change the Document Responsibility from Vessels to newly formed Heat Transfer Equipment Standards Committee per CSD-L-305/03 dated May 11, 2003.