Engineering Standard

SAES-E-007 31 May 2005

Design Criteria of Air-Cooled Heat Exchangers

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1 Scope

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

1.2 This standard does not cover exchangers used as integral radiators, or exchangers that are part of air conditioning equipment.

1.3 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.

1.4 The requirements in this standard shall be used by the Design Engineer for the completion of API STD 661 air-cooled heat exchanger data sheets (hereinafter referred to as data sheets).

1.5 This standard may not be attached to nor made a part of purchase orders.

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 equipment and facilities 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-105	*Noise Control*
SAES-A-112	*Meteorological and Seismic Design Data*
SAES-B-006	*Fireproofing in Onshore Facilities*
SAES-B-017	*Fire Water System Design*
SAES-G-115	*Lubrication, Shaft-Sealing and Control Oil Systems for Special Purpose Applications*
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-L-109	*Selection of Flanges, Stud Bolts and Gaskets*
SAES-N-001	*Basic Criteria, External Insulation*

Saudi Aramco Material Systems Specification

32-SAMSS-011	*Manufacture of Air-cooled Heat Exchangers*

Saudi Aramco Forms and Data Sheets

Form 6238-ENG	*Safety Instruction Sheet, Air Cooled Heat Exchangers*
Form 7305-ENG	*Noise Level*

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	*Nonmetallic Gaskets for Pipe Flanges*

American Petroleum Institute

API STD 661	*Air-Cooled Heat Exchangers for General Refinery Service*

Tubular Exchanger Manufacturers Association

TEMA	*Standards of the Tubular Exchanger Manufacturers Association*

4 Definitions

Amine Services: All amine solutions including MEA, DGA 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.

Critical Service: Is defined as a service where the ambient air temperature (summer design dry bulb) shall not be exceeded by 1% of the total hours (30 hours) during the months of June through September.

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.

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.

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

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

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

Non-critical Service: Is defined as a service where the ambient air temperature (summer design dry bulb) shall not be exceeded by 2.5% of the total hours (73 hours) during the months of June through September.

Saudi Aramco Engineer: The Supervisor of the Process Equipment Unit, 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.

Utility Services: Water, 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 sheets in accordance with the requirements of 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 sheets and the requirements of 32-SAMSS-011.

6 Basis for Thermal Design

6.1 General

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

6.1.2 The Design Engineer shall utilize the Air-Cooled Exchanger Checklist and Air-Cooled Exchanger Noise Data Sheet appended to API STD 661, when completing the air cooler data sheets and the Saudi Aramco noise data sheet, Form 7305-ENG.

6.1.3 Internal turbulence promoters for process type applications are prohibited. They are permitted for lube and seal oil coolers, provided they are not integral with the tube, are removable, are made from stainless steel and are of proven design.

Commentary Note:

The seal oil coolers shall have filters upstream the exchangers. This is to prevent the fouling in the turbulators.

6.1.4 The Design Engineer shall ensure that the Manufacturer's design, including bundle arrangement, tube pitch, number of rows, fin spacing/height, tube size, and number of passes are suitable for the intended service, for all operating sequences, including start-up, shut-down and upset conditions.

6.1.5 Water sprays for increasing thermal heat transfer duty shall not be used, except when humidified type exchangers are used where water spray is an integral part of the system.

6.1.6 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.

6.1.7 The airside fouling resistance shall be 0.000352 m^2 °K/W (0.002 ft^2 h °F/Btu).

6.1.8 For nonlinear condensation cases, the condensing curve and the corresponding vapor weight fraction curve for each design mode of operation shall be provided by the Design Engineer, and shall form an integral part of the exchanger data sheets.

6.2 Selection of Header Design

Headers shall be in accordance with 32-SAMSS-011.

6.3 Tubes and Fins

Tube diameters, wall thicknesses and finning shall be specified in accordance with 32-SAMSS-011.

6.4 Design Air Inlet Temperature

6.4.1 Design air inlet temperature shall be determined by the Design Engineer based on the value of the summer design dry bulb temperature for the particular site as specified in SAES-A-112. However, the minimum design air inlet temperature for all sites shall be specified as 3°C.

6.4.2 Design air inlet temperature shall either be the design dry bulb at 1% or at 2.5%. This temperature shall be increased due to: the location of the

exchanger with respect to processing units and buildings, and the number of bays, in accordance with the following requirements.

Commentary Notes:

The following shall be analyzed by the Design Engineer for determining the criticality of exchangers.

1) The effect on exchanger operation with air inlet temperatures in the summer months above the design temperature conditions.

2) The function of an exchanger with respect to the overall process, including: the value of loss of production, product degradation, degree of operational upset caused, and possible damage to equipment.

6.4.3 For exchangers located within industrial plants or shaded by buildings, an additional 1.1°C (2°F) shall be added to the basic summer design dry bulb temperature.

Commentary Note:

This increase in temperature is required to account for radiation from furnaces, flares, steam piping or other local heat sources.

6.4.4 For installations with more than five bays, the basic summer design dry bulb temperature shall be increased by a further amount as follows depending on the type of exchanger. The word "installations" in this context means individual exchanger service or different exchanger services placed side by side in the same bank.

1) For induced draft exchangers, add 1.7°C (3°F)

2) For forced draft exchangers, add 2.8°C (5°F)

3) For humidified air coolers, add 1.1°C (2°F)

6.4.5 Exchangers in excess of five bays shall be oriented such that their tubes are perpendicular to the prevailing summer wind direction. If due to the plant layout, this orientation cannot be obtained, an addition of 1.1°C (2°F) is required.

6.4.6 Final air-side design temperature shall be the sum of the values specified in paragraphs 6.4.2, 6.4.3, 6.4.4 and 6.4.5, as applicable.

6.4.7 The design inlet air temperature for exchangers in lube and seal oil services shall be the summer dry bulb temperature at 1.0% plus 4.4°C (8°F).

Commentary Note:

No further increase in this temperature is required due to the location or the number of bays for exchangers in lube and seal oil services.

6.4.8 For sites not covered by SAES-A-112, the values of the ambient dry bulb temperatures shall be agreed with the Saudi Aramco Engineer.

6.5 Airside Control

The type of airside control shall be specified on the data sheets by the Design Engineer.

Commentary Note:

The type of airside control depends upon the criticality of the process, the accuracy of control required, and economics. The various methods include but are not limited to: simple on-off control, two speed motor control, and the use of variable speed drivers, auto-variable fan pitch, manual or automatic louvres, or air recirculation.

7 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 (herein referred to as the Code), API STD 661, and the requirements of 32-SAMSS-011.

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

7.1.3 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 pressure and/or vacuum which can occur during operation, shutdown or any upset conditions.

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 of 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) at design temperature.

7.2.5 All exchangers that are subject to steamout conditions shall be designed for a partial vacuum of 50 kPa (7.5 psi) at 149°C (300°F).

Exception:

Except in steam services where these will be designed for an external pressure of 100 kPa (15 psi) at the design temperature.

7.2.6 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 Service Type

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

7.6 Joint Efficiency

Joint efficiency shall be a minimum of 85% and it shall be specified on the data sheet. Full radiography is required for services detailed in 32-SAMSS-011.

7.7 Corrosion Allowance

7.7.1 The minimum corrosion allowances of pressure components shall be in accordance with API STD 661 and 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 integrally cladded or weld overlayed with a corrosion resistant metallic lining.

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 sheets.

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 sheets.

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. The nozzles' loads shall not exceed the allowable values specified in API STD 661.

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

8 Nozzles and Gaskets

8.1 General

8.1.1 Quantity, types, sizes, and pressure classes of all nozzles shall be specified on the data sheets.

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 2-½, 3-½, and 5 shall not be used.

8.1.4 All main flow nozzles shall be flanged

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

Commentary Note:

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

8.1.6 For exchangers in total condensing services, a minimum of NPS 1.5 vent shall be provided located at condensate outlet headers.

8.2 Ratings (ASME Pressure Classes)and Facings

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

8.2.2 ASME pressure class 400 shall not be used.

8.2.3 Pressure ratings shall be in accordance with ASME B16.5.

8.2.4 The facings of flanges shall be raised face or ring-type joint except in utility services where flat facing may be used.

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 on adjoining piping.

8.4 Gaskets

8.4.1 All gaskets shall be in accordance with API STD 661 and ASME B16.20 and shall be type of gasket specified on the data sheet.

8.4.2 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.

8.4.3 The materials of all gaskets shall be specified in accordance with 32-SAMSS-011.

8.4.4 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 Fans and Drivers

9.1 The Design Engineer shall evaluate the Exchanger Manufacturer's design of fans and fan rings and ensure the following:

1) The clearance between the fan tip and fan ring, the fan ring length and the shape are acceptable.

2) The fan curves provided are valid for the specific fan ring specified by the Exchanger Manufacturer.

Commentary Note:

Larger fan rings and short cylindrical hubs will short circuit air at the fan tip resulting in loss of air flow and static pressure.

9.2 Where secure operation of fans at power failure is required, the use of steam turbine drives or hydraulic motor drives shall be considered.

9.3 Allowable noise levels shall be determined by the Design Engineer in accordance with SAES-A-105. Allowable noise levels shall be specified on Form 7305-ENG.

9.4 The requirements for lubrication and shaft sealing of drivers shall be specified in accordance with SAES-G-115.

9.5 Shutdown protection devices shall be provided in accordance with the table below. Assessment of applications for vibration protection will be on the basis of Production Criticality as shown in the below table.

Non-Critical Installations	Critical Installations
Protection is optional	Protection is Mandatory

Commentary Note:

Criticality is based on production loss assuming that Saudi Aramco effective operational & maintenance practices (i.e. relevant operational daily checklist, PM, vibration route etc.) and relevant safety procedures are being implemented and followed.

10 Material Selection

10.1 General

10.1.1 The materials of construction for pressure and non-pressure components shall be based on the design temperature, minimum design metal temperature, and the service in accordance with 32-SAMSS-011, Table 1, Acceptable Materials for Carbon and Low Alloy Steels.

10.1.2 Use of materials other than those listed in the materials section of 32-SAMSS-011 require prior approval from 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-011.

10.3 Postweld Heat Treatment

Postweld heat treatment shall be specified in accordance with 32-SAMSS-011.

11 Insulation and Surface Coating

11.1 The extent and thickness of external insulation shall be specified on the data sheets 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 sheets together with the applicable Class 09 Saudi Aramco Material System Specification for the surface preparation and painting systems.

12 Fireproofing

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

12.2 Supports that require fireproofing shall be specified on the data sheets.

12.3 The requirements of fire protection shall be in accordance of SAES-B-017.

13 Drawings and Calculations

13.1 The data sheets and any relevant forms shall be completed by the Design Engineer to the extent as detailed in this standard. The data sheets shall contain 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 shall complete the Exchanger-Safety Instruction Sheet (Form 6238-ENG) in accordance with SAES-A-005 and the data on the Exchanger Manufacturer's drawings.

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

13.5 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

31 May 2005 Major revision.