Engineering Standard

SAES-F-001 28 January, 2004

Design Criteria of Fired Heaters

Heat Transfer Equipment Standards Committee Members
Al-Anizi, S.S., Chairman
Al-Anezi, M.A.
Al-Bagawi, J.J.
Al-Dossary, M.A.
Al-Gahtani, M.S.
Al-Hamam, I.H.
Al-Rumaih, A.M.
Fernandez, G.T.
Moore, M.A.
Naffa'a, M.Y.

Table of Contents

1 Scope

1.1 This standard covers the minimum mandatory requirements for the process, mechanical, and structural design of fired heaters used for general refinery hydrocarbon services. It does not cover fired heaters that undergo repairs or alterations.

1.2 The requirements in this standard shall be used by the Design Engineer for the completion of the data sheets.

1.3 This standard may not be attached to nor 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 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 Procedures

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*
SAEP-341	*Equipment Life Cycle Cost Procedure*

Saudi Aramco Engineering Standards

SAES-A-005	*Safety Instruction Sheet*
SAES-A-102	*Air Pollutant Emission Source Control*
SAES-A-105	*Noise Control*

SAES-A-112	*Meteorological and Seismic Design Data*
SAES-B-006	*Fireproofing in Onshore Facilities*
SAES-B-054	*Access, Egress, and Materials Handling for Plant Facilities*
SAES-B-055	*Plant Layout*
SAES-B-058	*Emergency Isolation, Shutdown, and Depressuring*
SAES-B-063	*Aviation Obstruction Marking and Lighting*
SAES-H-001	*Selection Requirements for Industrial Coatings*
SAES-H-101	*Approved Protective Coating Systems*
SAES-J-600	*Pressure Relief Devices*
SAES-J-601	*Emergency Shutdown and Isolation Systems*
SAES-J-603	*Process Heater Safety Systems*
SAES-N-001	*Basic Criteria, External Insulation*
SAES-N-100	*Refractory Systems*
SAES-S-020	*Industrial Drainage and Sewers*

Saudi Aramco Materials System Specification

32-SAMSS-029	*Manufacture of Fired Heaters*

Saudi Aramco Forms and Data Sheets

7305-ENG	*Equipment Noise Data Sheet*
2731-ENG	*Safety Instruction Sheet – Heaters*
LCC-025	*Single Fuel Process Heaters*
LCC-025A	*Dual Fuel Process Heaters*

3.2 Industry Codes and Standards

American Petroleum Institute

API STD 560	*Fired Heaters for General Refinery Services*

4 Definitions

Conventional Heaters: Heaters used to provide heat primarily by radiation and convection to process streams for use in reformers, hydrotreaters, etc., and have service designations such as: reactor preheaters, and pipe stills.

Design Engineer: The Engineering Company responsible specifying on the data sheets the process and mechanical design conditions requirements for heaters.

Direct-Fired Heaters: Heaters used to provide heat primarily by conductive heat by flame impingement used for heating asphalt or bunker oil for loading or mixing.

Heater Manufacturer: The company responsible for the design, materials, fabrication, testing, preparation for shipment, of conventional, direct-fired, and pyrolysis-fired heaters for general refinery service in accordance with 32-SAMSS-029.

Hydrocarbon Service: Process streams of liquid or gaseous hydrocarbon materials.

Pyrolysis Heaters: These heaters provide heat for chemical reactions inside heater tubes for carbonization, cracking, distilling, etc., and have service descriptions such as: steam methane reformers, thermal crackers and visbreakers.

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

5 Responsibilities

5.1 The Design Engineer is responsible for specifying the process and mechanical design conditions for conventional, direct-fired and pyrolysis type heaters (hereinafter referred to as heaters) in accordance with the requirements of API STD 560 and this standard.

5.2 The Heater Manufacturer is responsible for the thermal design, mechanical design, supply of all materials, fabrication, inspection, testing, surface preparation, and preparation for shipment, in accordance with the completed data sheets and 32-SAMSS-029.

6 Process Design

6.1 General

6.1.1 This chapter outlines the basic process design considerations which shall be applied in the selection, sizing and specifying of heaters.

6.1.2 The Design Engineer shall use API STD 560 Appendix A, "Fired Heater Data Sheet" (herein referred to as data sheet) and Appendix B, "Fired Heater Checklist" of API STD 560 for specifying the process design conditions of heaters in accordance with the requirements of this standard. The Design Engineer shall complete the data sheet based on the requirements of this standard, project scope definitions, and the referenced documents listed in this standard.

6.1.3 Heater designations shall be based on the tube arrangement and configuration of the combustion box, as follows:

1) Horizontal tube cabin or box heater
2) Vertical tube cabin or box heater
3) Vertical cylindrical heater
4) Cruciform vertical tube box or cylindrical heater

6.2 Heater Selection

6.2.1 The selection of heaters shall be based on the following:

1) Type of service
2) Size of heater
3) Specific project and scope definitions

6.2.2 The selection of burners shall be determined based on the following criteria:

1) Fuel data supplied with the project scope definitions
2) Type of draft (natural or forced)
3) Maximum emissions
4) Maximum heat release limits

6.3 Heater Rating

6.3.1 Heaters shall be rated based on the net (lower) heating value.

6.3.2 Unless otherwise specified by a Process Design Licenser as part of a proprietary design, the maximum allowable average radiant design heat flux transfer rates shall be limited to the values shown in Table 1.

Table 1 – Average Radiant Heat-Flux Transfer Rates

Type of Service	Maximum Allowable Design Rates
Asphalt heaters	31.5 kW/m² (10,000 BTU/hr. ft²)
Circulating service heaters	19.0 kW/m² (6,000 BTU/hr. ft²)
Crude heaters (atmospheric and vacuum)	31.5 kW/m² (10,000 BTU/hr. ft²)
Reboilers	31.5 kW/m² (10,000 BTU/hr. ft²)
Reduced crude lube-heaters	22.0 kW/m² (7,000 BTU/hr. ft²)
Thermal cracking heaters: oil fired gas fired	 25.2 kW/m² (8,000 BTU/hr. ft²) 28.4 kW/m² (9,000 BTU/hr. ft²)
All other services	37.9 kW/m² (12,000 BTU/hr. ft²)

Notes:

1) The maximum allowable average heat rates specified in paragraph 6.3.2 are for one sided firing.
2) The maximum allowable average heat rates specified in paragraph 6.3.2 are for two-tube diameter tube pitch.
3) The maximum allowable average heat rates for two sided firing shall be 1.5 times those specified in paragraph 6.3.2.
4) The maximum allowable average heat rates for vertical cylindrical heaters shall be 31 KW/m² (10,000 BTU/hr. ft²)

6.3.3 Tube inside design flow, (except for vapor services, and cracking services) shall be limited to between 1220 to 1710 kg/sec. m² (250 to 350 lb./sec. ft²).

6.3.4 Turndown mass velocities shall be limited to 880 kg/sec. m² (180 lb./sec. ft²).

6.3.5 Recycling shall be considered if a lower mass turndown is required.

6.3.6 Maximum fluid velocity occurring at any point in vacuum services shall be limited to 85% sonic velocity.

6.3.7 Tube inside coking allowances shall not be included in the rating and pressure drop allowances, except in heavy coking services, such as vacuum flashing heaters, and thermal cracking heaters.

7 Mechanical Design

7.1 General

The Design Engineer shall use API STD 560 Appendix A, "Equipment Heater Data Sheet" (herein referred to as data sheet) and Appendix B, "Purchaser's Checklist" of API STD 560 for specifying the mechanical design conditions of heaters in accordance with the requirements of this standard.

7.2 Design Pressure and Temperature

7.2.1 Mechanical design pressure shall be specified in accordance with the following criteria:

1) Long term heater tube design pressure of each coil shall be equal to the maximum operating pressure at the inlet of each service plus 10%. However, the additional differential shall not exceed 350 kPa (50 psi) or be less than 175 kPa (25 psi).

2) Where outlet block valve are specified, short term overpressure excursions shall be considered as the design basis.

3) Heater tubes in coking services shall have pressure drop coking allowances equivalent to 6 mm for heavy coke and 3 mm for light coke.

7.2.2 Design metal temperatures for each heater section shall be the maximum tube metal temperature as determined per 32-SAMSS-029 for clean services or the maximum tube metal temperature to be expected under fouled tube conditions based on the design fluid temperature, whichever governs.

7.2.3 Steam-air decoking temperatures shall be considered when specifying the design metal temperatures of effected heater components.

7.2.4 The design fluid temperature shall not be less than the maximum fluid outlet temperature for the heater section under consideration.

7.3 Vents and Drains

Vents and drains on radiant tubes and convection coils that are required for operation and maintenance shall be specified on the data sheet.

7.4 Fans

7.4.1 Parallel forced draft fans discharging into a common duct or plenum shall be provided with positive, tamper proof fan shut off devices or automatic check dampers to prevent back-flow of air into fans while on standby.

7.4.2 Forced draft fans shall not be spared, except for critical services where shutdown of the heater would necessitate shutdown of the downstream processing unit.

7.4.3 Induced draft fans shall be provided with controls to switch the heater to natural draft.

7.4.4 Induced draft fans shall be provided with dampers in flue gas ducts.

7.5 Air Preheaters

7.5.1 To prevent corrosion in the flue gas system, air preheat may be required in order to ensure that the cold end metal temperatures are above the sulfur dew point of stack gases.

7.5.2 The maximum air preheat temperature for recuperative type air preheaters shall not exceed 65°C.

7.5.3 In order to provide air preheat, consideration should be given to combination of steam-air preheat, air preheater cold air bypass, and air preheater hot air spill-back.

7.5.4 The regenerative type of air preheaters shall not be used unless approved by the Saudi Aramco Engineer.

7.5.5 The mechanical design of air-preheater systems shall be in accordance with 32-SAMSS-029.

7.6 Stacks

Stack heights and locations with respect to other equipment shall be specified in accordance with SAES-B-055. Stack height over 60 m above ground shall meet the requirement of SAES-B-063.

7.7 Steam-Air Decoking

7.7.1 One directional steam-air decoking shall be specified for all heaters in normal coking services, examples, atmospheric and vacuum crude heaters.

7.7.2 Two directional (reverse flow) steam air-decoking for decoking in both directions shall be specified for heavy coking services, examples, thermal cracking, thermal reforming and visbreaking.

7.7.3 Steam-air decoking is not required for all vapor services, examples, reforming or hydrocarbon liquid flows with outlet temperatures below 320°C.

7.8 Pressure Relief and Emergency Shutdowns

The Design Engineer shall specify on the data sheets the pressure relief and emergency shutdown requirements in accordance with SAES-B-058, SAES-J-600 and SAES-J-601.

7.9 Burner Safety

The Design Engineer shall specify burner safety requirements in accordance with SAES-J-603.

7.10 Refractory and Insulation

7.10.1 The Design Engineer shall specify the refractory system to be used in accordance with SAES-N-100.

7.10.2 External heater piping shall be insulated in accordance with SAES-N-001.

7.11 Noise Levels

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

7.12 Emissions

7.12.1 Heaters shall be specified to operate in compliance with local environmental regulations as detailed in SAES-A-102.

7.12.2 Emission rates shall be expressed in Lb./MM BTU's when the heater is operated at its design rate firing the fuels specified. Flue gas emissions (NOx, CO, particulates, hydrocarbons, etc.) shall not exceed the levels specified in SAES-A-102.

8 Structural and Drainage Design

8.1 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 heater data sheet.

8.2 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 heater data sheet.

8.3 The number, extent, and locations of platforms, ladders, walkways, and stairways shall be in accordance with API STD 560 and SAES-B-054.

Commentary Note:

The extent of platforms, ladders, walkways, and stairways must be reviewed by the Proponent's operating and maintenance representatives and will depend on the amount of operating and maintenance traffic required on each individual heater.

8.4 The design of drainage and sewer systems shall be in accordance with SAES-S-020.

9 Equipment Layout

Heaters and their ancillary equipment shall be located in accordance with SAES-B-055.

10 Painting and Fireproofing

10.1 The selection for the type of coating to be applied on heaters shall be in accordance with SAES-H-001.

10.2 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.

10.3 The extent of fireproofing shall be in accordance with SAES-B-006.

11 Drawings and Calculations

11.1 The data sheet, drawings and forms are to be completed by the Design Engineer to the extent as detailed in 32-SAMSS-029 and this standard.

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

11.3 The Design Engineer is responsible for the completion of the Heater-Safety Instruction Sheet (Forms 2731-ENG) in accordance with the data on the Heater Manufacturers drawings and SAES-A-005.

11.4 Fired heater's manufacturer shall prepare drawings, which indicate the ultrasonic thickness of the heater's components. An adequate number of readings shall be taken to represent the actual thickness of the components.

11.5 Drawings and calculations that are approved by the Design Engineer shall not relieve the Heater's Manufacturer from the responsibility to comply with the applicable Codes, and this specification.

12 Life Cycle Cost Evaluation

Unless otherwise approved by the Coordinator, Mechanical & Civil Engineering Division, Consulting Services Department, Quotations for process heater in accordance with 32-SAMSS-029, shall be evaluated on the basis of Life Cycle Cost (LCC) as explained in SAEP-341. This cost is composed of the initial purchase cost of the heater(s) plus the present worth of the fuel consumption over an assumed operating period of 15 years. The Life Cycle Cost of the process heater(s) shall be determined using the following Life Cycle Cost spreadsheets:

- LCC-025, Single Fuel Process Heaters
- LCC-025A, Dual Fuel Process Heaters

The efficiency of the heater at 100% of the design heat releases shall be guaranteed. If the actual efficiency during performance tests is found to be less than the guaranteed efficiency, then the cost of the heater(s) shall be reduced by an amount equal to the difference in fuel consumption (MMBTU/hr) for not meeting the guaranteed efficiency, multiplied by the Evaluation Factor $-hr/MMBTU as given in the provided Life Cycle Cost spreadsheets included with heater data sheet. The maximum reduction shall not exceed 15% of the initial cost of the process heater(s).

Mathematically:

Single Fuel:

Efficiency Penalty = [actual efficiency –(guaranteed efficiency-0.01)] * L * EF

Commentary Note:

Efficiency values are in decimal representation. 0.01 in the equation is a 1% test tolerance allowed.

EF = PV * EC * AH

Dual Fuel:

Efficiency Penalty = Sum of Efficiency Penalty of all fuels

For each type of fuel the evaluation factor is defined by

$$EF = PV * EC * T$$

Where;

L	=	Heater Load (Duty) @ normal condition (MMBTU/hr) will be show on the data sheet.
EF	=	Evaluation Factor ($-hr/MMBTU) will be shown on the data sheet that goes with the quotation request
EC	=	Energy cost in $/MMBTU for each fuel
AH	=	Annual operating hours:
	=	OF * 8760
OF	=	Operating Factor, equal 1
PV	=	Present value factor = 5.85 based on 15% discount rate expressed as a decimal number and operating period of 15 years.
T	=	Operating time for each fuel type, in hours.

Revision Summary

30 November, 20002	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.
28 January, 2004	Minor revision to Section 12.