

DEP SPECIFICATION

FIRED HEATERS (AMENDMENTS/SUPPLEMENTS TO ISO 13705)

DEP 31.24.00.30-Gen.

February 2011

(DEP Circular 97/11 has been incorporated)

(Amendment A02 has been incorporated - February 2013)

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



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The objective is to set the recommended standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for design, materials, fabrication, inspection, testing, preparation for shipment, and erection of fired heaters. It includes related equipment such as convection banks, air preheaters, burners, air and flue gas ducts, and forced and induced draught fans.

This DEP also specifies requirements and gives recommendations for unfired waste heat recovery steam generation and steam superheating convection sections for fired heaters.

Excluded from the scope of this DEP are the following:

- Materials selection for special heaters such as high-temperature conversion and steam heaters (tube wall temperature above 700°C) and for heaters for catalytic chemical reactions The Principal shall be consulted for specific requirements in these cases.)
- Waste heat steam generators associated with gas turbine exhausts. This subject is covered by DEP 30.75.10.31-Gen.

This DEP is based on ISO 13705:2006/API Standard 560, Fourth Edition.

NOTE: 1. ISO 13705:2006 is identical to API Standard 560, Fourth Edition, August 2007. Further references in this technical specification will simply be stated as ISO 13705.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards

This is a revision of the DEP of the same number dated October 2004; see [1.5] regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use facilities related to oil and gas production, gas handling, oil refining, chemical processing and gasification, distribution and supply/marketing. Application in other facilities may also apply.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

NOTE: The term **Contractor** as used in this DEP is synonymous with the term **Purchaser** (as used in ISO 13705). ISO 13705 does not differentiate between the engineering contractor and owner (Shell).

Where the intent in this DEP is an action or decision primarily by Shell, the term **Principal** is used. Where the intent in this DEP is for an action or decision primarily by the Engineering Contractor working on behalf of the Principal, the term **Contractor** is used.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

- NOTE:
- 1 The terms Supplier and Manufacturer as used in this DEP are synonymous with the term **Vendor** (as used in ISO 13705) depending on the context in which the term is used.
 - 2 The **Manufacturer** has prime responsibility for the detailed engineering, material procurement, project management and manufacturing processes involved in the supply of the fired heater including all aspects of quality assurance, quality control for work of their own and others whom they qualify for providing work, products or services on their behalf i.e. Vendors, Fabricators, Refractory Manufacturers and Refractory Contractors.
 - 3 The term **Vendor** is used in reference to party that provides engineered products or sub-components for the project work. The Vendor whether they directly produce the materials or are agents in supply of such components, have responsibility for the quality of the product to either recognized industry or other standards as directed by the Purchaser whomever they may be. Vendors typically supply sub-components such as; burners, fans, dampers, instrumentation, pipe hangers, castings, refractory, pipe / tubes and fittings etc. A Vendor may also provide specialty engineering services such as; finite element analysis (FEA).
 - 4 The **Fabricator** is the party that provides the facilities and services to physically construct, all or part of the fired heater under contract to the Manufacturer. The Fabricator would be responsible for the quality control of their own works and quality assurance of any directly purchased or sub-contracted work by them.
 - 5 The **Refractory Manufacturer** is the party that manufactures the refractory products and/or ancillaries for supply to the Refractory Contractor. The Refractory Manufacturer has primary responsibility for material design properties, manufacturing quality control at the manufacturing site and specific procedures such as those for product mixing, installation and start-up.
 - 6 The **Refractory Contractor**, when different from the Manufacturer is the party that undertakes all, or part of, the construction design, engineering, material procurement and application of refractory products on behalf of the Manufacturer. The Refractory Contractor has responsibility for the quality control of their products and services.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

Design Class is a categorization defining fit-for-purpose facilities developed through Value Improvement Processes (VIPs) during a project Front End Development (FED) phase.

A **Delegated Technical Authority** is a person who has received delegated authority to approve Derogations from the Process Safety requirements from the Head of Shell P&T.

A **Derogation** is an authorised variance or exemption from a Process Safety requirement, with specified conditions.

Process Safety is the management of hazards that can give rise to major accidents involving the release of potentially dangerous materials, release of energy (such as fire or explosion) or both.

The word **SHALL [PS]** indicates a Process Safety requirement.

Note: Derogations from these requirements SHALL [PS] be approved by the Delegated Technical Authority.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

The words **tubes** or **tubing** shall also mean **pipe** or **piping** unless clearly distinguished otherwise. See also (Appendix 1).

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced clause number is shown in brackets. Other documents referred to in this DEP are listed in (Part IV).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated December 2004, which was based on ISO 13705:2001. This edition of the DEP is now based on ISO 13705:2006. This is a major rewrite hence changes are not listed here.

Amendment A02

Section	Change
Part I, 1.6	Updated feedback system.
Part III, 11.4	Updated to reflect latest Shell HSE policies with regards to the use of Refractory Ceramic Fibres
Part III, 11.4 subclauses	Changed references to “ceramic fibre” to “fibre”
Part IV	Added DEP 00.00.05.80-Gen. to the Reference section.

1.6 COMMENTS ON THIS DEP

Amendment A02

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the “Give feedback” link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select “Submit DEP Feedback”, fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

**Amended per
Circular 97/11**

Dual units have been incorporated throughout this DEP.

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used

PART II GENERAL REQUIREMENTS

1.1 GENERAL

Part III of this DEP of this DEP is written as amendments and supplements to ISO 13705

For ease of reference, the clause numbering of ISO 13705 has been used throughout Part III of this DEP.

Unless specified otherwise in this DEP, all occurrences of the word “should” in ISO 13705 shall be replaced with the word “shall”.

Clauses in ISO 13705 that are not mentioned in this DEP shall remain valid as written.

1.2 DESIGN CLASS CONSIDERATIONS

Decisions related to the Design Class performance categories for fired heaters are beyond the scope of this DEP. Such decisions are intended to be made by the Principal in the project “Define” phase and detailed in project scope defining documentation e.g. equipment BDEP (Basic Design Engineering Package), fired heater data sheet, fired heater checklist, project specific specifications, etc.

Fired heaters of any design class shall, as a minimum, adhere to Process Safety related requirements as specified in this DEP, unless derogations are approved by the Principal.

1.3 DECISIONS

A bullet (•) is shown in the margin of this DEP where further decisions or information are to be provided by the Principal or Contractor. Refer to Standard Form DEP 31.24.00.82 for recording decisions on the bulleted items of ISO 13705 and additional ones added to this DEP.

PART III AMENDMENTS/SUPPLEMENTS TO ISO 13705**1. SCOPE**

Delete this section and replace with (Part I, 1.1) of this DEP.

3. TERMS AND DEFINITIONS

Note: Additional terms and definitions related to refractory and insulation are included in (Appendix 1).

Add new terms:

3.85

design heat release

heat release including a defined capacity margin as a percentage of the calculated "normal" heat release for the burner(s)

3.86

commercial refractory

packaged and preblended refractory product offered with published technical data sheets, product compliance data, installation information, Material Safety Data Sheets (MSDS), and other safety and handling information

Note Refer to (Appendix 1) for Refractory property and classification tables.

3.87

WHMIS

Workplace Hazardous Materials Information System

4. GENERAL**4.1 PRESSURE DESIGN CODE**

Add to this clause:

- Unless otherwise specified by the Principal, the pressure design code shall be:
 1. ASME VIII and ASME B31.3 for process piping/tubing and auxiliary piping; and,
 2. ASME I and ASME B31.1 for steam piping/tubing and auxiliary piping.

Design, fabrication and testing requirements shall be in accordance with the pressure design code and as amended by the following standards:

- Process piping/tubing including any inlet, cross-over and outlet piping:
 1. ISO 13704
 2. DEP 31.24.49.31-Gen.
- Auxiliary piping:
 1. DEP 31.38.01.31-Gen.

4.2 REGULATIONS

Add to this clause:

Refer to (PART I, 1.2)

4.3 HEATER NOMENCLATURE

Add to this clause:

Vertical box-type heaters with radiant cells of rectangular or square horizontal cross section and separating walls consisting of single or double tube rows may also be applied.

Convection sections may be either top or side-mounted, provided an even flue gas distribution is obtained.

Add new clause:

4.4 CONFLICTING REQUIREMENTS

4.4.1 The descending order of precedence for requirements shall be:

- Regulatory requirements;
- Purchase order, including pre-purchase correspondence, clarifications, and notes of pre-selection and pre-award meetings;
- Data sheets, relevant Basic Design Package, related technical notes, and drawings;
- Design and Engineering Practice (i.e. this DEP)

4.4.2 Any exceptions/deviations to the above documents shall not be permitted unless:

- specified by the Manufacturer,
- approved by the Principal,
- included in the purchase order by the Contractor.

5. PROPOSALS

5.1 PURCHASER'S RESPONSIBILITIES

5.1.2 *Add to this clause:*

The Contractor/Manufacturer shall use ISO 13705 or equivalent data sheets. See (5.2 a).

5.1.3 *Add to this clause:*

- The Contractor shall provide fired heater data sheets and project specifications that specify:
 - Preferred refractory lining system requirements;
 - Expectations for the extent of shop and/or field installation of refractory linings;
 - Shop vs. field refractory dryout;
 - Degree of assembly for delivery to site including shipping requirements and constraints;
 - Handling of field joints including the need for supply of refractory materials;
 - Period of time before commissioning/heating for proper refractory preservation considerations;
 - Any alternates that may be requested and quoted in addition to the base requirements.

5.2 VENDOR'S RESPONSIBILITIES

The vendor's proposal shall include

1. *Replace this clause by:* Completed data sheets for each fired heater and the associated equipment (including burners, air preheaters, fans and motors) with all missing data including;
 - Process conditions with a note for Total Acid Number and feed S wt% and properties at the convection and shield section outlets, including mixture enthalpy and in-tube vapour or superficial liquid and vapour velocities
 - Combustion design conditions along with flue gas emissions for each identified operating case,

- Refractory hot face temperatures to be used for heat flow calculations
- e) *Replace this clause by:* Noise datasheet;
- i) *Replace this clause by:* List of electrical power requirements for motors, other utilities and quantities required;
- j) *Replace this clause by:* List of sub-suppliers and country of origin proposed for the supply, manufacture and fabrication of all components including but not limited to; heater coils, fittings, extended surfaces, castings, burners, fans, air preheaters, setting steel, refractory supply and including assembly/sub-assembly facilities and refractory installation and any other auxiliary equipment like SCR etc.;

Add new clauses:

- k) Confirmation that all heater parts are suitable for operation at up to 115% of "burner normal heat release" with the excess air level as indicated in (6.2.1) (no increase in design absorption is implied);
- l) Overall quality control/quality assurance plan applicable to all phases of the project.

Add new clauses:

Alternative designs may only be offered in addition to that requested by the Principal.

The proposal shall identify first-time use of any design or component including materials, capacity, emissions, or any aspect of performance. First-time use is considered to be fewer than two years of successful operation at two separate facilities. Such designs are subject to the approval of the Principal. Supporting data and/or references shall be provided to the Principal upon request.

5.3 DOCUMENTATION

5.3.1 Drawings for purchaser's review

- f) *Replace this clause by:*
refractory and insulation types, product brand names, product continuous use temperature, layer thicknesses, extent of coverage and method of application;
- g) *Replace this clause by:*
types, and materials, spacing and layout of anchors and supports for refractory and insulation;

Add new clauses:

- k) convection and shield section arrangement drawing including all inside lining dimensions, tube layout, corbels, clearances between tubes/fins, and refractory, tubesheet details and any intermediate tube supports, including attachments as applicable;
- l) detailed drawing of all ancillary nozzles, instrument and sample connections;
- m) visibility diagram related to placement of observation ports together with details of their design;
- n) detailed drawings of the heater auxiliary equipment including all louvers, dampers expansion joints, fans, motors, air heaters, burners, soot blowers, etc. as applicable.

Add new clause:

The Manufacturer/Supplier shall provide all drawings, design details, stress calculations, operation and maintenance manuals, and other information necessary for the design assessment, erection, operation and maintenance of the installation, all information specific to the installation being supplied and in English language. However, descriptions on drawings may be in other languages, provided English translations are given.

5.3.3 Documents for purchaser's review

c) *Replace this clause by:*

tube support details and design calculations, clearly stating basis, assumptions, and design margins;

e) *Replace this clause by:*

welding examination and test procedures for all pressure and structural components as well as refractory anchors, studs, and pins, all of which shall be defined in a quality inspection and test plan (ITP);

f) *Replace this clause by:*

installation procedures including surface preparation, curing, dry-out, and start-up and test procedures for refractories and insulation;

k) *Replace this clause by:* noise data sheets.

Add new clauses:

l) refractory quality documentation as specified in (17.5.2);

m) complete and current material safety data sheets (MSDSs) for each product;

n) pressure profile curves or information demonstrating draught and draught loss profile throughout the heater and air preheater from air suction to stack outlet based on the conditions as defined in [sub-section 6.2 – Combustion design];

o) percent of full travel vs. pressure loss curves for combustion air and flue gas control dampers for design flows. See (6.2.1);

p) burner capacity curves for all fuels specified and combustion air for forced draught burners at 15°C (60°F) and design temperature;

q) burner test procedures;

r) calculations and drawings for all lifting attachments;

s) Manufacturer's documentation of tube by tube temperature, pressure and % vapourization profile along the coil with intube vapour or superficial liquid and vapour velocities.

5.4 FINAL RECORDS

a) *Replace this clause by:*

certified as built drawings, calculations and inspection reports of lifting attachments (submitted 4 weeks prior to release of equipment to the Contractor).

f) *Replace this clause by:*

noise data sheets;

g) *Replace this clause by:*

refractory dry-out temperature recording charts including details of ambient conditions of lined equipment storage and time lapse between installation and first refractory dryout, when dry-out is included in the Manufacturer's scope of supply;

Add new clauses:

k) environmental performance data, if requested by Contractor;

l) burner test reports;

m) list of all spare parts, including list of initial spare parts necessary for start-up and first year of operation, with detailed prices and time of delivery;

n) list of all tools necessary for operation, maintenance, inspection and cleaning that are not normally found in a refinery workshop;

- o) weight of each unit.
 - empty
 - full (hydraulic test conditions)
 - full (working conditions).
 -

6. DESIGN CONSIDERATIONS

6.1 PROCESS DESIGN

6.1.1 *Add to this clause:*

Multi-pass heaters shall be designed for hydraulic symmetry of all passes and for equal heat pick-up per pass.

Collection and distribution manifolds on multi-pass heaters shall be sized so that the frictional head loss over the total manifold length, based on a constant velocity equal to the maximum (inlet) velocity, does not exceed 5% of the individual pass pressure drop.

6.1.2 *Add to this clause:*

- If in-tube decoking is not required and in non-vapourizing service, multiple passes in an upstream section (usually the convection section) may be combined to a single pass, if specified by the Principal.

6.1.3 *Replace this clause by:*

Average radiant absorption rate shall be calculated by dividing the total heat absorbed in the radiant section by the total radiant tube area. Convection shield tubes not directly exposed to the flame zone shall not be used in determining the average absorption rate or bridgewall temperature. If shield tubes are directly exposed to the flame zone, only the first row shall be considered in determining average radiant flux and bridgewall temperature.

6.1.4 *Replace this clause by:*

- Unless specified otherwise, the average heat absorption rates in the radiant cell shall be limited as follows:

Arrangement	kW/m ²	Btu/h-ft ²
Horizontal tube fired from one side	35.0	11 000
Vertical tube fired one side from bottom	31.5	10 000
<i>Single tube row uniformly fired both sides</i>		
a) From bottom	43.0	14 000
b) From both sides or ends	47.7	15 000

- Deviation from the above may be allowed, provided it can be proven by verifiable modelling that the maximum allowable film temperatures are not exceeded, this being subject to approval by the Principal.

Add new clause:

- 6.1.6 The maximum heat flux, basis the bare tube surface, to any convection or shield tube shall not exceed twice the average radiant heat flux for single fired tubes, in accordance with the data sheets or 70 kW/m² (22 000 Btu/h-ft²), whichever is more limiting. The maximum flux shall be calculated as the sum of (A + B + C) below based on the specified heater design conditions. Temperature difference for calculations is based on the process inlet temperature and flue gas temperature entering the tube row being studied.

A Calculated average convection flux multiplied by 1.15.

B Direct radiant heat flux from combustion chamber and reflected from reradiating walls to front 60° of tube and its extended surface.

C Average rate of radiant heat gain from flue gas to tube including extended surface.

- Deviation from the above may be allowed, provided it can be proven by verifiable modelling that the maximum allowable film temperatures are not exceeded, this being subject to approval by the Principal.

The maximum heat flux to the first row of finned tubes shall be lower than that to the shield tubes. Alternatively, an inspection lane may be provided between bare and finned section. Refer to [6.3.4].

Add new clause:

6.1.7 Design in-tube velocities in vapour and vapour-liquid flow shall be limited to a maximum of 85% of critical velocity. Critical velocity is calculated as:

$V_{crit} = (P_{crit}/\rho_{mix})^{0.5}$, assuming homogeneous mixture, unless otherwise specified by the Principal.

Add new clause:

- 6.1.8 All heaters in vapourizing or two-phase flow service, including the outlet piping and transfer line, shall be subject to detailed review of flow regimes and potential for flow instability or erosion-corrosion over the full operating range, with evaluations subject to approval by the Principal.

Where vapour and liquid phases coexist in the heater coil, the following conditions SHALL [PS] (Subclauses a) to c) below) be met:

- a) Heat tube coils shall be designed to maintain stable flow conditions over the complete range of specified operating flow rates and heat inputs.
- b) Flow regimes shall assure fully liquid-wetted walls. Acceptable two-phase flow regimes for both horizontal and vertical coils are bubble, froth, plug, and annular. Segregated flow regimes in horizontal coils of stratified, wave, and wave/mist shall be avoided. Unfavourable two-phase flow regimes can be prevented when the superficial liquid velocity is greater than 1 m/s (3.3 ft/s). When the superficial liquid velocity of less than 1 m/s (3.3 ft/s) is unavoidable, the superficial vapour velocity shall be greater than 8 m/s (26.2 ft/s) for vertical flow and 10 m/s (32.8 ft/s) for horizontal flow.
- c) For hydroprocessing heaters with vertical tubes, the minimum superficial vapour velocity may be relaxed to 3 m/s (9.8 ft/s).

In addition, the following items shall be evaluated:

- i) Design in-tube velocities shall also be evaluated with respect to erosion-corrosion potential. Heater coil designs with an erosional velocity coefficient of $C > 220$ in SI units (180 in US Customary units) shall be avoided. Designs in excess of these values shall be subject to approval by the Principal.

$$C = V_m \times \text{SQRT } \rho_m$$

Where:

V_m = homogeneous mixed phase velocity; m/s (ft/s)

ρ_m = homogeneous mixed phase density; kg/m³ (lb/ft³)

- ii) The Ensure Safe Production (ESP) operating limits shall be established by the Principal during design and incorporated into operating controls and procedures.

Add new clause:

6.1.9 Transfer lines from a heater to a distilling column shall, immediately upon leaving the heater, rise to an elevation above the one at which the column is to be entered and slope down towards the column.

Vertical parts of lines transporting gas/liquid mixtures shall have stable flow conditions in the complete operating range of the heater as specified in the requisition.

Add new clause:

- 6.1.10 For the design of new convection sections, the preferred minimum flue gas mass flux at design process duty is $2.5 \text{ kg/m}^2\text{s}$ ($0.52 \text{ lb/ft}^2\text{-s}$) (flux between bare tubes). However, in the case of natural draught heaters with top mounted convection sections and stacks, when the relatively large pressure drop over the convection section associated with the above noted minimum mass velocity results in either insufficient draught at the heater or impractical stack heights, the flue gas mass flux may be reduced to a minimum of $1.8 \text{ kg/m}^2\text{s}$ ($0.37 \text{ lb/ft}^2\text{-s}$).

Add new clause:

- 6.1.11 If the convection section of the fired heater contains waste heat recovery coils in steam generation service, the Principal shall provide additional requirements in the project specifications.

6.2 COMBUSTION DESIGN

6.2.1 *Replace this clause by:*

The combustion system (fuel gas train and controls) shall be sized for a maximum heat release of 115% of normal burner heat release for the heater operating at the specified process design conditions, with design air excess levels as specified in (6.2.3). This margin is not intended to permit continuous operation of the heater at greater than the design process duty.

Refer to Table 6.2 for further definition of burner heat release in reference to ISO 13705, API RP 535, and guidance for sizing of fuel gas trains and alarm and trip settings.

Burner shall be capable of operating at minimum and maximum stable heat release conditions as per Table 6.2. Where required, this should be verified during the burner test.

Refer to (14.1) for further information on burner sizing and testing.

Table 6.2 Fuel gas train design, alarm, and trip settings

ISO 13705 / API 560		Fuel Gas Train Design		API 535	
Burner Heat Release	Definition	Fuel Flow	Definition	Burner Heat Release	Definition
		125%	HIGH-HIGH burner pressure TRIP to minimum firing TRIP Pressure = pressure @ 120 to 125% of <u>normal heat release</u>	Maximum Stable Heat Release	The maximum heat release for the burner at the point of CO breakthrough with the air register at the same setting as "design" heat release or 100% open
			HIGH fuel pressure "critical alarm" and cutback to 90% of last temperature control setting - midpoint between "Design" and HIGH-HIGH pressure TRIP pressures	Maximum	The heat release for the burner with design excess air and design draft loss with air register 100% open
Design¹ <u>Low ΔP burners</u> #. Burners ≤5 =120% 6-7=115% ≥8=110% <u>High ΔP burners</u> 115%	The heat release per burner including a defined capacity margin as a percent of the calculated "normal" heat release	115%	Design fuel flow for fuel gas train and controls with all burners operating at 115% of the calculated Normal heat release with "leanest design" fuel ^{2,3} - Burner tip pressure Design ~ 185 kPag ⁴ - "Active high burner pressure control" - HIGH Fired Duty "standard alarm"	Design	The specified "design" heat release for the burner with the air register set for the design excess air with design draft loss
Normal	The heat release per burner required for the design total absorbed duty for the heater divided by the calculated fuel efficiency.	100%	The fuel flow for control valve sizing with all burners operating at 100% of the calculated Normal heat release with "leanest design" fuel.	Normal	The specified "normal" heat release for the burner with the air register set for the design excess air with design draft loss
		4:1 of Design	Upper range of fuel flow and pressure for the "active minimum burner pressure control". Pressure = 1/16 th of Design		
Minimum	The heat release per burner for the specified turndown of the heater or burner	5:1 of Design	Lower range of fuel flow and pressure for the active minimum burner pressure control. Pressure = 1/25 th of Design - LOW burner fuel pressure "critical" alarm = pressure @ midpoint of min. pressure control and LOW-LOW TRIP	Minimum	The specified "minimum" heat release for the burner with the air register set at the same setting as the "normal" heat release <u>or</u> with the air register set for the design excess air
		6:1 of Design	Expected minimum burner pressure for stable operation below which the fuel should be tripped. Pressure = 1/36 th of Design LOW-LOW burner pressure total fuel TRIP	Minimum Stable Heat Release	The minimum heat release for the burner at the point of CO breakthrough with the air register at the same setting as "normal" heat release

- NOTE:
- 1 Refer to (14.1.7)
 - 2 Leanest design fuel does not include natural gas when natural gas is identified for start-up considerations only.
 - 3 Refer to (6.2.1)
 - 4 Design burner tip fuel pressure established in consideration of providing measurable fuel pressure at T/D & trip and avoiding sonic flow conditions at maximum heat release.

6.2.2 *Add to this clause:*

Efficiency shall be based on the specified ambient air temperature at the stated (site/project specific) relative humidity.

Notwithstanding the design excess air levels as indicated in this clause, heaters shall be designed and constructed for minimum air infiltration so that operation with 10% excess air can be continuously sustained at 100 to x% duty, where x is the specified process turndown (but not lower than 50%).

6.2.3 *Replace this clause by:*

Unless otherwise specified, calculated efficiencies for heaters without lead/lag closed loop combustion control (e.g. natural-draught operation) shall be based upon 15% excess air if gas is the primary fuel, and 20 % excess air if oil is the primary fuel. For heaters with lead/lag closed loop control combustion control (e.g. forced-draught burners or balanced-draught operation), calculated efficiencies shall be based on 10% excess air for fuel gas, and 15% excess air for fuel oil. The design excess air for heater sizing basis shall be as stated in this clause, unless otherwise specified in the project documents.

6.2.5 *Replace this clause by:*

Volumetric heat release shall not exceed 83 kW/m³ (8 000 Btu/h-ft³) for oil firing and 124 kW/m³ (12 000 Btu/h-ft³) for gas firing at the design heat absorption and excess air.

6.2.6 *Add to this clause:*

For heaters with induced draught fans, the stack and flue systems downstream of the fan shall be sized for 120% of normal burner heat release. The induced-draught fans shall be sized in accordance with the combustion system design specified in (6.2.1) and a 1.15 test-block flow factor as specified in (F.7.4.2).

Add new clause:

6.2.7 Stack sizing/draught calculations shall be based on summer/maximum specified ambient temperature.

6.3 MECHANICAL DESIGN

6.3.4 *Add to this clause:*

The convection section tube layout shall provide open access lanes to permit inspection, with a. minimum vertical clear space of 600 mm (24 in.) at the following locations:

- between bare shock tubes and finned tubes (Note 1);
- preferentially at locations where there is a change in process;
- for clean gas firing between each 15th tube row; and,
- for oil firing further inspection lanes correspond with soot blower lanes [see ISO 13705, clause 14.2.4].

Note 1 This is not required if the heat flux to the first finned tube row is lower than that to the shield tubes. Refer to [6.1.6]

6.3.5 *Replace this clause by:*

Vertical tube cylindrical heaters should have a maximum radiant chamber height of 2.8 times the tube circle diameter (typically for single burner heaters) and a minimum height of 1.75 times the tube circle diameter (typically for heaters with 8 to 12 burners) and 1.5 times the tube circle diameter for heaters with more than 12 burners.

The above radiant cell dimension requirements should be read in conjunction with [6.3.13 and 6.3.14].

6.3.6 *Replace this clause by:*

Box type heaters with floor firing should have a chamber height between 2.2 and 3.5 times the centre-to-centre distance between tube rows or between tube row and enclosing parallel wall.

The above radiant cell dimension requirements should be read in conjunction with (6.3.13 and 6.3.14).

6.3.8 *Replace this clause by:*

- Unless otherwise specified, the tubes of convection sections shall be designed with end tubesheets and be placed with a staggered pitch, only if clean, solids-free fuel gas is fired or an in-line pitch otherwise (as specified) in such a way that standard short-radius welding return bends (twice the nominal diameter) can be used.

Corbels having a width of one half of the transverse tube pitch shall be used, except for coil sections with in-line tube arrangements, or for the first two shield rows of convection sections with staggered pitch.

6.3.9 *Replace this clause by:*

The minimum headroom clearance from top of finished grade to the underside of the firebox floor shall be the greater of:

- 3.1 m (10 ft) for natural draught burners with individual air registers, or;
- 3.65 m (12 ft) for forced draught or plenum mounted natural draught burners, or
- 2.0 m (6.5 ft) from the burner face-plate bottom, or;
- burner, fuel gun or pilot removal clearance plus 0.5 m (1.6 ft).

Add new clause:

- 6.3.13 In addition to (6.3.5) and (6.3.6), the height, width, and length of any radiant cell (cylindrical, square, or rectangular) shall be suitably sized in line with the number of burners and their heat release with firebox inside lining dimensions chosen in accordance with (Table 13 or Table 14).

Burner flames shall be appropriately matched to the firebox dimensions and vice versa.

In any case, for vertical firing, the flame length shall be;

- greater than or equal to 1/2 of the firebox inside lining dimension at burner "normal" heat release, and;
- less than, or equal to, 3/4 of the firebox inside lining dimension at burner "design" heat release.

Add new clause:

- 6.3.14 In order to prevent too high radiant heat flux on tube ends in radiant sections, the following requirements shall be adhered to:

- In vertical heaters, the radiant cell tubes shall cover the full height of the radiant cell wall, apart from the space required for expansion of the tubes.
- In horizontal heaters with single side fired tubes in the radiant cell, tubes shall cover the full height and length of the long wall of the radiant cell, apart from the space required for expansion of tubes. This implies that, for the top and bottom tubes, the vertical spacing between the centreline of the tubes and the refractory shall be 1.5 times the nominal tube diameter, with a minimum clearance of 100 mm (4 in.).

Add new clause:

- 6.3.15 Vertical cylindrical heaters with cruciform-style coil sections shall be designed in consideration of the following parameters:

- all tubes are double fired and form a cross pattern in the centre of the radiant section

with four burners (no tubes against the wall);

- burners cantered within the cold plane of tubes;
- burner circle diameter in consideration of burner clearances in line with Table 13 or Table 14; and,
- use long radius fittings at the centre of the heater for one and two pass heaters and use a radial clearance of half of the flange diameter plus 50 mm (2 in.) for four pass heaters with centre outlets.

NOTE: Long radius return bends may be required in consideration of burner clearance, centering burners within the cold plane and optimum radiant chamber height to diameter.

Add new clause:

6.4 COILS AND COIL LAYOUT

6.4.1 General

- Heater coils shall be seamless tubes according to general requirements of ASTM A450 and seamless pipes per ASTM A530. For further details on material selection, see (7).

Pipe shall be used for all-welded coils. Tubes may be used if they have to be expanded into return bend fittings or other specialized applications, if specified by the Principal.

In vertical heaters, the inlet/outlet of coils of radiant cells shall be located at the top of the heater.

In radiant sections of heaters only bare coils shall be used.

Centre-to-centre spacing of radiant tubes/pipes shall be at least twice the nominal diameter.

Cross-over piping shall be made of the same material grade as the upstream coil. Cross-over piping shall be located outside the radiant or convection section.

6.4.2 Coils for crude, reboil, hot oil, vacuum, visbreaker, and thermal cracking heaters

- Coils for crude, reboil, hot oil, vacuum, visbreaker, and thermal cracking heaters are normally fitted with welded return bends. The Principal shall specify whether mechanical cleaning is possible, in which case horseshoe-type return bend fittings (plug type fittings) are required to be installed at the top only for vertical heaters or at one side for horizontal heaters). If hydraulic pigging is specified, no horseshoe type fittings shall be applied.

In heaters where coke is not expected to form inside the coils, or in heaters for which steam/air decoking or hydraulic pigging is specified, maximum use should be made of welded return bends.

If two-phase flow is envisaged in parts of the heater coils, an automatic flow controller shall be incorporated in the inlet of each process pass of the heater where the flow condition is still in the liquid phase.

- Process passes shall not be split at any point between the flow controller and heater outlet. However, process passes may be combined downstream of their flow controllers.
- Connections for steam-out of radiant coils of both residue and distillate cracking heaters shall be provided in the inlet piping.

6.4.3 Coils for platforming, hydrotreating, and hydrodesulphurization heaters

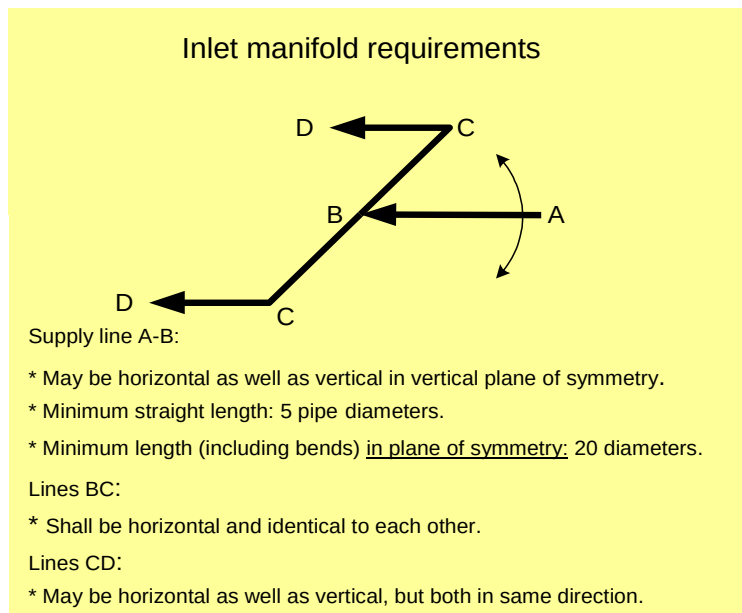
Coils for platforming, hydrotreating, and hydrodesulphurization heaters shall be of all-welded construction using tubes and welded return bends.

The nominal diameter of the pipes/tubes should not exceed 200 mm (8 in.).

The number, size, and arrangement of tubes and the size and arrangement of interconnecting piping pertaining to each parallel coil shall be such that an equal flow in each parallel coil is obtained at all required working loads. Equal flow shall be achieved

only through symmetrical coil arrangements and not through installing valves. Flow measuring elements shall not be installed.

Two-phase flow division of a feed stream into a multiple parallel coil system shall be effected in several stages, each stage consisting of a split from one into two streams. Each split shall also be fully symmetrical. The two outlets of each split shall be in the horizontal plane, and the inlet shall be in the vertical plane of symmetry for a minimum of 20 diameters (see following sketch). Since splitting is done via bifurcation, the number of passes is restricted to 1, 2, 4, 8 etc. The passes may be combined via one large header.



6.4.4 Hydraulic pigging considerations

- If hydraulic pigging is specified, pig launch/receiving connections shall be installed at the inlet and outlet of each coil section with the pigging connection having the same diameter as the relevant inlet or outlet tube. To prevent damage to pigs, there shall be no branch connections (other than small bore instrument connections) between the pig launch/receiving connections.

If hydraulic pigging is specified, the engineering contractor shall perform a pigging study to determine the need for dry risers or cross-over piping in order to pig clean the entire heater with the minimum number of flow circuits with pig launching/receiving connections located at grade.

If specified, the Manufacturer shall supply the necessary piping, and design the heater to accommodate this piping and facilities.

Refer to (7.1.8) for additional considerations related to changes in tube diameter.

Add new clause:

6.5 NOISE CONTROL

6.5.1 Requirements

- Noise levels shall comply with the relevant project specifications provided by the Contractor.

Noise limits apply to both individual noise generating components as well as to the composite heater. Unless otherwise specified, the composite noise limits apply at grade and routinely accessed operating platforms.

Add new clause:

6.6 ELECTRICAL INSTALLATIONS

- Electrical installations shall comply with the relevant project specification to be provided by the Contractor.

7. TUBES

7.1 GENERAL

7.1.1

Add new clause:

7.1.1.1 Design of tubes in the elastic range

If heater tubes are designed to operate in the elastic range, the wall thickness shall be such that the calculated stress does not exceed the elastic allowable stress (σ_{el}) as given in ISO 13704 for the applicable material.

Stress calculations shall be based on the maximum pressure that the heater coil will experience (even for a short period during a pressure excursion).

- For heaters where a blocked outlet can be excluded, the elastic design pressure shall be taken as the relief valve setting of the downstream equipment plus the dynamic pressure loss from the heater tube to the downstream equipment. In all other cases the elastic design pressure shall be taken as the (upstream) relief valve set pressure or the pump shut-off pressure, whichever provides protection in a total blocked flow case.

The allowable stress shall be based on the design metal temperature of the coil. For non-coking services, this is the highest metal skin temperature calculated in accordance with ISO 13704, with the inside heat transfer coefficient based on clean tube conditions (i.e., without fouling layer thickness) and increased by a temperature allowance of minimum 15°C (27°F). It is a good practice to increase this temperature allowance if the selected schedule and material would allow for that. However, the design temperature of the coil shall not be increased beyond the sum of the maximum allowable film temperature + the calculated temperature difference over the tube wall under maximum heat flux conditions. Refer to (7.1.1.3) for coking/high fouling services.

The design metal temperature shall be based on the combination of peak heat flux on the coil and local bulk process temperature that results in the highest tube metal temperature. The values of bulk temperature and peak heat flux shall be based on the same operating conditions. In addition to the above, the thermal stresses shall be checked in accordance with ISO 13704.

Add new clause:

7.1.1.2 Design of tubes in the creep-rupture range

If heater tubes are designed to operate in the creep-rupture range, the wall thickness shall be such that the calculated stress does not exceed the rupture allowable stress (σ_r) for a life time of 100,000 hours. The calculated stress shall be equal to, or less than, the elastic allowable stress (σ_{el}) at that temperature.

The allowable stress shall be based on the design metal temperature as specified in (7.1.1.1) without any temperature allowance, or (7.1.1.3), if applicable.

The elastic allowable stress at design temperature shall not be exceeded when the maximum possible pressure is applied as explained in (7.1.1.1).

Add new clause:

7.1.1.3 Operation under fouled conditions

- If fouling of tubes is expected under normal operation, this possibility shall be indicated by the Principal and accommodated in the tube design. This is, for example, applicable for;
 - thermal cracking heaters where coke formation inside the tubes cannot be prevented;
 - high vacuum unit heaters where coke formation is probable.

If fouling of tubes under normal operation is indicated by the Principal, the maximum design metal temperature shall be the limiting design metal temperature in accordance with ISO 13704, Table 4, e.g. 650°C (1200°F) for P5 material.

In order to prevent premature failure of heater tubes, the accumulated damage over the entire design tube life shall be estimated by calculation. The calculation procedure as given in ISO 13704, Annex A based on the Larson Miller correlations, shall be used with the calculated accumulated damage not exceeding 1.0.

- Unless otherwise specified by the Principal, the estimated operational conditions during the entire tube life shall be taken as 100,000 hours divided into two cycles:
 - One long cycle, typically 95,000 hours, during which the tube wall temperature (clean) linearly increases with time from the initial design value, as specified in (7.1.1.1), to the limiting design metal temperature (fouled), or to a lower temperature, as specified by the Principal. During this long cycle all the corrosion allowance is used up.
 - Followed by a short cycle, typically 5,000 hours, during which the tube skin temperature is constant at the limiting design metal temperature, or a temperature specified by the Principal.

- For rupture stress calculations for each coil section, the local maximum sustainable operating inlet pressure for fouled conditions shall be used. To this end, if specified by the Principal, the radiant coil may be split into more than one section, provided each coil section is separately specified in the heater data requisition sheets.

The minimum rupture strength Larson Miller parameter curves shall be used. For the accumulated damage calculation for the long cycle (95,000 hours), an equivalent metal temperature shall be calculated in accordance with ISO 13704. Since it is assumed that the corrosion allowance is consumed, an average tube wall thickness shall be used in the stress calculation.

For the accumulated damage calculation for the short cycle (5,000 hours), the limiting design metal temperature from ISO 13704 Table 4 shall be used in combination with the normal heater inlet pressure and the tube wall thickness minus the corrosion allowance.

In addition to the lifetime calculations, the elastic allowable stress at the limiting design metal temperature (fouled conditions) shall not be exceeded when the maximum possible pressure is applied as explained in (7.1.1.1).

Add new clause:

- 7.1.1.4 The calculation method for thick wall tubes outside the applicable code limits shall be submitted to the Principal for approval.

Delete this clause. Refer to (7.1.1.1).

7.1.3

7.1.4 *Add to this clause:*

Straight tubes shall not have circumferential welds, unless approved by the Principal. If a circumferential weld is located in the exposed straight length of a tube in the radiant section, it shall be at the location of relative low heat flux (e.g. for vertically fired heaters with vertical tubes the weld shall not be located within one meter (three feet) of the elevation of maximum heat flux).

7.1.6 *Add to this clause:*

The required minimum tube wall thickness shall be determined according to (7.1.1). The selected wall thickness shall be in accordance with ASME B36.10M, with the minimum being Schedule 40, irrespective of ferritic or austenitic steel. The applicable tolerances for tubes shall be taken into account when selecting a wall thickness.

Add new clause:

7.1.8 Wherever a change in tube diameter is required on heater coils, concentric reducers shall be used. A reducer shall not be located closer than two nominal diameters to an elbow or return bend.

7.2 EXTENDED SURFACE

7.2.1 *Replace this clause by:*

- The Principal shall specify in which cases extended surfaces are acceptable in conjunction with an effective on-line cleaning system, such as a soot blowing system.

The extended surface in convection sections shall be finned, with helically wound fins high-frequency continuously welded to the tube and shall comply with tolerances specified in Table 7.2. Segmented fins shall not be applied. Studded tubes shall not be applied unless approved by the Principal.

Table 7.2 Fin manufacturing tolerances

Feature	Tolerance
Spacing of fin tips	–10%, +10% measured over at least 300 mm (12 in) of welded fins and –2% +5% measured over at least 1000 mm (3.3 ft)
Fin inclination	5° maximum
<i>Weld interruptions</i>	Per tube, maximum 2.5% of the tube length Distance between two interruptions or to end of finned section: more than 150 mm (6 in) Length of one interruption: less than 5 wraps
<i>Weld attachment width (fractured surface on tube when fin is removed)</i>	Average attachment percentage of 16 measurements in more than 4 wraps: ≥ 90 % of nominal fin thickness
<i>Fin height tolerance</i>	1.0 mm (-0.04 in.)
<i>Straightness</i>	Finished finned tubes shall be straight with a maximum deviation of 5 mm (0.2 in.)

7.2.3 *Change Table 2 as follows:*

The maximum fin density for oil firing is 80 fins per metre (2 fins per inch), and the maximum fin density for gas firing is 160 fins per metre (4 fins per inch).

7.3 MATERIALS

Replace this clause by:

- **7.3.1 Material selection**

Materials used for heater coils, welded return bends, and horseshoe-type return bend fittings shall be selected according to the design conditions and all applicable degradation mechanisms. All material selected shall be subject to approval by the Principal.

Materials shall comply with the tables below, unless otherwise specified on the heater data sheets and related project specific requirements.

Table 7.3.1 Heater tube materials – pipe

Material	Pipe	Additional Requirements
Carbon steel	A 106-B	Carbon Equivalent < 0.45 (A 106, S5)
1¼Cr-½Mo	A 335-P11	
2¼Cr-1Mo	A 335-P22	
5Cr-½Mo	A 335-P5	
9Cr-1Mo	A 335-P9	
16Cr-12Ni-2Mo	A 376-TP316 A 376-TP316 H	Intergranular Corrosion Test (A 376, S10)
	A 312-TP316 A 312-TP316L A 312-TP316H	Seamless Intergranular Corrosion Test (A 312, S7)
18Cr-10Ni-3Mo	A 312-TP317 A 312-TP317L	Seamless Intergranular Corrosion Test (A 312, S7)
18Cr-10Ni-Ti	A 376-TP321 A 376-TP321H	Stabilizing Heat Treatment (A 376, S9) Intergranular Corrosion Test (A 376, S10)
	A 312-TP321 A 312-TP321H	Seamless Stabilizing Heat Treatment (A 312, S6) Intergranular Corrosion Test (A 312, S7)
18Cr-10Ni-Nb	A 376-TP347 A 376-TP347H	Stabilizing Heat Treatment (A 376, S9) Intergranular Corrosion Test (A 376, S10)
	A 312-TP347 A 312-TP347H	Seamless Stabilizing Heat Treatment (A 312, S6) Intergranular Corrosion Test (A 312, S7)
18Cr-12Ni-2Mo-Ti (see EN 10088)	DIN 17458 316Ti =1.4571	Seamless Stabilizing Heat Treatment (A 312, S6) Intergranular Corrosion Test (A 312, S7)

Table 7.3.2 Heater tube materials – tube

Material	Tube ¹	Additional Requirements
Carbon steel	A 192	NDT plus hydrostatic Elevated temperature properties
1¼Cr-½Mo	A 213-T11	
2¼Cr-1Mo	A 213-T22	
5Cr-½Mo	A 213-T5	
9Cr-1Mo	A 213-T9	
16Cr-12Ni-2Mo	A 213-TP316 A 213-TP316L A 213-TP316H	Intergranular Corrosion Test (A 213, S4)
18Cr-10Ni-3Mo	A 213-TP317 A 213-TP317L	Intergranular Corrosion Test (A 213, S4)
18Cr-10Ni-Ti	A 213-TP321 A 213-TP321H	Stabilizing Heat Treatment (A 213, S2) Intergranular Corrosion Test (A 213, S4)
18Cr-10Ni-Nb	A 213-TP347 A 213-TP347H	Stabilizing Heat Treatment (A 213, S2) Intergranular Corrosion Test (A 213, S4)
18Cr-12Ni-2Mo-Ti (see EN 10088)	DIN 17458 316Ti = 1.4571	Stabilizing Heat Treatment (A 312, S6) Intergranular Corrosion Test (A 312, S7)

Table 7.3.3 Heater tube materials – welded return bends

Material	Butt-Welded Return Bends	Additional Requirements
Carbon steel	A 234, WPB	Seamless Carbon Equivalent < 0.45 (A 234, S3)
1¼Cr-½Mo	A 234, WP11 CL2	Seamless
2¼Cr-1Mo	A 234, WP22 CL3	Seamless
5Cr-½Mo	A 234, WP5	Seamless
9Cr-1Mo	A 234, WP9	Seamless
16Cr-12Ni-2Mo	A 403-WP-316 A 403-WP-316L A 403-WP-316H	Seamless Intergranular Corrosion Test
18Cr-10Ni-3Mo	A 403-WP-317 A 403-WP-317L	Seamless Intergranular Corrosion Test
18Cr-10Ni-Ti	A 403-WP-321 A 403-WP-321H	Seamless Stabilizing Heat Treatment (A 403, S2) Intergranular Corrosion Test
18Cr-10Ni-Nb	A 403-WP-347 A 403-WP-347H	Seamless Stabilizing Heat Treatment (A 403, S2) Intergranular Corrosion Test
18Cr-12Ni-2Mo-Ti (see EN 10088)	316Ti = 1.4571	Seamless Stabilizing Heat Treatment (A 403, S2) Intergranular Corrosion Test