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# Reforming Furnaces for Hydrogen and Synthesis Gas Production in General Refinery and Petrochemical Services

API STANDARD 561
FIRST EDITION, XXX 20XX

***Ballot Draft September 14, 2024***

For API Committee Review Only

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# Introduction

Steam reforming for the production of hydrogen and synthesis gas, is a process where steam and a hydrocarbon (most commonly methane) are heated in a high temperature furnace in the presence of catalyst. The reformer furnace differs from general fired process heaters for refinery services due to the presence of catalyst and the chemical reactions inside the tubes. The reforming reaction is endothermic, which requires high process operating temperatures and higher firebox temperatures than typically experienced in fired process heaters for general refinery service. The steam reforming process requires high radiant section temperatures and correspondingly high furnace flue gas outlet temperatures. The residual heat in the flue gas is recovered in a convection section typically preheating the feed/process fluid, providing steam generation and steam superheating. The specification of a steam reformer furnace addresses both the production of the synthesis gas and the heat integration and recovery of available residual heat.

In most cases, steam reforming is associated with a technology licensed process and associated with many proprietary designs and materials. This standard is not intended to supersede any requirements of licensor supplied information. This standard is not intended to promote or restrict the use of any specific licensed design or material. This standard covers several firing configurations such as, but not limited to, multilevel up fired, top fired, bottom fired, and side fired designs. This standard does not include upstream or downstream reforming equipment (pre-reformers, post-reformers, secondary reformers or autothermal reformers) nor process gas boilers.

API Standard 560, *Fired Heaters for General Refinery Service*, is considered integral to the use and technical requirements of this standard with reference and amending requirements as noted. Auxiliary equipment, such as air-preheat systems, fans, stacks, post combustion selective catalytic reduction, etc. is addressed in other API documents and referenced accordingly in this standard.

Several annexes to this standard provide information and guidance to an owner for integrity management of new and existing reformer equipment and components over the life of the equipment. These annexes include Annex E - Pre-commissioning Inspection, Annex F - Onstream Inspection and Testing, Annex G - Turnaround Reformer Inspection, and Annex H - Fitness for Service and Remaining Life Assessment.

Users of this standard should be aware that further or differing requirements may be needed for individual applications. This standard is not intended to inhibit a supplier from offering or the purchaser from accepting alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the supplier shall identify any variations from this standard and provide details.

In API standards, the SI system of units is used. In this standard, where practical, US Customary units are included in brackets for information.

A bullet (●) at the beginning of a clause or sub-clause indicates that either a decision is required, or further information is to be provided by the purchaser. This information should be indicated on datasheets (see Annex B), on the purchaser’s checklist (see Annex C) or stated in the inquiry or purchase order.

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# 1 Scope

This standard specifies the requirements and recommendations for the design, materials, fabrication, inspection, testing, preparation for shipment, and erection unique to direct fired steam reforming furnaces for hydrogen and synthesis gas production (steam hydrocarbon reformers) in refining and chemical plant applications.

# 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 530, *Calculation of Heater Tube Thickness in Petroleum Refineries*

API Standard 535, *Burners for Fired Heaters for General Refinery Service*

API Standard 560, *Fired Heaters for General Refinery Service*

API Standard 582, *Welding Guidelines for the Chemical, Oil, and Gas Industries*

API Standard 673, *Centrifugal Fans for Petroleum, Chemical, and Gas Industry Services*

API Standard 936: *Refractory Installation Quality Control—Inspection and Testing, Monolithic Refractory Linings and Materials*

AISC Steel Construction Manual[1]

ANSI[2]/ISA-5.1[3]; *Instrumentation Symbols and Identification*

ASME B31.3 [4], *Process Piping*

ASTM A530 / A530M [5] *, Standard Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe*

ASTM B407, *Standard Specification for Nickel-Iron-Chromium Alloy Seamless Pipe and Tube*

ASTM C892, *Standard Specification for High-Temperature Fiber Blanket Thermal Insulation*

ASTM E112*, Standard Test Methods for Determining Average Grain Size*

ASTM E139, *Standard Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials*

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[1] American Institute of Steel Construction One East Wacker Drive Suite 700, Chicago, IL 60601-1802, www.aisc.org.

[2] American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, www.ansi.org.

[3] The International Society of Automation 67 T.W. Alexander Drive PO Box 12277 Research Triangle Park, NC 27709, www.isa.org.

[4] ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

[5] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

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National Institute of Standards and Technology (NIST)[6]

# 3 Terms, Definitions and Abbreviations

For the purposes of this document, the following terms and definitions apply.

NOTE The terms and definitions contained in API Standard 560 are considered an integral part of this standard. Terms and definitions considered unique to direct fired steam reforming furnaces are contained in 3.2.

## 3.1 General Definitions

NOTE 1 The following general definitions are provided to better define and distinguish the multi-disciplined workforce and the typical areas of responsibility involved in the specification, design, and supply work processes required in the overall procurement process for fired heat transfer equipment, such as a reforming furnace. These definitions are intended to build upon the typical definitions of purchaser and vendor normally used in API Standards.

NOTE 2 Recognizing that the work process and areas of responsibility may differ between projects and owner organizations, the terms and definitions contained in the purchaser's procurement documentation take precedence over definition of parties of the multi-disciplined workforces and their respective areas of responsibility.

**3.1.1**
**fabricator**
The party that provides the facilities and services to physically construct, all or part of the project work as directed by the supplier.

NOTE 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.

**3.1.2**
**licensor**
The entity that holds the technology and or patents for a particular process or design.

NOTE 1 Typically, the licensor provides the process design requirements and process guarantees based on their technology and has unique knowledge of their technology provided in their licensed design package.

NOTE 2 Also see technology provider.

**3.1.3**
**owner**
**purchaser**
The party with responsibility for all or part of the process duty, the thermal design requirement, the mechanical specification, procurement, and construction of the purchased equipment**.**

NOTE The owner or purchaser most often works through an engineering contractor (contractor) as an agent undertaking owner's requirement for the engineering, procurement, and construction phases of work, including representation of the owner on decisions related to operation and maintenance as may be required. The term "purchaser" within this document will be considered synonymous with the term "contractor" or "owner".

**3.1.4**
**refractory contractor**
The refractory contractor, when different from the refractory 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 supplier.

NOTE The refractory contractor has responsibility for the quality control of their products and services.

[6] National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899, www.nist.gov

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**3.1.5**
**refractory manufacturer**
The party that manufactures the refractory products and/or ancillaries for supply to the refractory contractor.

NOTE 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.

**3.1.6**
**supplier**
The party that manufactures or supplies equipment and services to perform the duties specified by the purchaser.

NOTE The supplier typically has the prime responsibility for the detailed engineering, material procurement, project management and manufacturing processes involved in the physical supply of the fired equipment 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.

**3.1.7**
**technology provider**
The party that provides licensed or proprietary technology information typically in the form of a process design or licensor package including a process performance guarantee.

NOTE Also see licensor.

**3.1.8**
**vendor**
The party that provides engineered products, sub-components, or services for the project work.

NOTE The vendor, whether they directly produce the materials or are agents in supply of such components, has 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). Within the context of this standard, the supplier has prime responsibility for the products and services provided by the vendor.

## 3.2 Terms and Definitions – Reformer Furnaces

**3.2.1**
**auxiliary burners**
Burners that introduce supplemental heat downstream of the radiant section.

NOTE May also be referred to as tunnel burners or duct burners.

**3.2.2**
**bow**
The deviation from straightness of tube segments.

**3.2.3**
**breeching**
Furnace section where flue gases are collected after the last convection coil for transmission to the stack or the outlet ductwork.

**3.2.4**
**bull tee**
A cast high alloy material connecting on a hot outlet manifold system two legs of the outlet manifold to a transfer line.

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**3.2.5**
**carbon formation**
The deposit due to the high temperature cracking or side reaction of reforming.

**3.2.6**
**catalyst**
Proprietary material within the reformer tubes used to promote the reforming reaction.

**3.2.7**
**catalyst (reformer) loading**
The action of placing the catalyst inside the vertically oriented catalyst tubes with uniform distribution as the goal.

**3.2.8**
**catalyst poison**
Components that cause catalyst degradation and reduce catalyst activity..

**3.2.9**
**catalyst (reformer) support cone**
**catalyst (reformer) support grid**
A device placed near the bottom of the catalyst tube to support the catalyst while allowing the process fluid to pass through.

**3.2.10**
**catalyst tube**
**cat tube**
Vertically oriented radiant tubes in which the catalytic reaction (reforming) takes place.

NOTE The effective surface is the inside surface due to this reaction.

**3.2.11**
**catalyst tube assembly**
The completed catalyst tube including, for example, flanges, weldolets, reducers, catalyst support grids, and internal insulating cans/plugs/top hats.

**3.2.12**
**collector**
**header**
**manifold**
Multiple branch piping used to collect the synthesis gas from each catalyst tube and transfer to downstream process equipment for further refinement.

**3.2.13**
**condensation (acid dewpoint) corrosion**
Corrosion caused by acid gas condensation on metal surfaces at temperatures lower than the flue gas dewpoint.

**3.2.14**
**end walls**
Typically, in a rectangular furnace, the two (2) parallel radiant walls with the shortest width.

**3.2.15**
**firing configuration**
The arrangement of burners within the reforming furnace.

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**3.2.16**
**flow modelling**
Computational fluid dynamics (CFD) or cold flow modeling (CFM) used to predict the distribution of flue gas or combustion air flow inside furnace or flue gas channels and ducts.

NOTE Used to identify any uneven flow patterns, potential flame impingement, or uneven heating issues.

**3.2.17**
**harp**
A linear array of parallel tubes with common inlet and outlet headers.

**3.2.18**
**heated riser**
**riser**
The pipe (non-catalyst tube) located in the radiant section that is absorbing radiant heat that collects the process gas from the catalyst tubes and transports it to the outlet manifold on top of the radiant section.

**3.2.19**
**inner porosity**
The unsound surface metal on the inside of castings resulting from final solidification.

**3.2.20**
**ladle**
A bucket like, refractory-lined container that holds a specific charge of molten metal required to pour one segment of a cast component.

**3.2.21**
**microalloy**
Fe/Ni/Cr alloys with small alloy additions of titanium, rare earths, and other transition metals used to further enhance the high temperature stability of complex carbides.

**3.2.22**
**minimum sound wall**
The minimum thickness of sound metal required for the internal or external pressure, including mechanical, corrosion, and erosion allowances.

NOTE Minimum sound wall is not inclusive of manufacturing tolerances.

**3.2.23**
**outer roughness**
The condition of the external surface of a cast component consisting of the relatively finely spaced irregularities: the height, width, and direction of which establishes the resultant surface pattern.

**3.2.24**
**penthouse**
Structure on top of the radiant section for weather protection of components and personnel.

**3.2.25**
**penthouse circulation**
**penthouse ventilation**
A means to moderate temperature in penthouse area of the reformer in consideration of safe temperature exposure for operating or maintenance personnel.

NOTE Temperature moderation is typically provided using louvers, fans, and other means of air circulation.

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**3.2.26**
**pigtails**
Small bore pipes that connect the inlet manifold to the inlet of the catalyst tube (inlet pigtail) and used to connect the outlet of the catalyst tube to the outlet manifold (outlet pigtail).

NOTE 1 Pigtails may be straight or trombone-shaped to accommodate thermal growth.

NOTE 2 Some technology providers use the term hairpin for inlet and outlet connection to the catalyst tubes.

**3.2.27**
**pre-reformer**
Reforming method external to the steam reformer used to pre-treat the feeds, unload the reformer duty, or address other reforming reactions.

NOTE Other reforming methods external to the steam reformer include post-reformers and autothermal reformers.

**3.2.28**
**pressure design code**
Recognized pressure design code or standard specified or agreed by the purchaser or licensor/technology provider.

EXAMPLE ASME *BPVC* Section I, or EN 12952 (all parts) for boilers, ASME B31.1 or EN 13480 (all parts) for piping.

EXAMPLE ASME *BPVC* Section VIII or EN 13445 (all parts) for pressure vessels and ASME B31.3 or EN 13480 (all parts) for piping.

**3.2.29**
**pressure swing adsorption**
The technology used to purify the hydrogen produced by the reforming process typically supplied as a unit or system.

**3.2.30**
**promoted catalyst**
A catalyst that contains a component that is used to prevent the formation of carbon components.

**3.2.31**
**PSA tail gas**
Byproduct of the pressure swing adsorption (PSA) unit used as fuel in the reformer furnace.

**3.2.32**
**revert material**
The fabrication scraps that have similar nominal chemical composition to the cast tube segments, i.e. crop ends which have not been in service.

NOTE This definition does not consider argon oxygen decarburization (AOD) ingots.

**3.2.33**
**selective catalytic reduction**
**SCR**
A unit/process to lower NOx in combustion gases.

**3.2.34**
**side walls**
Typically, in a rectangular furnace, the two (2) parallel radiant walls with the longest width.

**3.2.35**
**spring hanger**
Support system for various components in a steam reforming furnace.

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NOTE Used on cat tubes, manifolds, and piping to reduce thermal growth loads or provide support.

**3.2.36**
**steam methane reformer**
**SMR**
A fired furnace designed to promote the catalytic reaction of methane and steam to hydrogen and syngas.

**3.2.37**
**temperature allowance**
Number of degrees Celsius (Fahrenheit) to be added to the maximum calculated tubemetal temperature or fluid temperature (if located outside the firebox) to obtain the design metal temperature.

**3.2.38**
**transfer line**
An internally refractory lined piping system conveying the reformed gas from the steam reformer to the downstream equipment, typically a process gas boiler.

**3.2.39**
**trombone**
A term used to describe the shape of some pigtails.

NOTE 1 See pigtails, applicable to both inlet and outlet pigtails. A typical arrangement used on cylindrical reformers.

NOTE 2 This design is typically seen on multilevel fired reformers.

**3.2.40**
**tube seals**
A flexible temperature and gas flow resistant seal to prevent cold air intrusion and/or flue gas leakage where the tubes penetrate through the furnace casing.

**3.2.41**
**tube segment**
The individual cast-tube segments in between two adjacent intermediate welds.

NOTE Multiple tube segments are welded together in the fabrication of cat tube assemblies.

**3.2.42**
**tube sheet**
A flat plate with holes that accept tubes arranged in a specific configuration.

**3.2.43**
**tunnels**
The flue gas collection chambers on the floor of the radiant section on top fired units that are directly under the burner lanes and used to properly collect the flue gas and direct it into the downstream convection section.

NOTE On top fired units, these are the flue gas collection chambers on the floor of the radiant section directly under the burner lanes. On other units, tunnels are the flue gas flow ducts from the radiant section directly to the base of the convection section.

## 3.3 Terms and Definitions--Refractory

**3.3.1**
**air set mortar**
Mortar that requires only air to gain a significant green strength.

**3.3.2**
**bedding**
Layer of refractory that serves the purpose of leveling a surface before placing additional refractories.

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**3.3.3**
**buttress**
Brick or other support design meant to give a free standing or other wall added stability in service.

**3.3.4**
**castable**
A combination of refractory grain (aggregate) and suitable bonding agent that is installed after the addition of a proper liquid to form a refractory shape or structure that becomes rigid from thermal or chemical action.

**3.3.5**
**classification temperature**
The temperature at which MMVF has a linear shrinkage (measured as per ASTM C892), not exceeding 4 % (for blanket, paper) and 2 % (for vacuum form, boards) after 24-hour heat treatment and in a neutral (not oxidizing or reducing) atmosphere.

NOTE 1 In the field, the continuous application temperature is typically at least 165 °C (300 °F) below the classification temperature. Above the continuous application temperature, increased crystallization can occur, and shrinkage increases. Polycrystalline wool (PCW) fiber can generally be used at up to classification temperature.

NOTE 2 MMVF and PCW are available in three types (classification temperature):

a) AES fiber up to 1450 °C (2642 °F)
b) RCF fiber up to 1426 °C (2600 °F)
c) PCW fiber > 1426 °C (2600 °F)

**3.3.6**
**cold wall**
An insulating refractory lining system with a metal shell temperature less than 260 °C (500 °F).

**3.3.7**
**construction joint**
A joint formed in a lining to mechanically decouple refractory components without expansion allowance.

**3.3.8**
**design temperature**
The maximum continuous use temperature of the hot face or interface, plus a design margin.

**3.3.9**
**dual layer**
Refractory construction comprised of two refractory materials wherein each material performs a separate function, e.g. ceramic fiber over insulating monolithic refractory layer.

**3.3.10**
**expansion joint (refractory)**
A non-bonded joint in a refractory lining system designed to accommodate thermal expansion of adjoining materials, commonly packed with a temperature resistant compressible material, such as fiber.

**3.3.11**
**ferrules**
A metal or ceramic hollow cylinder with a flared or flat head that is used at the junction of the transfer line and process gas boiler tube sheet/boiler tubes.

NOTE Ferrules add protection to the tube sheet/boiler tube entrance against direct process flow.

**3.3.12**
**fiber**
General term for various high temperature insulating wool products of different lengths and diameters produced synthetically from mineral raw materials.

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NOTE Fibers includes alkaline earth silicate (AES), alkali metals (AMS), refractory ceramic fiber (RCF), (et. al) as well as polycrystalline wool (PCW) fiber with a classification temperature >1000 °C (1832 °F).

**3.3.13**
**fiberboard**
Rigidized fiber blanket manufactured and supplied in a rigid board form.

**3.3.14**
**footer**
Refractory material under the tunnel brick and below the floor level that provides an insulating and level base for the tunnel walls.

**3.3.15**
**insulating firebrick**
**IFB**
A refractory brick characterized by low density, low thermal conductivity, and low heat capacity.

**3.3.16**
**metal liner**
A high alloy metallic material used on internally refractory-lined manifolds or collectors.

**3.2.17**
**polycrystalline wool fiber**
**PCW**
Fibers containing greater than 70 wt.% $Al_2O_3$ that are produced by a "sol-gel method" from aqueous spinning solutions.

NOTE Generally used at application temperatures greater than 1426 °C (2600 °F) and in critical chemical and physical application conditions.

**3.3.18**
**precast**
A monolithic refractory that has been formed into a specific shape before installation.

**3.3.19**
**silica volatilization**
the transformation and loss of gaseous free silica from refractory materials.

**3.3.20**
**target wall**
A refractory wall that receives direct flame or flow for the purpose of diverting or spreading over a wider area.

**3.3.21**
**tunnel covers**
**coffin covers**
Pre-cast or extruded refractory part that spans a single tunnel.

## 3.4 Abbreviations

For the purposes of this document, the following abbreviations apply.

APH air preheat system

CFD computational fluid dynamics

DFT dry film thickness

FCAW(g) flux cored-arc welding with external shielding gas

FCAW(s) flux cored-arc welding self-shielded

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| | |
|---|---|
| GMAW | gas metal-arc welding |
| GTAW | gas tungsten-arc welding (manual and automatic) |
| HDFB | high duty firebrick |
| ID | inside diameter |
| IFB | insulating firebrick |
| ITP | inspection and test plan |
| ISO | *International Organization for Standardization* |
| MSW | minimum sound wall |
| MTR | material test report |
| NDE | non-destructive examination |
| OD | outside diameter |
| PAUT | phased array ultrasonic testing |
| PGB | process gas boiler |
| PMI | positive material identification |
| ppmw | parts per million by weight |
| ppmv | parts per million by volume |
| PSA | pressure swing adsorption |
| PT | penetrant testing |
| QA | quality assurance |
| QC | quality control |
| RMS | root mean square |
| RT | radiographic testing |
| SDS | safety data sheet |
| SMAW | shielded metal arc welding |
| SMR | steam methane reformer |
| TOFD | time of flight diffraction |
| UT | ultrasonic testing |

# 4 Documentation

## 4.1 Purchaser's Responsibilities

**4.1.1** The purchaser's inquiry shall include datasheets, checklist, and other applicable information outlined in this standard. This information shall include any special requirements or exceptions to this standard.

NOTE The items on the datasheet designated by an asterisk (*) and the purchaser's checklist, at a minimum, are the purchaser's responsibility for providing information in the inquiry. Refer to Annex B and Annex C, respectively.

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**4.1.2** The purchaser shall be responsible for defining the full process specification, identifying all operating cases, and process stream characterization including potential catalyst poisons and masking agents that may be present in the feed gas, to enable the supplier to prepare the system design.

**4.1.3** The purchaser shall specify the minimum or maximum amount of export steam required.

**4.1.4** Process performance and guarantee requirements shall be communicated through the equipment data sheets or documentation requirements as defined in this standard.

**4.1.5** The purchaser's inquiry shall clearly state the supplier's scope of supply.

**4.1.6** The purchaser's inquiry shall provide a plot plan of the area showing existing equipment and area available for the reformer and auxiliary equipment.

**4.1.7** The purchaser's inquiry shall specify the number of copies of drawings, data sheets, specifications, data reports, operating manuals, installation instructions, spare parts list, and other data to be supplied by the supplier, as defined in 4.3 and 4.5.

**4.1.8** The purchaser shall specify the required degree of shop assembly and/or modularization and the site transportation limits.

**4.2 Supplier's Responsibilities**

**4.2.1** The supplier's proposal documentation shall include:

a) completed data sheet for each system and the associated equipment (see examples in Annex B);

b) an outline drawing showing radiant and convection section dimensions, burner layout and clearances, arrangement of tubes, flue gas ducting, outlet manifold layout, steam system details, platforms, ducting, stack, breeching, air preheat system (APH), selective catalytic reduction (SCR) unit (if applicable), and fans;

c) full definition of the extent of shop assembly, including the number, size and mass of prefabricated parts, skids, and the number of field welds;

d) detailed description of any exceptions to the specified requirements;

● e) when specified by the purchaser, a completed noise datasheet representative of the supplier's experience and reference list for the applicable system;

f) a project timeline after receipt of a purchase order for the submittal of data sheets, general arrangement drawings, foundation loading, and delivery date, including the shipping duration and the duration allowed for purchaser's review of documents submitted;

g) a list of utilities and quantities required;

● h) when specified by the purchaser, a list of vendors and fabricators proposed for the materials, fabrication, and equipment within the supplier's scope.

i) preliminary process and instrumentation diagram (P&ID) of the proposed system, including scope of supply interfaces and control philosophy for the range of operation;

j) guarantees and warrantees;

● k) when specified by the purchaser, the supplier's experience and reference list for the applicable system;

● l) when specified by the purchaser, spare parts lists for commissioning, start-up, and two years of operation;

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## 4.3 Documentation

### 4.3.1 Drawings for Purchaser's Review

The supplier shall submit general arrangement drawings, P&IDs, an overall plot plan of the equipment, and other detail drawings within the supplier's scope. Other detail drawings shall include the following information:

a) reformer service, the purchaser's equipment number, the project name and location, the purchase order numbers and the supplier's reference number;

b) all tube, manifold, inlet and outlet system terminal sizes, including flange ratings and facings, dimensional locations, direction of process flow, and allowable loads, moments, and forces on terminals and connections;

c) all tube, crossover, manifold, inlet, and outlet system arrangements, spacing, diameters, wall thicknesses, lengths, material specifications, including grades for pressure parts, and extended surface data;

d) all tube, manifold, inlet, and outlet system design pressures, hydrostatic test pressures, design fluid and tube-wall temperatures and corrosion allowance;

e) all tube, manifold, inlet, and outlet system design and fabrication code or specification, and technology provider specifications;

f) refractory and insulation types, thicknesses, and service temperature ratings;

g) types and materials of anchors for refractory and insulation;

h) refractory lining lay-out and detail drawings including refractory and insulation types, thicknesses, and service temperature ratings;

i) structural steel drawings, details of stacks, ducts and dampers and structural calculations basis;

j) burner assembly drawings and, burner piping drawings and fuel skids (where applicable);

k) location and number of access doors, observation doors, burners, dampers, instrument, and auxiliary connections;

l) location and dimension of platforms, ladders, and stairways;

m) overall dimensions, including auxiliary equipment;

### 4.3.2 Foundation Loading Diagrams

The supplier shall submit foundation-loading diagrams for reformer and associated equipment for purchaser's review. The diagram shall include the following information:

a) number and location of piers and supports;

b) baseplate dimensions;

c) anchor bolt locations, bolt diameters, and projection above foundations;

d) dead loads, live loads, wind or earthquake loads, reaction to overturning moments, and lateral shear loads.

### 4.3.3 Documents for Purchaser's Review

**4.3.3.1** The supplier shall submit to the purchaser the following documents for review and comment:

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a) instrument details;

b) welding examination and test procedures;

c) refractory material datasheet, safety data sheet, API 936 compliance datasheet, installation and storage procedure, dry-out and test procedures for refractories and insulation;

d) refractory thickness calculations, including temperature gradients through all refractory sections and sources of thermal conductivities;

e) performance curves or datasheets for APH fans, drivers, and other auxiliary equipment;

● f) noise datasheets, if specified by the purchaser;

● g) tube-support details and, if specified by the purchaser, design calculations;

h) factory acceptance test results;

● i) when specified by the purchaser, preliminary results from computational fluid dynamics (CFD) or cold flow modeling.

j) pressure part mechanical calculation including all the accessory such as weldolets, fittings, flanges, drain and vent, gaskets, and bolting;

k) inspection and testing plan;

l) burner test procedure including details of the test rig and testing points;

m) safety datasheets (SDS).

**4.3.3.2** When catalyst is within the supplier's scope, the catalyst description for each catalyst including formulation, discussion of catalyst performance, catalyst deterioration mechanism, catalyst poisons, receiving, unloading, handling, catalyst SDS, and storage shall be provided.

### 4.3.4 Certified for Construction Drawings and Diagrams

After receipt of the purchaser's comments on the general arrangement drawings and diagrams, the supplier shall furnish the following drawing and diagrams which the supplier has certified for construction:

a) general arrangement drawings;

b) foundation loading diagrams;

c) design-detail drawings;

NOTE Design detail drawings contain information required for equipment installation and maintenance and are not the detail shop fabrication drawings.

d) drawings of all auxiliary equipment;

e) the following instrumentation and electrical drawings:

1) a P&ID with instrument symbols and identification in accordance with ANSI/ISA-5.1;

2) all instrumentation and controls shown on the job P&ID;

3) all wiring, instrumentation, and instrument tubing within the confines of each skid;

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4) all instrumentation datasheets for each tagged instrument item;

5) all wiring, calibration, and installation data for each instrument and/or panel.

NOTE The erection drawings, including erection sequence and a bolt list, shall be furnished prior to the shipping of system steel.

### 4.4 Performance Tests

● **4.4.1** When specified by the purchaser, a performance test shall be performed.

**4.4.2** The purchaser and supplier shall agree and determine the test protocols and timing.

**4.4.3** The overall performance assessment shall be based on corrections with the supplier's correction curves for test conditions other than the specified guaranteed conditions.

**4.4.4** The variation of operating conditions, feeds, and fuels as compared to design and its impact on performance test conditions shall be adjusted pursuant to purchaser and supplier agreement.

### 4.5 Final Records

**4.5.1** The supplier shall provide the purchaser with the following documents:

a) data sheets and drawings representing the as manufactured equipment;

● b) if field-changes are made, drawings and datasheets with scope of service decided between purchaser and supplier;

c) certified material reports, mill test reports, or ladle analysis for all pressure parts and alloy extended surfaces;

d) installation, operation, and maintenance instructions for the reformer and auxiliary equipment, such as air preheater, fans, drivers, dampers, and burners;

e) performance curves or data sheets for APH fans, drivers, burner, and other auxiliary equipment;

f) bill of materials;

● g) noise data sheets when specified by the purchaser (see 4.3.3.1 f);

h) field erected refractory dry-out procedures;

i) shop refractory dryout records;

j) test certificates for tube-support castings;

k) all other test documents, including test reports and non-destructive examination reports with all signed-off inspection test reports;

l) all pressure part registration certificates;

m) all electrical part compliance certifications;

n) factory acceptance test certifications;

**4.5.2** The final records shall include an electronic copy of all drawings and documents.

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# 5 Design Requirements

## 5.1 General

● **5.1.1** The pressure design code shall be specified by the licensor and agreed upon by the purchaser.

**5.1.2** Pressure components shall conform with the pressure design code and the supplemental requirements in this standard.

● **5.1.3** The structural design code shall be specified or agreed by the purchaser.

**5.1.4** Structural components shall conform with the structural design code and the supplemental requirements in this standard.

**5.1.5** Structural welding shall conform with the structural welding code and the supplemental requirements in this standard.

● **5.1.6** The purchaser and the supplier shall mutually determine the measures required to conform with all local and national regulations applicable to the equipment.

**5.1.7** The supplier shall conform with all local and national regulations specified by the purchaser.

## 5.2 Combustion Design

**5.2.1** Combustion design shall be in accordance with API 560 and the additional or amending requirements specified in this section.

**5.2.2** When pressure swing adsorption (PSA) tail gas is used, the quantity shall be agreed upon between the technology provider, vendor, and purchaser.

**5.2.3** When PSA tail gas is used, variation in PSA tail gas composition, flows, and heating value can impact the performance (emissions and stability) of the burner and shall be considered in the design.

**5.2.4** For reformers with down-fired burners, stack and flue-gas systems shall be designed so that a negative pressure of at least 50 Pa to 125 Pa (0.2 in. to 0.50 in. $H_2O$) is maintained in the arch section or point of minimum draft location at design heat release with design excess air and design stack ambient air temperature. For other reformer designs, a negative pressure of at least 25 Pa (0.1 in. $H_2O$) shall be maintained in the arch section.

## 5.3 Reformer Design

**5.3.1** Reformer mechanical design shall be in accordance with API 560 and the additional or amending requirements specified in this section, excluding the requirement for radiant firebox geometry described in API 560.

**5.3.2** Minimum design pressures shall be specified as follows for various pressure containing components:

a) Inlet System: 110 % of the reformer maximum operating pressure based on the results of the process design.

b) Catalyst Tubes: 100 % of the reformer maximum sustained operating pressure at the inlet of the catalyst tube based on the results of the process design.

c) Outlet Pigtail: 110% of the reformer maximum operating pressure at the outlet of the catalyst tube based on the results of the process design.

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d) Outlet Sub-Header:110% of the reformer maximum operating pressure of the sub-header based on the results of the process design.

e) Transfer Line and Cold Collector: 110 % maximum operating pressure.

**5.3.3** The pressure design code break between the internal process piping and external process piping shall be defined as followings:

a) the internal process piping includes all process pressure components that are exposed to radiant heat or transfer heat from the products of combustion to process fluids, e.g. pressure components in the firebox and process coils in the convection section.

b) external process piping including inlet pigtails are external to the firebox.

NOTE: Outlet pigtails may be designed in accordance with API 530 or the pressure design code for process piping as defined by the technology provider and as appropriate to their design configuration.

**5.3.4** Unless otherwise specified, the pressure design codes for the design of the reformer pressure part components as defined in 5.3.3 shall be in accordance with the following:

a) internal process piping in accordance with API 530;

b) external process piping in accordance with the pressure design code, e.g. ASME B31.3;

NOTE Reformer process piping typically includes hydrocarbon feed lines as well as the mixture of feed and process steam (mixed feed).

c) external steam piping in accordance with the pressure design code, e.g. ASME 31.1 or ASME B31.3, depending on the applied design code;

NOTE The pressure design code for steam piping also applies to steam piping between steam drum and steam superheat coil inlet manifold, as well as steam export line from steam superheat outlet manifold.

d) steam system in accordance with the applicable pressure design code;

NOTE Steam generation is normally covered by local jurisdiction.

e) internal process manifolds in accordance with the pressure design code, e.g. ASME B31.3, however using the allowable stress values in accordance with API 530.

**5.3.5** Manifolds internal to the reformer enclosure made from castings, the allowable stress values shall be reduced by the casting quality factors in accordance with the pressure design code, e.g. ASME B31.3.

**5.3.6** Design of the furnace structural steel and foundations shall include all loads, moments and movements of the radiant inlet and outlet systems, including support systems.

● **5.3.7** When specified by the purchaser, a design margin shall be added to the calculated structural steel loads. The design margin shall be agreed upon between the purchaser and supplier.

### 5.4 Catalyst

**5.4.1** Catalyst shall be uniformly loaded into the catalyst tubes.

NOTE A successful loading is determined by the deviation from the average value of a pressure drop test on the loaded tubes.

**5.4.2** The technology provider shall specify the maximum allowable deviation from the average value of pressure drop of a loaded tube.

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# 6 Tubes

## 6.1 General

**6.1.1** Convection coils shall be designed in accordance with API 560, together with the additional or amending requirements specified in this standard.

**6.1.2** For proprietary materials such as cast alloys, tube-wall thickness shall be determined in accordance with API 530 methods, unless otherwise agreed upon between purchaser and supplier.

**6.1.3** For proprietary materials, the following additional requirements apply:

a) The allowable stress shall be taken as 100 % of the minimum stress to cause rupture.

b) The minimum stress to cause rupture values shall be appropriate to represent the variance expected at a 95 % confidence interval.

**6.1.4** Calculations made to determine the wall thickness for the components listed in Table 1 shall include considerations for erosion and corrosion allowance. The following allowances shall be used as a minimum.

**Table 1—Erosion and Corrosion Allowance**

| Tube Component | Corrosion Allowance mm (in.) |
|---|---|
| Catalyst tubes, stainless or higher alloy inlet, and outlet systems | 0.0 (0.0) |
| Carbon steel or low alloy inlet and outlet systems | 1.6 (0.0625) |
| Convection section | Refer to API 560 |

**6.1.5** Catalyst tube metal design temperature shall be determined from the process design as the maximum calculated tube metal temperature plus an allowance of 15 °C (27 °F). A higher temperature allowance shall be agreed upon between the technology provider and the owner.

**6.1.6** Outlet pigtail design temperature shall include a minimum temperature allowance of 28 °C (50 °F) based on the process or metal temperature for locations as follows:

a) outside firebox – process fluid temperature;

b) inside firebox (shielded) – process fluid temperature;

c) inside firebox (insulated) – maximum metal temperature;

d) inside header box (shielded) – process fluid temperature.

**6.1.7** For the process inlet system, including crossovers and inlet manifolds, the design temperature shall be the maximum expected operating process temperature plus a minimum of 28 °C (50 °F).

**6.1.8** The process outlet system/sub-header design temperature shall be the maximum process fluid temperature plus a minimum of 28 °C (50 °F).

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**6.1.9** The overall temperature design margin for the process outlet system/sub-header shall include consideration of the temperature margin specified in 6.1.7, the maldistribution caused by catalyst loading tolerances, and the overall design of the reformer system.

**6.1.10** Catalyst tube flange design temperature shall be determined by the configuration of the inlet pigtail as follows:

a) For top entry inlet pigtails, the design temperature shall be the process inlet design.

b) For side entry inlet pigtails, the design temperature shall be the process inlet design temperature and based on the catalyst tube plug design. The catalyst tube flange (for side entry inlet pigtails) design temperature shall be the calculated metal temperature plus a minimum of 28 °C (50 °F) unless otherwise specified.

**6.1.11** The catalyst tube flange design shall be in accordance with the pressure design code, e.g. ASME B31.3

**6.1.12** Custom flanges shall be in accordance with design code, e.g. ASME Section VIII, Division 1 Appendix 2 and ASME Section II, Part D for allowable stress.

**6.1.13** Circumferential welds on centrifugally cast tubes shall be minimized.

**6.1.14** The casting factor for centrifugally cast tubes and piping shall be 1.0.

## 6.2 Materials

**6.2.1** Tube materials for reforming furnaces other than cast catalyst tubes and cast outlet manifolds shall be in accordance with the specifications in API 560.

**6.2.2** Tube materials for cast tubes shall conform to the material specification/chemical analysis listed in Table 2 or their equivalent, subject to approval by the purchaser.

**6.2.3** Catalyst tube segments shall be cast from no less than 90 % virgin materials. Only revert material shall be used for the balance.

**6.2.4** Chemical analyses shall be performed on each furnace heat of material. For ladle additions, chemical analysis shall be performed on every ladle. Chemical composition shall conform to the requirements of Table 2 and be reported on the material test report (MTR).

**6.2.5** Testing shall be performed using optical spectrometry methods. Calibration of the spectrometer shall comply with an internationally recognized quality management system. Calibration shall be traceable to National Institute of Standards and Technology (NIST) or other globally recognized standards.

**6.2.6** Nominal content of each micro alloying addition shall be specified and submitted by the material vendor

**Table 2—Catalyst Tube Alloy Chemical Composition**

| Element [1] | Material Grade | | | |
|---|---|---|---|---|
| | HK 40 | HP 50 | HP 50 mod | HP mod micro |
| C | 0.38 – 0.48 | 0.40 min. | 0.40 min. | 0.40 min. |
| Si | 1.75 max. | 1.50 max. | 1.50 max. | 1.50 max. |
| Mn | 1.50 max. | 1.25 max. | 1.50 max. | 2.00 max. |

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| | | | | |
|---|---|---|---|---|
| Cr | 23 –27 | 24 - 28 | 24 - 28 | 24 - 28 |
| Ni | 19 – 22 | 34 - 37 | 34 - 37 | 34 - 37 |
| Mo | 0.5 max. | 0.2 max. | 0.2 max. | 0.2 max. |
| P | 0.03 max. | 0.03 max. | 0.03 max. | 0.03 max. |
| S | 0.03 max. | 0.03 max. | 0.03 max. | 0.03 max. |
| Sn | 0.01 max. | 0.01 max. | 0.01 max. | 0.01 max. |
| Pb | 100 ppmw max. | 100 ppmw max. | 100 ppmw max. | 100 ppmw max. |
| Nb | - | - | 0.7 – 1.5 max. | 0.7 – 1.5 max. |
| Fe | Balance | Balance | Balance | Balance |
| Ti | - | - | - | 1 |
| Zr | - | - | - | 1 |
| NOTE 1 Element quantities are in wt. % unless otherwise indicated. | | | | |

## 6.3 Catalyst Tube Mechanical Properties

● **6.3.1** When specified by the purchaser, and unless otherwise specified, stress-rupture testing shall be performed in accordance with the following schedule:

a) one sample from the first five cast tubes;

b) one sample per 25 subsequent tubes;

c) one sample from the beginning of each shift for each spinning machine shall be included as part of the one sample per 25-tube requirement.

**6.3.2** Stress-rupture testing when specified in 6.3.1 shall be performed on samples pre-aged for 10 hours at 870 °C (1600 °F). Samples shall be tested at a calculated minimum stress value (per vendor published data) at a temperature of 1070 °C (1950 °F) to cause failure in 200 hours. A minimum of five samples shall run to failure. Results shall be reported in the final documentation.

**6.3.3** If a stress-rupture testing sample fails to achieve the 200-hour life requirement, an additional sample from the same tube shall be retested. If the second sample fails to achieve 200 hours, the tube segment shall be scrapped. Tubes cast immediately before and after the scrapped tube shall be tested. The sampling frequency shall be doubled until five consecutive tests pass and then return to original test frequency.

**6.3.4** Stress rupture specimens shall be taken from the cold end of the tube segment cropping. Testing shall be performed in accordance with ASTM E139 or other internationally recognized code or standard approved by the purchaser.

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# 7 Return Bends

Return bends shall be designed in accordance with API 560.

NOTE Return bends are applicable only to convection section of reforming furnaces.

# 8 Piping, Terminals, and Manifolds

## 8.1 General

● **8.1.1** If an external crossover or manifold piping is a different material than the connecting tubes or manifold, the supplier and the purchaser shall determine and agree upon any special welding procedures, testing, and other requirements of the dissimilar metal weld.

**8.1.2** Manifolds internal to the reformer enclosure shall be designed in accordance with the pressure design code, e.g. ASME B31.3, however, using allowable stress values in accordance with API 530. For proprietary cast alloys, the allowable stress shall be taken as 100 % of the minimum stress to cause rupture. The minimum stress to cause rupture values shall be appropriate to represent the variance expected at a 95 % confidence interval.

**8.1.3** For manifolds internal to the reformer enclosure made using cast components, they shall be designed in accordance with ASME B31.3 with the allowable stress values as defined in 8.1.2, however reduced by the casting-quality factors.

## 8.2 Flexibility Analysis of Reformer Piping Systems

**8.2.1** The reformer piping system flexibility analysis shall be performed in accordance with the pressure design code, e.g. ASME B31.3.

**8.2.2** **T**he extent of the reformer piping system flexibility analysis, as a minimum shall start at the mixed feed preheater convection coil outlet header and end at the inlet of the process gas boiler, equivalent process equipment tie-in upstream, or downstream of the reformer system. The scope of analysis shall include catalyst tubes, crossovers, pigtails, and inlet and outlet piping.

NOTE: Figure 1 illustrates a sample scope of a modeled reformer piping system for flexibility analysis.

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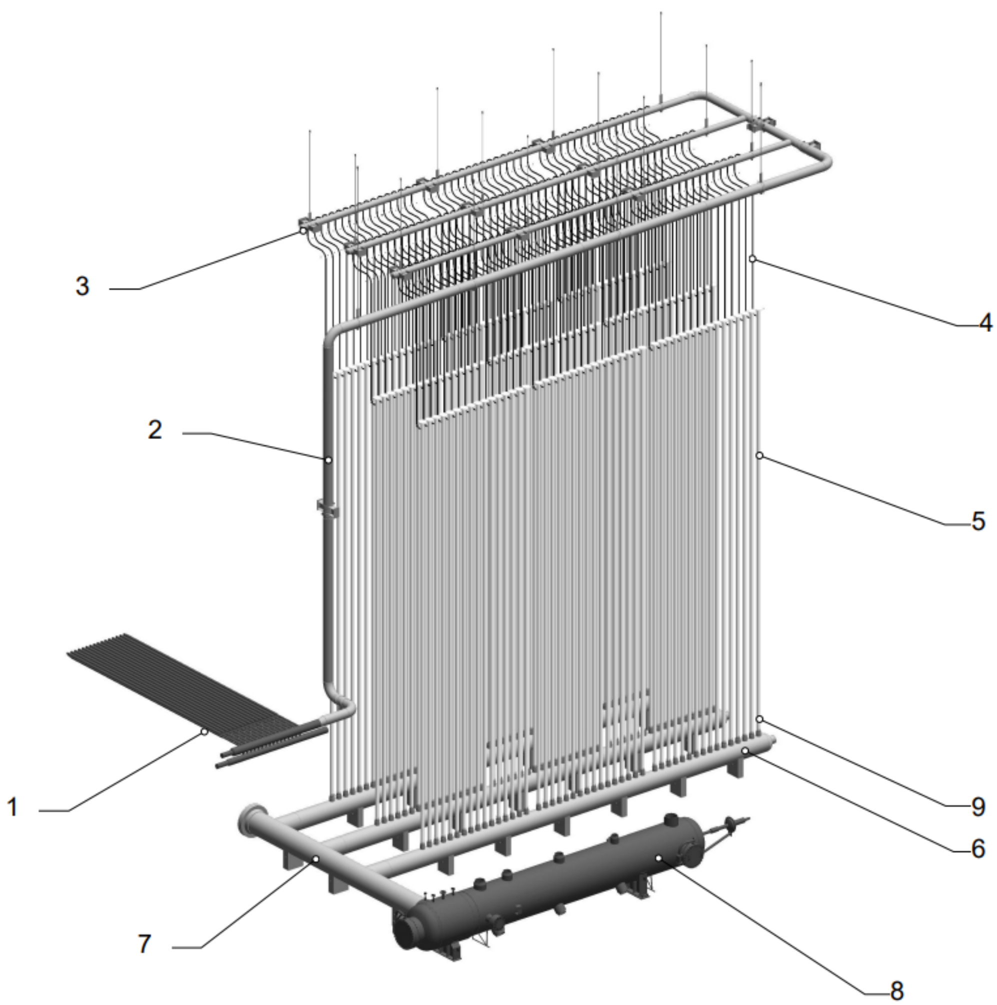


**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | feed superheater bundle | 4 | feed inlet pigtail | 7 | cross collector |
| 2 | feed inlet line | 5 | catalyst tube | 8 | process gas boiler |
| 3 | feed inlet header | 6 | cold outlet header | 9 | outlet pigtail |

**Figure 1—Sample Scope of a Modeled Reformer Piping for Flexibility Analysis**

- **8.2.3** The flexibility analysis shall include operating, sustained, and thermal expansion load cases for the design operating case. The purchaser shall specify the following information for the flexibility analysis:

a) wind and seismic loads;

b) any additional design cases, such as alternate operation, startup, shutdown, or trip cases.

**8.2.4** Unless otherwise specified, methods of pipe support, such as constant or variable spring hangers, counterweights, and rigid supports, shall follow the supplier's best practice design.

**8.2.5** The type selection and design of support systems shall include the available space for the support in consideration of the location and attachment of ladders and platforms, location of sight ports for monitoring burner flames and tube temperatures, and maintenance access.

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# 9 Tube Supports

## 9.1 General

**9.1.1** Convection section tube supports, where applicable to the reformer furnace arrangement, shall be designed in accordance with API 560 and any additional or amending requirements specified in this section.

**9.1.2** Unless otherwise specified by the technology provider, and agreed to by the purchaser and supplier, the minimum corrosion allowance on each side for all exposed surfaces of each tube support and guide contacting flue gases shall be 1.3 mm (0.05 in.) for austenitic materials and 2.5 mm (0.10 in.) for ferritic materials.

**9.1.3** Tube support materials, as a minimum, shall be selected based on the maximum design temperatures specified in API 560. If the design temperature exceeds the limit of the stress curves of API 560 and use of other materials or alternate specifications to those in API 560 are required, the allowable stress curves shall be subject to approval by the purchaser.

# 10 Refractories and Insulation

NOTE Refer to Annex D.

● **10.1** The purchaser shall specify whether the normative statements contained in Annex D shall be used directly, with or without modification, or alternate specifications and requirements shall be provided.

NOTE The informative content of Annex D is provided for guidance. If the purchaser adopts the informative content as a project requirement, it can be stated in the project specifications together with any exceptions or selections, where optional alternatives are provided.

# 11 Structures and Appurtenances

## 11.1 General

**11.1.1** Structure and appurtenances, as applicable to reforming furnaces, shall be designed in accordance with API 560, together with the additional or amending requirements specified in this section.

**11.1.2** For reformer configurations that have an elevated fan supported by the structure, the elevated fan mount and structure shall be designed to accommodate vibration induced by the fan.

**11.1.3** The supplier and erection contractor shall take adequate precautions and document quality control measures to avoid contact of reformer tubes with low-melting point materials through all phases of supply and construction.

CAUTION Contact of low melting point materials such as zinc coatings or aluminum liquid, can cause metal embrittlement tube damage when exposed to high temperature.

**11.1.4** Access doors having a minimum clear opening of 610 mm x 920 mm (24 in. x 36 in.) shall be provided in the radiant section. The number of access doors shall be agreed upon between the purchaser and the supplier.

## 11.2 Penthouse Design

**11.2.1** A penthouse shall be provided for top-fired, and side-fired reformers.

NOTE A penthouse is not typically required for cylindrical or terrace wall type reformers.

● **11.2.2** The purchaser shall specify access requirements for operation and maintenance inside the penthouse during operation.

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**11.2.3** The penthouse roofing shall have removable sections for catalyst tube removal and installation.

● **11.2.4** When specified by the purchaser, additional removable panels shall be provided subject to agreement between the purchaser and supplier.

**11.2.5** For top-fired reformers, penthouses for reformers with natural draft burners shall be enclosed to minimize the effect of wind on the burner performance.

## 12 Stacks Ducts and Breeching

Unless otherwise specified, stacks ducting and breeching shall be in accordance with API 560.

## 13 Burners and Auxiliary Equipment

### 13.1 General

Unless otherwise specified, reformer furnace burners and auxiliary equipment shall be in accordance with API 560, together with the additional or amending requirements specified in this section. The following are exceptions to API 535 and API 560:

a) burner count, arrangement, and clearances based on normalized burner spacing;

b) horizontal opposed firing burners;

c) burner heat release margin;

d) liquid-fuel-fired burners;

e) natural draft mode of operation for forced draft burners;

f) sootblowers;

g) natural draft air doors.

### 13.2 Burners

**13.2.1** Unless otherwise specified, burner-to-burner spacing, burner-to-coil spacing, and burner-to-end wall refractory clearance shall be specified by the technology provider and subject to approval by the purchaser.

**13.2.2** All burners shall be sized with a design margin on heat release. The margin shall be specified by the technology provider and subject to approval by the purchaser.

**13.2.3** Flames shall be designed to be parallel to the fired or radiant wall. Flames of adjacent burners shall not interfere with each other.

**13.2.4** The burner design and layout together with the firebox and tube lane arrangement shall be designed to avoid flame impingement on the process catalyst tubes under all specified operating conditions and fuel combinations.

NOTE Modeling may include CFD for the firebox.

**13.2.5** The burner flame shall remain stable over the full range of specified operating conditions, fuel compositions, and fuel combinations, including the loss of PSA tail gas.

● **13.2.6** The purchaser shall specify when modeling of combustion air ductwork is required to demonstrate even distribution of air to the burners.

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NOTE Modeling may include CFD or cold flow modeling to verify the air distribution.

**13.2.7** The packing and sealing material installed between the tile and furnace lining shall be ceramic, AES, or PCW fiber and have a temperature rating consistent with burner tile.

**13.2.8** Burner fuel and air connections shall be designed so that individual burner gas tips/risers can be removed without further dismantling any other fuel piping or air ducting during operation from the dedicated furnace platform.

● **13.2.9** When specified by the purchaser, the burner assembly and the air damper on forced draft burners shall be two different independent mechanical bodies.

**13.2.10** Burners in top-fired reformers shall include lifting lugs or other suitable features to assist lifting the burners to and from the reformer.

**13.2.11** The burner tile assembly for burners in side-fired reformers shall be designed to be removable from outside the firebox.

**13.2.12** Air ducting and fuel piping inside-fired reformers shall be designed such that the burner tile mounting plate is removable during shutdowns from its dedicated platform without dismounting the incoming piping or air ducts.

**13.2.13** Burner tiles inside-fired reformers shall be designed to prevent flame damage to the surrounding refractory.

### 13.3 Fans and Drivers

**13.3.1** Fan process sizing requirements shall be in accordance with the technology provider's requirements.

**13.3.2** Fans and drivers shall be designed and supplied in accordance with API 673.

### 13.4 Dampers and Damper Controls for Stacks and Ducts

Dampers and damper controls for stacks and ducts shall be designed and supplied in accordance with API 560.

### 13.5 Air Preheat Systems

Air preheat systems shall be designed and supplied in accordance with API 560.

## 14 Instrumentation and Protective Systems

NOTE This section is on hold for the next edition API 561.

## 15 Shop Fabrication and Erection

### 15.1 General

**15.1.1** Steel structures shall be fabricated in accordance with the structural design code.

**15.1.2** The reformer, all auxiliary equipment, ladders, stairs, and platforms shall be shop assembled to the extent agreed in the purchase order, consistent with the available shipping, receiving, and handling facilities specified by the purchaser.

**15.1.3** Fabrication of critical components as specified by the licensor shall be conducted in facilities pre-approved by the purchaser.

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**15.1.4** Catalyst tubes and other stainless steel pressure parts shall be protected from contact with zinc and other low melting point materials, e.g. low melting point eutectics, from any source, including galvanized scaffolding and paint. See 11.1.3.

**15.1.5** Unless otherwise specified, casing plate shall be seal-welded externally to prevent air and water infiltration.

**15.1.6** The roof design for all sections shall allow for runoff of rainwater.

NOTE This may be accomplished by arrangement of structural members and drain openings.

**15.1.7** The supplier's fabrication and erection notes shall appear on drawings to ensure that the code and any other special requirements are well communicated to the fabricator.

**15.1.8** Erection drawings and a bolt list shall be furnished by the fabricator prior to shipping reformer furnace steel. Erection marks and the size and length of field welds shown on erection drawings shall be in 3 mm (1/8 in.) high (minimum) lettering. The bolt list shall specify the number, diameter, length, and alloy grade for each connection.

**15.1.9** Weld stress intensification shall be minimized when welding pressure-retaining components. Appropriate good practice measures such as component fit-up and alignment criteria shall be defined and included in the fabrication procedure documents.

NOTE Outlet manifold welds and pigtail welds are examples of areas prone to stress intensification due to misalignment, improper welding and PWHT.

**15.1.10** Welding consumables for pressure components shall be stored and handled in accordance with the requirements of API 582 or the electrode manufacturer's instructions*.*

● **15.1.11** Consumables used in the welding of thermocouple and other non-pressure retaining attachments to the pressure parts shall be as specified by the purchaser*.*

### 15.2 Structural Steel Fabrication

#### 15.2.1 General Requirements

**15.2.1.1** Welders for structural-steel fabrication shall be qualified in accordance with the structural design and welding code.

**15.2.1.2** Welding filler materials shall be in accordance with the structural design and welding code. Welding filler materials shall have a chemical composition matching the base material being joined.

**15.2.1.3** Approved WPS consumables shall be Charpy V-notch impact tested to provide 20.3 N m (15 ft lb) (minimum) prior to use for components with design metal temperatures colder than -29 °C (-20 °F).

**15.2.1.4** Circular and slotted bolt holes in primary structural members and base plates shall be drilled or punched. Circular and slotted bolt holes shall not be flame cut.

**15.2.1.5** Baseplates shall be designed to allow compensation for discrepancies and tolerance issues with foundations.

**15.2.1.7** The threads of bolts securing damper blades to the shaft shall be scored or tack-welded after installation. If tack welding of bolts is used to secure damper blades to the shaft, then tack welding shall only be performed on low-strength carbon steel or 300 series SS threaded fasteners. Tack welding of low-alloy bolts shall not be used, e.g. ASTM A193 B7/ASTM B7M, ASTM A193 B16/ASTM B16M.

**15.2.1.8** Attachment of refractory anchors or tiebacks to the furnace casing shall be by manual or stud-gun welding. If manual welding is employed, welds shall be "all around".

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NOTE 1 Weld all-around may not be applicable for footed anchors.

NOTE 2 Stud-gun is more accurately known as stud arc welding.

15.2.1.9 The minimum requirements for lifting lug design and quality assurance include the following:

a) The lifting load used in calculations shall be at least 1.5 times the section mass to allow for impact.

b) Calculations for lifting lugs and lifting frames shall be approved by the purchaser.

c) Where required by codes and standards or specified by purchaser, proof testing of detachable lifting lugs and lifting frames or NDE (UT & PT) shall be performed.

d) Re-pads shall be ultrasonically examined for lamination. Welds shall be examined using PT or MT.

NOTE 1 Test documentation can be attached to the component and travel with it.

NOTE 2 Lifting frames may be provided by the supplier or others in accordance with the requirements specified by the supplier.

**15.2.1.10** A tabulation shall be furnished by the reformer fabricator indicating individual sections with a mass greater than 1820 kg (4000 lb). The center of gravity of such sections shall be clearly marked.

### 15.2.2 Fabrication Tolerances on Modules

NOTE 1 For the purpose of this section, the term "module" identifies a shop fabricated and assembled heat transfer equipment or piece of equipment, square or rectangular shaped, complete of steelwork, lining anchors, internal lining, coils, tube supports, guides and ancillaries. Modules are designed for site installation on foundations and/or for connections among them in vertical or horizontal sequence. Typical examples are convection section modules or radiant section modules.

NOTE 2 Ducting, assembled ancillary steelwork, stacks, machinery or piping skid, any assembled part without internal heat transfer surface or refractory, etc. are not considered as modules, however, when applicable, the fabrication tolerance requirement may also be referred to these materials.

NOTE 3 The degree of shop fabrication and assembly foreseen for modules is such that the reformer modules will be erected at site by bolting on steelwork and bolting or welding between coils of each different module, and that the field activities will be limited to the minimum.

**15.2.2.1** All module tolerances shall be checked at the fabrication shop after the modules have been completed.

NOTE Checks on modules have the purpose of ensuring easy and correct field final assembly. Dimensions to be checked are those relevant to modules interconnection, or between one module and its foundation and /or between module and connected items, e.g. ducting.

**15.2.2.2** All inspections, tests and tolerance checks on the components such as steelwork (plates and members), internal coils or pressure parts, tube sheets, refractory materials, or any other component of the module, shall be performed before final assembly of the module in accordance with the provisions of the applicable clauses of this standard.

**15.2.2.3** Unless otherwise specified, the following tolerance requirements shall apply on the external dimensions of module steelwork. Refer to Figure 2a, Figure 2b, Figure 3, and Figure 4.

a) Module length, width and height measured at base plate or interconnecting flange: ± 0.2 %, max. ± 15 mm (± 5/8 in.). See Figure 2a.

b) Diagonals shall be same length ± 0.2 %, max. ± 15 mm (± 5/8 in.). See Figure 2a.

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c) Span between adjacent column at base and top section of each module: ± 3 mm (± 1/8 in.). See Figure 2a.

d) Module vertical walls out of plumb shall not exceed the lesser of ± 1 mm/m or 20 mm (± 0.012 in./ft or ¾ in.).

e) Base plate dimensions: - 0 / + 5 mm (- 0 / + 3/16 in.). See Figure 2b.

f) Base plate holes ± 1 mm (0.039 in.). See Figure 2b.

g) Base plate holes spacing ± 1 mm (0.039 in.) not cumulative. See Figure 2b.

h) Base plate thickness: - 0 mm/ + 5 mm (- 0 / + 3/16 in.).

i) Base plate alignment ± 5 mm (± 3/16 in.). See Figure 4.

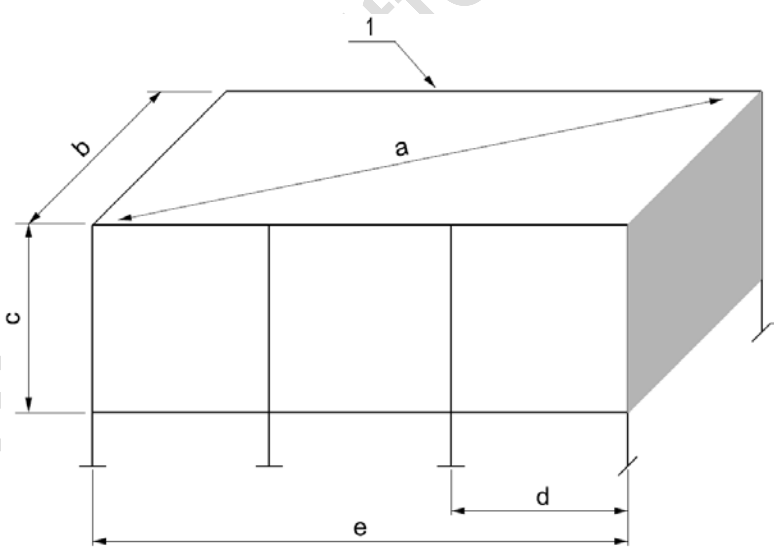
j) Flanges hole pitch ± 1 mm (0.039 in.) but not cumulative. See Figure 3.

**15.2.2.4** Both foundation plate and interconnecting plates or flanges level (deviation in horizontal or vertical plane shall not exceed 3 mm (1/8 in.) between the extreme edges).

**15.2.2.5** Fabrication of flanges and plates shall be performed using properly fabricated templates. The same templates shall be used to check the above tolerances after fabrication.

**15.2.2.6** Tolerances on module internal dimensions shall also be checked according to the applicable requirements specified in 15.2.2.3.

**15.2.2.7** Clearance for intermediate tubesheet expansion and applicable tolerance shall be indicated in the fabrication drawing.




**Key**

1 prefabricated module

**Notes**

a module diagonal with tolerance of ±0.2 %; max tolerance ±15 mm (5/8 in.)

b module width with tolerance of ±0.2 %; max tolerance ±15 mm (5/8 in.)

c module height with tolerance of ±0.2 %; max tolerance ±15 mm (5/8 in.)

d adjacent column span with tolerance of ± 3 mm (1/8 in.)

e module length with tolerance of ±0.2 %; max tolerance ±15 mm (5/8 in.)

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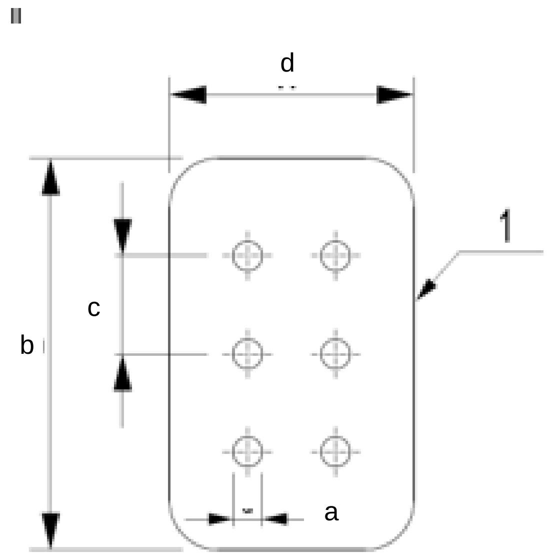
**Figure 2a—Dimensional Tolerances - Rectangular Modules (Typical)**




**Key**

1 base plate (typical)

**Notes**

a bolting holes with tolerance of ±1 mm (0.039 in.)

b base plate length with tolerance of -0 / +5 mm (3/16 in.)

c spacing between adjacent bolting holes with tolerance of ±1 mm (0.039 in.)

d base plate width with tolerance of -0 / +5 mm (3/16 in.)

**Figure 2b—Dimensional Tolerances – Base Plate (Typical)**

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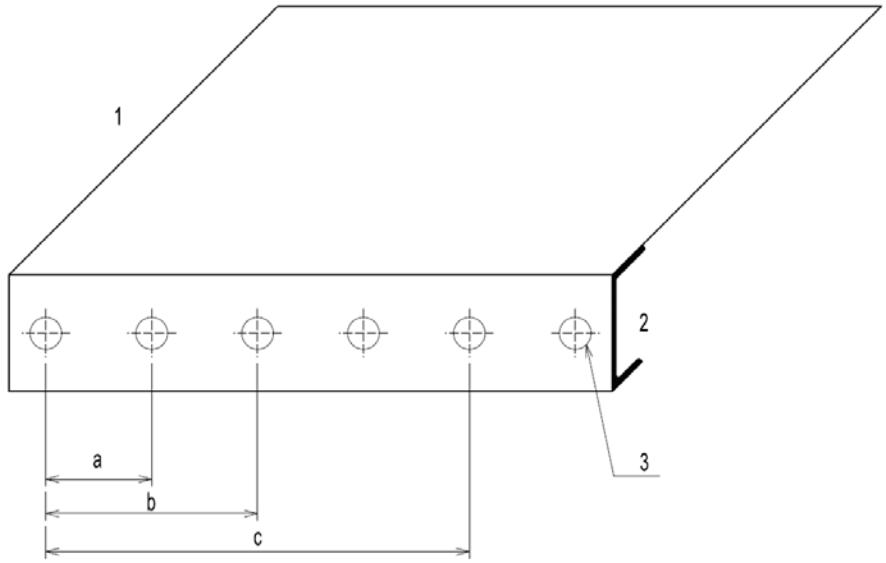



**Key**

1 steelwork casing panel

2 steelwork flange

3 bolt holes

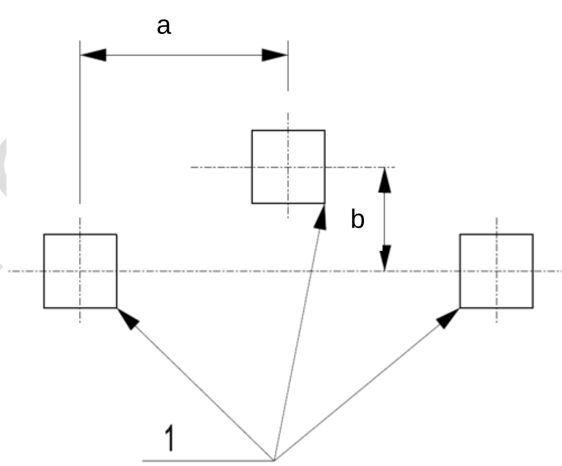
**Notes**

a distance between first and second hole with tolerance of ±1 mm (0.039 in.)

b distance between first and third hole with tolerance of ±1 mm (0.039 in.)

c distance between first and “n” hole with tolerance of ±1 mm (0.039 in.)

**Figure 3— Dimensional Tolerances for Steelwork Flanges on Modules (Typical)**




**Key**

1 base plates

**Notes**

a maximum misalignment of baseplates referred to design axis with a tolerance of ± 5 mm (3/16 in.)

b adjacent base plate span with tolerance of ± 3 mm (1/8 in.)

**Figure 4—Base Plates**

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### 15.3 Convection Coil Fabrication

NOTE Refer to 5.2.4 for information on pressure design code selection.

**15.3.1** Unless otherwise specified by the purchaser, only the following welding processes shall be permitted, provided satisfactory evidence is submitted that the welding procedure is qualified in accordance with the pressure design code:

a) SMAW: shielded metal arc welding;

b) GTAW: gas tungsten-arc welding (manual and automatic);

c) GMAW: gas metal-arc welding (spray transfer mode only) See 15.4.2;

d) FCAW(g): flux cored-arc welding with external shielding gas.

**15.3.2** Modified waveform GMAW processes that are not back purged shall not be used for root pass welding on convection coil components operating in the creep range.

**15.3.3** Machined weld bevels shall be examined by PT.

**15.3.5** An argon or helium internal purge shall be used for GTAW root pass welding of alloys with more than 9 % chromium. The root pass in carbon steel and low-alloy steels shall not be deposited without an internal purge, unless the welding process and welding procedure specification/qualification has been accepted by the purchaser.

**15.3.6** For carbon steel pipes, semi-automatic flame (or arc) cutting and beveling shall be permitted provided the cut/bevel is smooth and true, and oxides are removed from the flame-cut surfaces.

**15.3.7** Where possible, the number of intermediate welds shall be minimized and shall be agreed to by the purchaser.

**15.3.8** The location of intermediate welds in convection coils shall be at least 200 mm (8 in.) away from the central line of tube-supports**.**

**15.3.9** The fabrication tolerances for crossovers and inlet systems (or part thereof) shall be in accordance with the pressure design code.

### 15.4 Reformer Piping Systems

NOTE Unless otherwise specified by the technology provider or purchaser, the requirements herein specified are intended for fabrication of inlet and outlet hairpins, inlet distributors and crossovers.

#### 15.4.1 Pigtails

**15.4.1.1** The requirements for site fabrication of pigtails are as follows:

a) Pigtails ends subject to site welds shall have a minimum 100 mm (4 in.) extra length for site adjustment.

b) Extra length shall also consider a dedicated length necessary to reweld the pipe in case of unsuccessful site welder performance.

c) In case of unsatisfactory site weld inspection, only one reweld of a pigtail shall be allowed.

d) The final length shall be accommodated at site.

e) The extra length shall be cut.

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g) The edge shall be properly beveled.

NOTE The requirements of 15.4.1.1 do not apply to short straight outlet pigtails.

**15.4.1.2** The linear dimension tolerance on the sections of the hairpin not subject to site welds, shall be ± 5mm (± 3/16 in.).

**15.4.1.3** The difference between maximum and minimum diameter at any cross section of the bent portion of the pigtails shall not exceed 8 % of nominal outside diameter.

### 15.4.2 Inlet Distributors

**15.4.2.1** The straightness maximum acceptable deviation of each single distributor spool shall not exceed 1 % of the length of each spool, with a maximum of 5 mm (3/16 in.). The straightness maximum acceptable deviation on the whole length of the distributor shall not exceed 19 mm (3/4 in.).

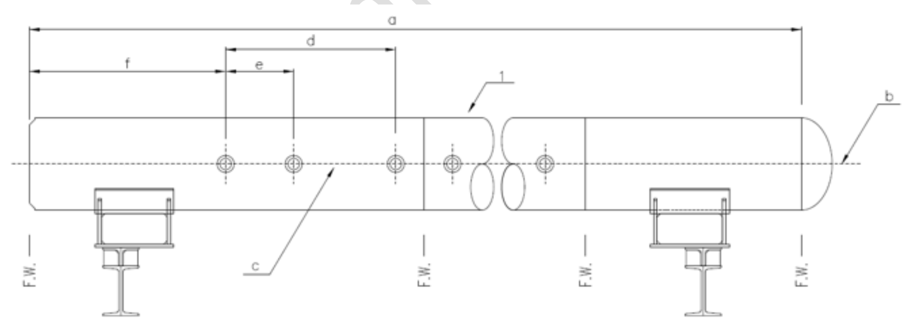
**15.4.2.2** The tolerance of the distance between the first weldolet centerline and the beveled end of the spool shall not exceed -0 / +2.5 mm (0.098 in.). Refer to dimension "f" in Figure 5.

**15.4.2.3** The tolerance of the distance between adjacent weldolet centerline shall not exceed ±1.5 mm (±1/16 in.). The maximum tolerance between the first and the last weldolet of each spool shall not exceed 5 mm (3/16 in.).

**15.4.2.4** Total distributor length measured at shop trial assembly shall not exceed ±12.7 mm. (±½ in.).

**15.4.2.5** The external diameter and thickness shall be in accordance with the applicable pipe specification, e.g. ASME B36.10.

**15.4.2.6** The dimensions tolerances as shown in Figure 5 shall be followed unless otherwise specified by the technology provider.




**Key**

1 inlet distributer assembly

**Notes**

a inlet distributor assembly total length with tolerance of ±12.7 mm (±1/2 in.)
b Inlet Distributor assembly centreline with maximum tolerance on straightness of ±19 mm (3/4 in.)
c inlet distributor spool centerline with maximum tolerance on straightness of 0.1% to a max. ±5 mm (3/16 in.)
d distance between first and "n" weldolet with tolerance of ±5 mm (3/16 in.)
e distance between adjacent weldolets with tolerance of ±1.5 mm (0.059 in.)
f distance between Distributor inlet and first weldolet with a tolerance of -0/+2.5 mm (0.098 in.)
FW field weld

**Figure 5—Inlet Distributor Tolerances**

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### 15.4.3 Crossovers

**15.4.3.1** The linear dimension tolerance on sections of crossover not subject to site welds shall be ±5 mm (3/16 in.).

**15.4.3.2** The crossover ends subject to site welds should have a minimum 100 mm (4 in.) of extra length for site adjustment.

**15.4.3.3** Extra length should also consider a dedicated length necessary to reweld the pipe in case of unsuccessful site welder performance.

**15.4.3.4** In the case of an unsatisfactory site welding inspection, one reweld of pipe should be permitted.

**15.4.3.5** Crossovers fabrication should be completed with any extra length removed and the pipe end properly beveled for the welding

**15.4.3.6** The external diameter and thickness of the tubes shall be in accordance with the applicable pipe specification, e.g. ASME B36.10.

## 15.5 Catalyst Tube Fabrication

### 15.5.1 General

**15.5.1.1** Tubes shall be centrifugally cast. Cast tube segments shall conform to the requirements of the applicable specification, e.g. ASTM A608/A608M. The minimum cast tube segment length shall not be less than 1800 mm (6 ft) long unless otherwise agreed between the purchaser and supplier.

● **15.5.1.2** The purchaser shall be specified the minimum sound wall thickness of tube segments.

**15.5.1.3** Unless otherwise specified by the purchaser, cast tube tolerances shall be as follows:

- outside diameter (OD): 0.0 mm / +2.0 mm (-0.0 in. / +0.079 in.)
- inside diameter (ID): +0.0 mm / -1.0 mm (+0.0 in./ -0.039 in.)

**15.5.1.4** Unless otherwise specified by the technology provider, the ID of cast tubes, including catalyst tubes, riser tubes, or manifolds, shall be machined to a maximum surface roughness of 125 RMS.

**15.5.1.5** Prior to shipment, the overall tube assembly length tolerance shall be +6.4 mm (1/4 in.) and -0.0 mm (0.0 in.) for assemblies up to 9.1 m (30 ft) in length. For assemblies longer than 9.1 m (30 ft), the overall length tolerance shall be +9.5 mm (+3/8 in.) and -0.0 mm (-0.0 in.).

**15.5.1.6** Tube segments shall be pull-bored to remove inner porosity and to produce a finish of 125 RMS or finer on the ID surface.

**15.5.1.7** The cast tube finished internal bore eccentricity of the finished bore shall not exceed 0.8 mm (1/32 in.) as measured in two planes 90° apart, unless agreed upon by purchaser and supplier.

**15.5.1.8** The tube outer roughness shall have a maximum thickness of 0.8 mm (1/32 in.), see Figure 6.

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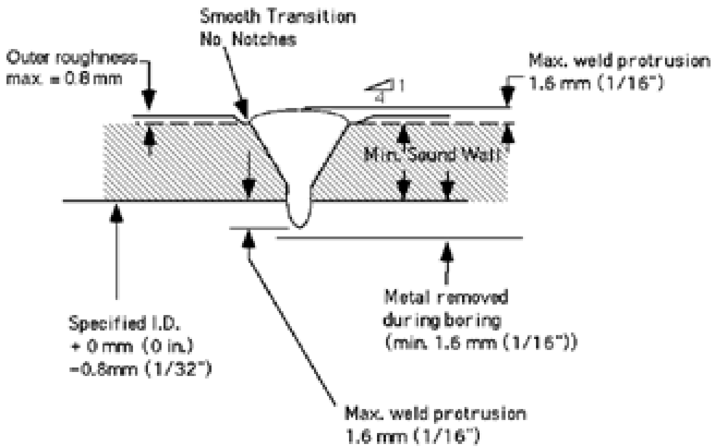


**Figure 6—Outer Roughness Detail**

**15.5.1.9** The maximum allowable bow in any tube segment after straightening shall not be greater than 3 mm (1/8 in.) per 5m (18 ft) of length.

**15.5.1.10** There shall be no visible change centerline of tube segments at the welded joints.

**15.5.1.11** The maximum bow of the entire tube assembly shall be less than 25 mm (1 in.) when the assembly is lying in a fully supported, horizontal position, e.g. shop floor. Straightening shall not be permitted after welding of the assembly.

### 15.5.2 Catalyst Tube Segment Marking and Identification

**15.5.2.1** Full traceability of materials and components shall be maintained from casting to final assembly. A record log shall be maintained of each heat and its identification markings, with the identifiers being part of each tube assembly weld map.

**15.5.2.2** Each tube assembly shall be permanently marked at the flange or the cold end of the tube assembly using low-stress metal stamps, unless another suitable method is approved by the purchaser.

**15.5.2.3** Painting, or other marking used for identification shall be free of low melting materials, halogenated compounds, or other substances that can cause damage to the tubes at high temperature.

### 15.5.3 Catalyst Tube Testing and Examination

**15.5.3.1** Nondestructive examination shall be carried out by the supplier's QA organization. Personnel involved in nondestructive testing shall be qualified to a nationally recognized standard, e.g. ASNT-TC-1A level II or equivalent. There shall be no duplication with Section 16.

**15.5.3.2** Internal tube-segment surfaces shall be examined visually after pull-boring. When defects or discontinuities are observed, further examination shall be conducted. Rejection criteria shall be defined in the purchaser's specifications.

### 15.5.4 Catalyst Tube Segment Liquid Penetrant Testing

**15.5.4.1** After removal from the mold or pull-boring and before welding, each tube segment shall be examined by using PT to detect OD surface defects in accordance with relevant standard, e.g. ASTM E165/E165M. Acceptance criteria shall be in accordance with the pressure design code, e.g. ASME BPVC, Section VIII, Div. 1, Appendix 8, except no linear indications are permitted.

**15.5.4.2** ID surfaces of each tube segment shall be inspected at both ends to a depth of at least two tube IDs. There shall not be any indications of shrinkage porosity, hot tears, cracks, or other defects.

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**15.5.4.3** Tube segment machined weld bevel surfaces shall be PT inspected before welding. There shall not be any indications of shrinkage porosity, hot tears, cracks, or other defects.

### 15.5.5 Catalyst Tube Assembly Welding

**15.5.5.1** Catalyst tube to catalyst tube, flange-to-tube, and fitting to tube welding procedures, procedure qualification records, welding-consumable specifications, and NDE procedures shall be in accordance with the pressure design code and applicable project specification submitted by the supplier for review, comment, and acceptance by the purchaser.

**15.5.5.2** Where manual processes are used to deposit the root pass, PT shall be performed on the root pass.

**15.5.5.3** Butt welds for catalyst tubes and pigtails shall be full penetration.

**15.5.5.4** Weld-crown/cap reinforcement shall be limited to 1.6 mm (1/16 in.) See Figure 6.

**15.5.5.5** Tubes and fittings OD shall be machined in a length not less than 25 mm (1 in.) on beveled ends. OD weld surfaces and adjacent base metal shall be free of discontinuities and irregularities to permit effective non-destructive examination (NDE). The weld shall smoothly transition to the base metal to inhibit the formation of stress risers.

**15.5.5.6** Root passes shall be made by electron beam, PAW, or GTAW processes. Backing rings shall not be used.

**15.5.5.7** Weld deposits between catalyst tube segments shall have the same nominal chemical composition as the base metal, unless otherwise agreed with the purchaser.

**15.5.5.8** Arc strikes on catalyst tubes shall be avoided. If they occur, affected surfaces shall be ground to remove all stress risers. Affected areas shall be examined by liquid-penetrant examination (PT) and have minimum sound wall (MSW) verified by using ultrasonic testing (UT).

**15.5.5.9** Weld repair of casting defects in catalyst tubes shall not be permitted.

**15.5.5.10** Completed welds shall be examined by using PT.

**15.5.5.11** Tube ID measurements at circumferential welds shall be verified using a plug (go/no-go) gauge as required by the technology licensor.

**15.5.5.11** Internal borescope examination shall be conducted after completion of assembly welding.

## 15.6 Pigtail Fabrication

### 15.6.1 General

**15.6.1.1** Outlet pigtails shall be seamless.

**15.6.1.2** Inlet pigtails shall be fabricated, and heat treated in accordance with the pressure design code, e.g. ASME B31.3.

**15.6.1.3** Unless otherwise specified by purchaser, outlet pigtails shall be fabricated and heat treated in accordance with the pressure design code, e.g. ASME B31.3.

**15.6.1.4** The supplier shall evaluate the necessity for heat treatment after bending high-alloy outlet pigtails. Heat treatment shall be subject to approval by the purchaser.

NOTE For guidance see API Technical Report 942-A and API Technical Report 942-B.

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**15.6.1.5** The minimum distance between two welds shall not be less than 200 mm (8 in.).

### 15.6.2 Pigtail Welding

**15.6.2.1** For low-alloy and stainless steel and nickel-base alloy pigtails, flame-cut bevels shall only be accepted where machine cutting is not feasible and is accepted by the purchaser. After flame cutting/beveling, approximately 3 mm (1/8 in.) of material shall be removed from the surface of the bevel by grinding.

**15.6.2.2** When located external to the firebox, high-alloy outlet pigtails shall be welded in accordance with the requirements of the welding code, e.g. ASME Section IX.

**15.6.2.3** Pigtail welds to catalyst tube fittings, cones, and outlet headers shall not exhibit any measurable undercut.

**15.6.2.4** Weld-crown / cap reinforcement shall be limited to 1.6 mm (1/16 in.).

**15.6.2.5** Maximum internal-weld protrusion shall be limited to 1.6 mm (1/16 in.).

**15.6.2.6** OD weld surfaces and adjacent base metal shall be free of discontinuities and irregularities to permit effective NDE. The weld shall smoothly transition to the base metal to inhibit the formation of stress risers.

**15.6.2.7** Root passes shall be made by PAW or GTAW processes. Backing rings shall not be used.

**15.6.2.8** Weld deposits shall have the same nominal chemical composition as the base metal, unless otherwise specified by Purchaser.

**15.6.2.9** Piping component connections of different wall thickness shall be smoothly tapered (1:4).

**15.6.2.10** Permanently installed backing rings shall not be used in radiant reformer furnace components. Backing rings in reformer outlet system piping shall only be used when approved by the purchaser.

### 15.6.3 Pigtail Testing and Inspection

**15.6.3.1** After bending, the outside portion of the bend shall be checked for minimum wall thickness using an ultrasonic thickness checker. Any pipe that does not meet design minimum wall thickness shall be rejected.

**15.6.3.2** Thickness checks shall be made on the first five bends, for each bend radius, and 10 % of subsequent bends that are made by each bending machine and/or operator.

**15.6.3.3** Before actual production, destructive testing of one spare pipe of each size and material shall be done after bending and heat treatment.

**15.6.3.4** The following tests shall be performed on the spare pipe section.

a) Ovality, hardness, wall thickness and scaling (inside and outside) at the tube bend section;

b) Annealed high Ni-Cr pipe examination for grain size (5 or coarser per ASTM E112);

c) Flattening test per ASTM A530/ASTM 530M for each pipe material (including ASTM B407).

**15.6.3.5** Ovalling of a bend shall not exceed 8% of the nominal diameter.

NOTE Ovalling is the difference between the maximum and minimum diameter at any cross section along the axis.

## 15.7 Painting and Galvanizing

Unless otherwise specified, painting and galvanizing shall be in accordance with API 560.

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### 15.8 Preservation and Preparation for Shipment

● **15.8.1** Equipment, including reformer components, shall be suitably prepared for the type of shipment specified, including blocking of fan rotors if necessary. When specified by the purchaser, the equipment shall be prepared so that it is suitable for a minimum of six months of outdoor storage from the time of shipment. If storage for a longer period is contemplated, the supplier shall provide recommended protection procedures.

**15.8.2** Preparation for shipment shall be made after testing and inspection of the equipment has been completed and the equipment has been approved by purchaser. The shipping preparations shall be specified by the purchaser.

● **15.8.3** Catalyst tubes and other high alloy components shall be packaged to prevent damage from handling and environmental conditions during loading, transport, offloading, and site storage. If required, the purchaser shall specify the need for approval of the packaging before shipment.

**15.8.4** Openings such as at the tube ends, and weldolets shall be covered to prevent debris from entering the tubes and to protect the tubes from damage.

**15.8.5** Panels, modules, and shipping crates shall be clearly labeled with the following information:

b) any special lifting instructions including center of gravity;

c) lift points;

d) order number;

e) supplier's component identification number;

f) shipping weight of each container;

g) destination.

**15.8.6** The reformer supplier shall specify any special instructions for handling or storage, which are required to maintain the quality and mechanical integrity of the design and the materials of construction which have been utilized.

**15.8.7** Machined flange faces shall be protected by an organic rust preventative and capped. If there is the possibility of mechanical damage, a service gasket and blind flange shall be supplied and tightened to prevent ingress of air.

NOTE In some cases, purchaser may approve a neoprene gasket and steel plate bolted to the reformer flange.

**15.8.8** Reformer pressure-retaining components shall be verified as dry prior to preparation for shipment.

NOTE Dryness can be achieved by blowing air through the component and measuring relative humidity.

**15.8.9** Pressure-retaining circuits shall be isolated from the environment.

### 15.9 Field Erection

Attention shall be paid to protection and preservation of catalyst tubes during erection to avoid exposure to materials containing low-melting eutectics (sulfur compounds, zinc coatings, etc.).

## 16 Inspection, Examination, and Testing

NOTE Refer to Annex E for guidance to an owner for pre-commissioning inspections as part of an asset integrity program for pressure components in a reforming furnace.

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## 16.1 General

**16.1.1** The purchaser shall have unrestricted right to inspect and observe work at any time during all stages of fabrication to ensure such equipment, materials, and workmanship are in accordance with the purchase order.

**16.1.2** The supplier shall submit their quality assurance and inspection and test plan (ITP) for purchaser's review and approval. The ITP shall include the type and extent of purchaser involvement in terms of hold and witness points and documents for review.

● **16.1.3** When specified by the purchaser, pre-inspection meetings between the purchaser and the supplier and their approved fabricator(s) shall be held before the start of fabrication.

**16.1.4** All test procedures shall be submitted to the purchaser for review and approval. The purchaser reserves the right to reject the results of testing made prior to approval of test procedures.

**16.1.5** The purchaser's inspectors and/or purchaser's nominated inspection authority shall have the right to use any additional testing and/or inspection method when defects are found.

**16.1.6** Welding procedures, PQRs, and welding-consumable specifications for all pressure-retaining welds shall be in accordance with the pressure design code.

## 16.2 Weld Examination

**16.2.1** All reformer catalyst tubes and cast/wrought outlet manifold welds shall be 100 % examined by the fabricator using appropriate NDE methods and in accordance with the applicable pressure design code. For field welds of outlet manifolds where RT is not possible, 100% UT or other method acceptable by applicable code shall be used.

NOTE Radiographic examination may be replaced with UT, time of light diffraction (TOFD), and PAUT when agreed between the purchaser and the supplier/fabricator.

**16.2.2** All weld examination requirements shall be in accordance with API 560.

**16.2.3** Ferrite testing shall be required for austenitic stainless steels and 800H Metallurgy.

**16.2.4** PMI (100%) shall be performed on low-alloy; austenitic stainless steel; and high-alloy tubing, fittings, pressure-retaining welds, and supplied pigtail-tube stubs.

**16.2.5** Inspection records shall be retained for the life of all reformer pressure components.

**16.2.6** Unless otherwise specified, examination of pressure part welds in reformers during fabrication and erection shall be in accordance with Table 3, which indicates different methods that can be applied.

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**Table 3—Applicable Methods for Shop Fabrication and Field Erection Weld Inspection**

| Components | Weld Description | Fabrication: Root Pass [a] | Fabrication: Final |
|---|---|---|---|
| Radiant Tubes | Cast tube to tube welds | 1,2,5 | 1,2,3 |
| | Dissimilar tube to tube or catalyst tube flange butt welds | 1,2,4,5 | 1,2,3,6 |
| | Weldolet/support trunnion penetration welds | 1,2,4,5 | 1,2,6 |
| Inlet/Outlet Pigtails | Butt welds to tube reducer | 1,2,5 | 1,2,3,6 |
| | Butt welds to headers | 1,2 | 1,2,3,6 |
| | Sockolet weld to headers and pigtails | 1,2,4,5 | 1,2,6 |
| | Tube to tube butt welds | 1,2,5 | 1,2,3,6 |
| Collection Headers (Cast) | Butt welds | 1,2,4,5 | 1,2,3 |
| | Weldolets | 1,2,4,5 | 1,2 |
| | Dissimilar metal welds | 1,2,4,5 | 1,2,3 |
| | Thermocouple welds | 1,2 | 1,2 |
| Collection Headers (Wrought) | Butt welds | 1,2,4,5 | 1,2,3 |
| | Dissimilar metal welds | 1,2,4,5 | 1,2,3 |
| NOTES Inspection/NDE Techniques: 1 - 100% Visual (VT), 2 – 100 % Penetrant Examination (PT) for austenitic materials for field welds, and 10% minimum for shop welds for all materials, 3 – 100 % Radiographic Examination (RT)[b], 4 - Ultrasonic Examination (UT)[c], 5 – minimum 10 % PMI of austenitic materials and welding filler materials, 6 – Ferrite (if required by WPS) | | | |
| [a] -Upon agreement with the purchaser, root pass exam may be waived for automatic welding. PMI of root pass is for non-autogenous welding.<br>[b] -Includes conventional RT and digital / computerized methods<br>[c]-Includes computerized and UT, TOFD, and phased array methods | | | |

## 16.3 Casting and Forgings Examination

**16.3.1** Major repair requirements of cast components other than catalyst tubes/headers, as defined in API 560 shall require written approval by the purchaser and performed in accordance with applicable codes approved by the purchaser.

**16.3.2** Inspection of the pilot casting for the outlet bull tee shall be 100 % examined using appropriate volumetric methods.

- **16.3.3** When specified by the purchaser, centrifugally cast tees and cones shall be examined as in 16.3.2.

**16.3.4** Data required for remaining life assessment shall be requested from the manufacturer.

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### 16.4 Examination of Other Reformer Components

**16.4.1** Inspection of external piping shall be in accordance with the pressure design code, e.g. ASME B31.3.

**16.4.2** In addition to the general requirements for component assembly inspection, examination, and testing as specified in API 560, the following requirements shall be included for erection of reformer components:

a) Tolerances for steel erection shall be in accordance with AISC.

b) Examination of reformer assembly of catalyst tubes, inlet and outlet pigtails and manifolds shall include:

1. check inlet/outlet manifolds for proper clearance and expansion prior to start up;
2. check inlet/outlet piping for adequate supports;
3. check for adequate expansion gaps in the reformer furnace floor for the outlet manifold;
4. ensure guides and slides for the outlet manifold are correctly installed;
5. check for clearance for inlet and outlet pigtails with structural steel due to thermal expansion;
6. ensure temporary piping supports/braces are removed;
7. ensure spring hanger cold and hot position are on the set mark.

NOTE Spring hanger or constant spring supports supporting the catalyst tubes and other piping provided with shipping locks which should be removed after ensuring that the hanger is not slack and is in tension. Adjustment can be made using turnbuckle.

8. check counterweights for freedom of movement and expansion, and ensure cold and hot position are on the set mark;
9. inspect the catalyst tubes for possible contamination from zinc, lead based paints, and galvanized steel/bolting materials;
10. confirm that all refractory materials are cleaned off the catalyst tubes;
11. check all pressure parts in the catalyst tube, inlet, and outlet assemblies for the required clearances or allowance for thermal expansion or movements.

c) Examination of the refractory lined transfer line shall include:

1. check the transfer line refractory for cracks and gaps;
2. verify that coverage and installation of temperature sensitive paint system for the transfer line, where applicable, is in accordance with specification and verify that stainless steel parts are left bare;
3. confirm proper installation of the transfer line and ensure provision for expansion is in accordance with the design.

d) Examination of refractory and insulation system shall include:

1. visual examination of castable refractory and insulation to ensure that there are no cracks that exceed acceptance criteria or gaps in the insulation, i.e. crack/gaps greater than 3 mm (1/8 in.) and depth greater than half the thickness of the castable;
2. check all expansion gaps are filled with ceramic fiber blanket in accordance with specifications;

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3. check that there are no gaps around observation doors or between ceramic fiber modules;
4. confirm that the pattern of openings in the flue gas tunnel walls matches the engineering drawings;
5. confirm that tunnel expansion joints are free of mortar and installed in accordance with the engineering drawings;
6. ensure gap between observation doors is filled with ceramic fiber;
7. check that all external insulation in waste heat recovery system convection section and ducting is installed in accordance with the engineering drawings.

e) Other insulation checks shall include:

1. any transitions between internal and external insulation for possibility of future hot spots;
2. around structural steel. (for example, check whether the columns are supposed to be externally insulated or fireproofed);
3. fabric expansion joint details;
4. where weather plates are used to protect fabric expansion joints, check that the installation is in accordance with the drawings and that ambient air circulation is possible to keep the outer layer cool;
5. tube seals where radiant tubes transition between penthouse and radiant box to ensure proper clearance/gaps.

NOTE Improper clearance/gaps restrict axial movement required for expansion.

**16.4.3** External piping outside the footprint of reformer shall be inspected in accordance with the pressure design code, e.g. B31.3.

### 16.5 Pressure Testing

**16.5.1** Reforming furnace process piping and pressure circuits shall be tested in accordance with the pressure design code or with the licensor's requirements.

NOTE 1 For reforming furnace field assembled process circuits starting with the convection section outlet, including crossover piping, inlet headers, inlet pigtails, catalyst tubes, outlet pigtails, hot manifold, and cold manifold up to the inlet to the process gas boiler, the field pressure testing loop can become too large to perform pressure test as required by the pressure design code.

NOTE 2 Usually the circuit dimensions and internal refractory in the cold collector makes a hydrotest not feasible or not practical.

● **16.5.2** With agreement by the purchaser, pressure testing of a field assembled reforming furnace process circuit shall be replaced with an equivalent alternative procedure aimed at proving the assembled circuit integrity.

EXAMPLE Considerations, calculations, and perimeter zone requirements for pneumatic or gas sensitive leak pressure testing may be found in ASME PCC-2 Article 5.1, Appendix 2 and Appendix 3.

**16.5.3** When pneumatic leak testing is used, the following requirements apply:

a) The test pressure shall be maintained for a length of time sufficient to examine for leaks, but in no case for less than 15 minutes.

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b) A bubble surfactant shall be applied to the field weld seams to aid visual leak detection.

**16.5.4** Field assembled convection section coils shall be tested in accordance with API 560 and the pressure design code.

**16.5.5** Test fluids shall be removed from all reformer components upon completion of pressure testing.

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# Annex A

(informative)

# Reformer Equipment Overview--Reformer Nomenclature

## A.1.1 General

In a steam reformer, heat is provided by the combustion of fuels to cause an endothermic high temperature reaction to take place inside catalyst filled radiant tubes. The heat available from the flue gases is utilized for further process heat recovery by feed streams, process streams, and utility (steam) generation. A steam reformer is a complex system comprising of a radiant section, convection section, and flue gas stack. Steam reformer configurations can be Induced Draft, Balanced Draft, or Natural Draft. Examples of the various arrangements include side-fired, top-fired, bottom-fired, and multilevel-fired. Figure A.1 through Figure A.4 illustrate some typical reformer types.

## A.1.2 Reformer Configurations

### A.1.2.1 Side Fired

**General Description:**

A side-fired reformer consists of vertical tubes in a single row in each radiant cell, which are double fired using several horizontal rows (usually 4-6) of radiant wall burners at multiple levels.

See Figure A.1 for a typical arrangement.

**Application:**

This configuration is used for hydrogen, ammonia, and methanol production and typically applicable to medium to large capacity reformers. Large capacities can be achieved. Plot space requirements are usually developed in length, rather than in width. The width is usually standardized as depending on a nearly fixed distance between burners and tubes and not on the heater capacity; Length is depending on the heater capacity.

**Limits of Use:**

None.

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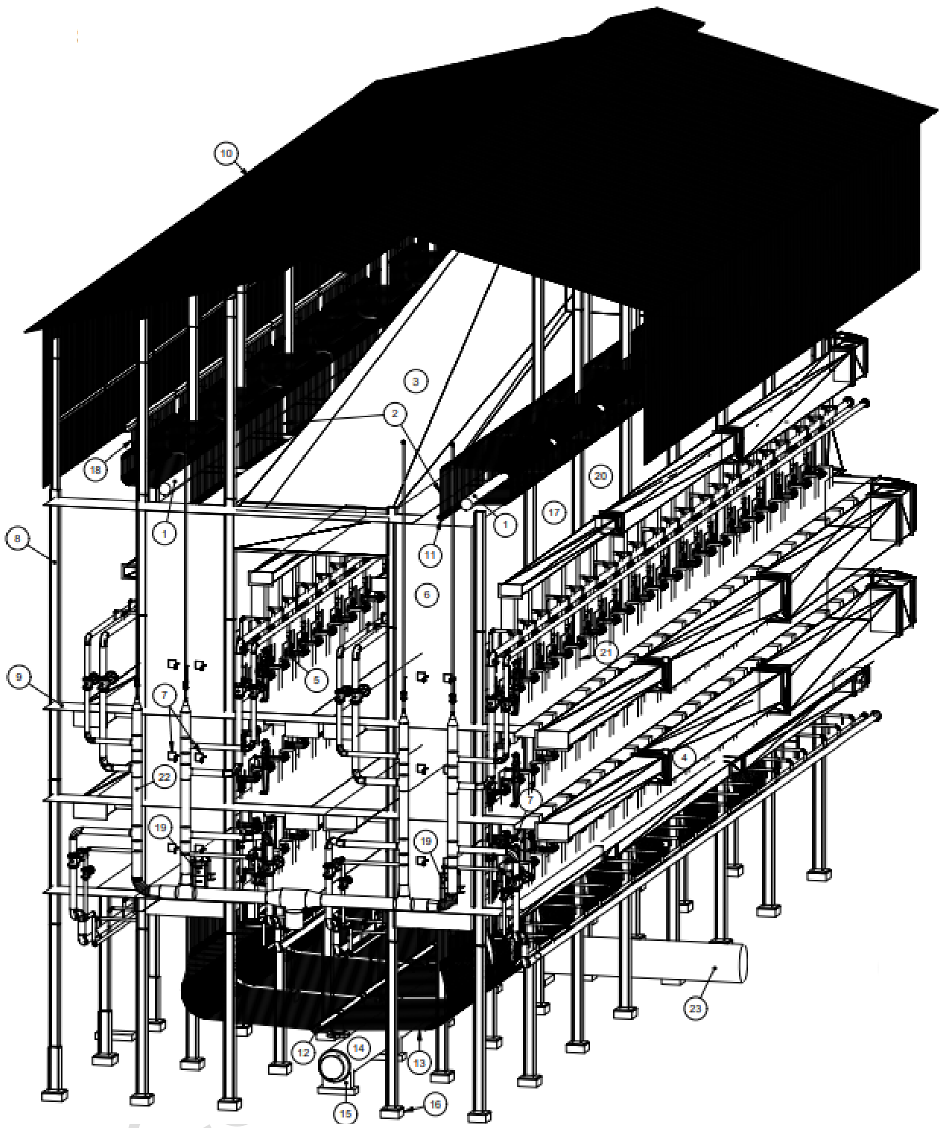


**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | inlet distributor | 9 | platforms | 17 | side wall |
| 2 | inlet hairpin tube | 10 | roof | 18 | hairpin spring support |
| 3 | flue gas duct | 11 | catalyst tube assembly | 19 | access door |
| 4 | combustion air ducting | 12 | hot collector | 20 | casing plate |
| 5 | burner | 13 | outlet hairpin | 21 | burner connection air |
| 6 | end wall | 14 | cold outlet collector | 22 | fuel pipe |
| 7 | peep door | 15 | support saddle | 23 | transfer line |
| 8 | steel structure | 16 | foundation | | |

**Figure A.1—Side-fired Reformer**

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### A.1.2.2 Bottom Fired

**General Description:**

A bottom-fired reformer consists of vertical tubes that are in a firebox with one or more up-fired burners mounted in the floor.

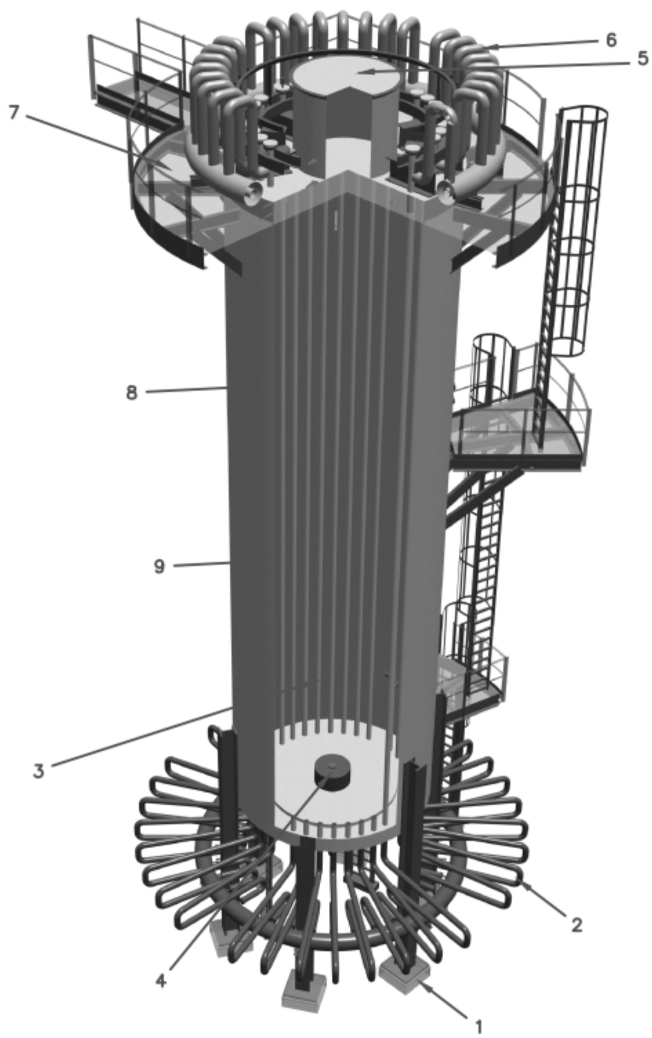
See Figure A.2 for a typical arrangement.

**Application:**

This configuration is used for hydrogen, ammonia, and methanol production and is typically applicable to medium capacity reformers.

**Limits of Use:**

Large capacities can be achieved. The plot space requirements are usually developed in length, rather than in width.

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**Key**

1 structural foundation
2 inlet pigtails
3 catalyst tubes
4 burner
5 duct to heat recovery
6 outlet pigtails
7 arch platform
8 radiant box
9 blanket insulation

**Figure A.2—Bottom-fired Reformer**

### A.1.2.3 Multi-level Up Fired

**General Description:**

A multi-level up-fired reformer has burners mounted close to the side walls and firing upwards. In addition to the burners at the floor level, another row of up-fired burners are installed at a higher elevation in the radiant firebox. To mount the upper row of burners on a horizontal surface, a shelf is created by angling the side walls inwards towards the center of the radiant firebox. The tubes are arranged in a single row and are double fired.

See Figure A.3 for a typical arrangement.

**Application:**

This configuration is used for hydrogen, ammonia, and methanol production and is typically applicable to medium capacity reformers.

**Limits of Use:**

None.

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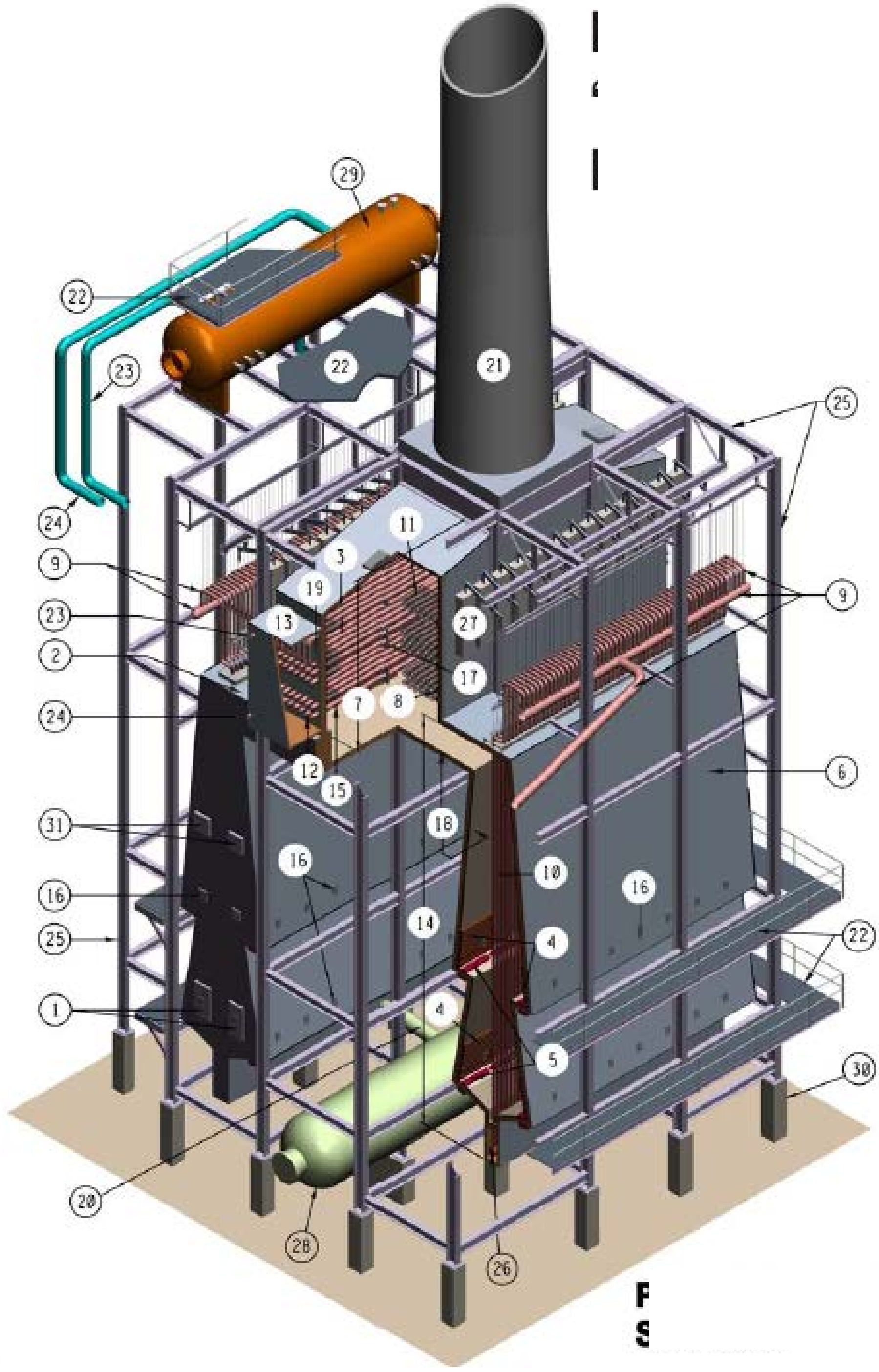


**Key**

1 access door w/sight port
2 arch
3 sloped breeching
4 IFB wall
5 burner
12 return bend
13 header box
14 radiant section
15 shield section (bare tubes)
16 sight port
22 side wall
23 hairpin spring support
24 maintenance platform
25 structural steel/support frame
26 outlet manifold

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6 casing plate
7 convection section
8 corbel
9 inlet manifold, pigtails, crossover
10 catalyst tube
11 finned tubes
17 tube support casting
18 refractory lining
19 end tube sheet
20 closed-coupled transfer line
21 stack/duct
27 counterweights
28 process gas boiler
29 steam drum
30 structural foundation
31 pressure relief door

**Figure A.3—Multilevel Up-fired Reformer**

### A.1.2.4 Top Fired

**General Description:**

A top-fired reformer consists of vertical tubes in multiple rows in each radiant cell that are double fired by using several rows of roof mounted down-fired burners. Unit capacity can be increased by adding the number of rows of burners and tubes to the firebox.

See Figure A.4 for a typical arrangement.

**Application:**

This configuration is used for hydrogen, ammonia, and methanol production typically applicable to medium to large reformers.

**Limits of Use:**

None.

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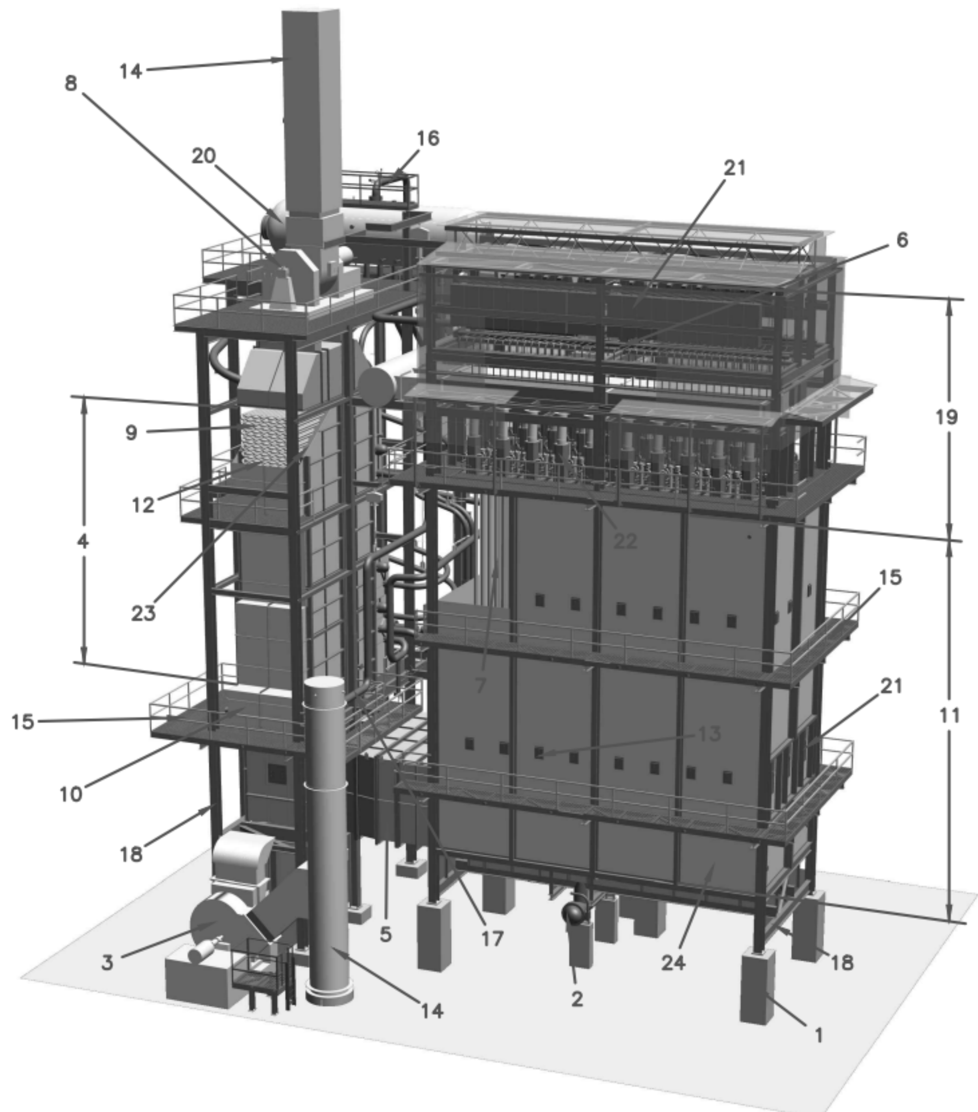


**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | structural foundation | 9 | return bend | 17 | convection process outlet |
| 2 | manifold to process gas boiler | 10 | header box | 18 | steel support frame |
| 3 | forced draft fan | 11 | radiant section | 19 | penthouse |
| 4 | convection section | 12 | convection section | 20 | steam drum |
| 5 | flue gas tunnel | 13 | peep door | 21 | burner connection air |
| 6 | inlet pigtails and crossover | 14 | flue gas outlet (top) / air inlet (btm) | 22 | burner row(s) |
| 7 | catalyst tubes | 15 | access platform | 23 | convection wall corbel |
| 8 | induced draft fan | 16 | convection process inlet | 24 | casing |

**Figure A.4—Top-fired Reformer**

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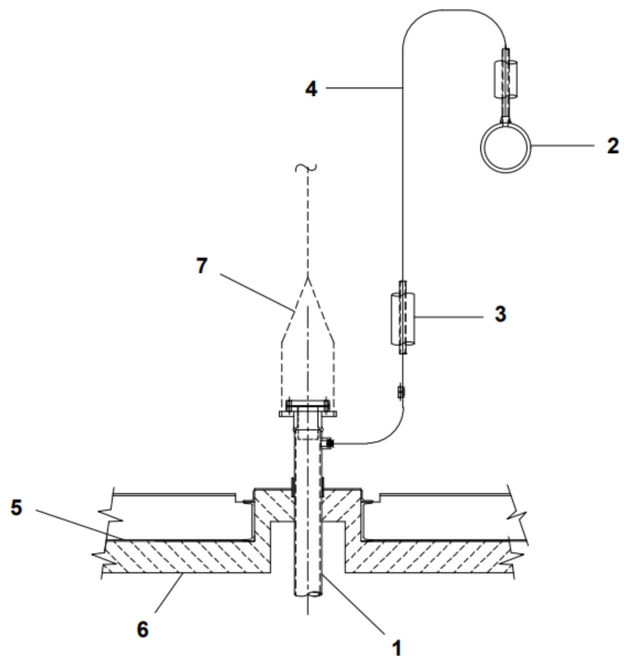
## A.1.3 Pigtail Configurations

Refer to Figures A.5 to Figure A.8 for various pigtail configurations.




**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | catalyst tube | 4 | pigtail | 7 | tube support |
| 2 | header | 5 | arch (roof plate) | | |
| 3 | insulation | 6 | refractory lining | | |

**Figure A.5--Inlet Pigtail--Side Entry**

For side entry pigtails, caution is warranted to ensure the catalyst tube above the entry is designed to maintain wall temperature above the process saturation temperature.

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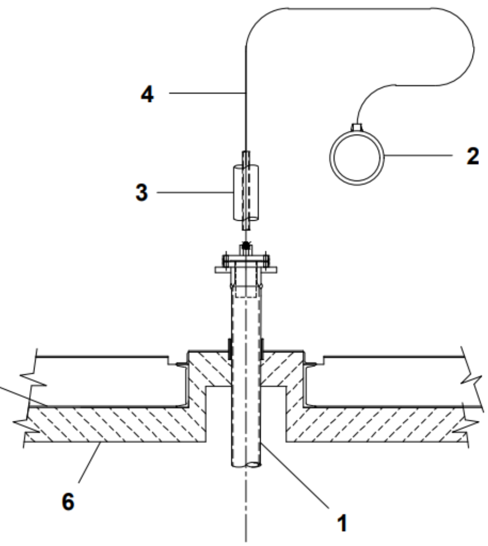
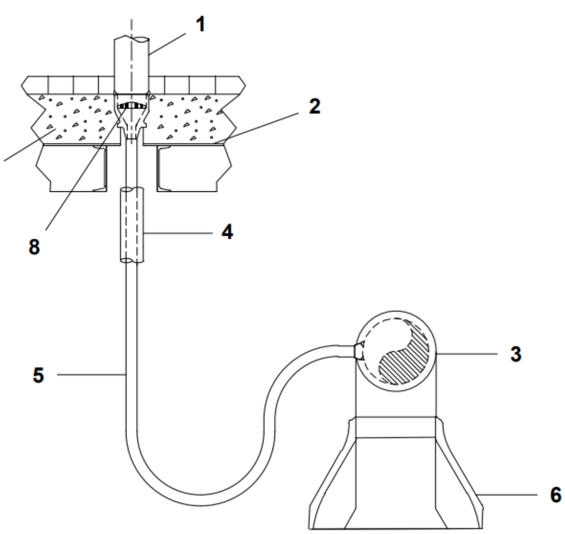



**Key**

| | | | |
|---|---|---|---|
| 1 | catalyst tube | 4 | pigtail |
| 2 | header | 5 | arch (roof plate) |
| 3 | insulation | 6 | refractory lining |

**Figure A.6--Inlet Pigtail - Top Entry**




**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | catalyst tube | 4 | insulation | 7 | refractory lining |
| 2 | floor casing | 5 | pigtail | 8 | catalyst grid plate |
| 3 | header | 6 | transition cone | | |

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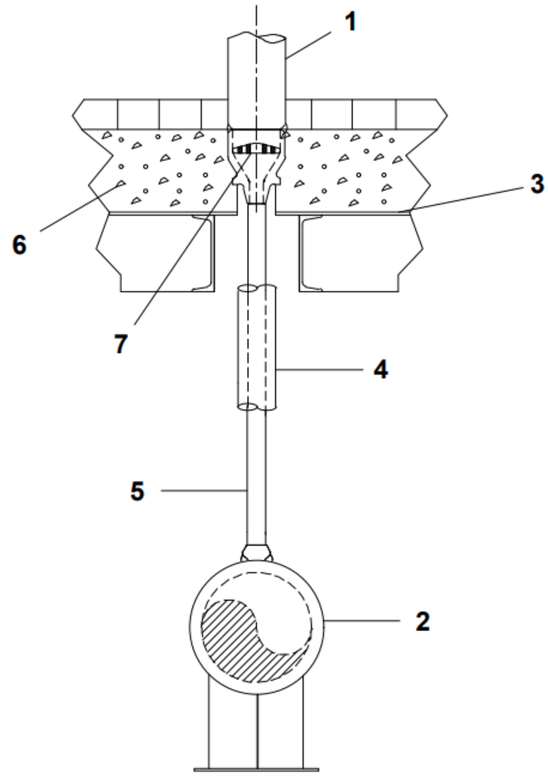
**Figure A.7—Outlet Long Pigtail**




**Key**

1 catalyst tube
2 header
3 floor casing
4 insulation
5 pigtail
6 refractory lining
7 catalyst grid plate

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**Figure A.8—Outlet Short Pigtail**

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### A.1.4 Catalyst

Catalyst is installed in the reformer furnace tubes, generally using proprietary installation technology, to ensure that the catalyst does not break due to excessive free-fall and that a uniform density loading is achieved. If large void spaces are included in the catalyst fill, it will contribute to increased tube wall temperatures and will result in settling of the catalyst over time, possibly into the heated section of the furnace causing overheating of the tops of the tubes. A successful loading is determined by the deviation from the average value of a pressure drop test on the loaded tubes. The loading company should provide the pressure drop rig. Generally, a deviation of ± 5% from the average pressure drop is acceptable (2.5% gas flow variation).

Consideration should be given to the impact of the pressure drop variation on the temperature distribution of the process gas coming out of the catalyst tubes relative to the temperature rating of the outlet pigtail system. Given uniform heat input to all tubes, the heat input per unit mass of gas flow will increase in a low flow tube due to higher pressure drop. Given that the reaction takes a fixed amount of heat per unit mass of gas, this extra heat will go towards increasing the gas temperature. A sufficient design temperature margin for the outlet pigtail, should be evaluated considering other criteria such as heat flux distribution.

Catalyst vendors each have a proprietary shape and often offer various sizes. These variations provide options to the plant owner such that activity and pressure drop can be balanced based on the operating objectives of the plant.

Promoted catalysts may be recommended at the inlet section of the tube to help prevent carbon formation. Carbon formation is one of the most common causes of hot bands/spots.

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# Annex B
(informative)

# Equipment Datasheets[7]

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## General

The following datasheets are provided to assist the technology provider, purchaser, and supplier in specifying the data necessary for the design of reforming furnaces for hydrogen and synthesis gas production in refining and chemical plant applications for general refinery service.

Completion of the datasheets is a joint responsibility of the purchaser and the supplier. The purchaser (owner or technology provider) is responsible for the process data, which define the purchaser's explicit requirements.

After the reformer has been designed and supplied, the supplier should complete the datasheets to make a permanent record that accurately describes the equipment "as-built."

This annex includes datasheets for the following equipment items:

a) reforming furnace datasheets: 20 sheets (10 in SI united, 10 in USC units);

Other datasheets such as those below are included in the respective standards.

b) burner datasheets: API 535;

c) air preheater datasheets: API 560;

d) fan datasheets: API 560;

e) louver damper datasheets API 560;

f) guillotine damper datasheets API 560;

g) SCR datasheets API 536.

[7] Users of datasheets should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

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| PURCHASER / OWNER: | ITEM No.: |
|---|---|
| SERVICE: | LOCATION: |

# REFORMING FURNACE DATASHEET

**API STD. 561**

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Note:
***** next to an API datasheet entry indicates purchaser required input.

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| **SI UNITS** | **PROJECT NUMBER** | **DATASHEET NUMBER** | **SHEET** | **REV** |
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| REFORMING FURNACE DATASHEET | |
|---|---|
| | PROJECT No.: |
| | ITEM No.: |
| | REVISION No.: |
| SI Units | SHEET No.: 2 of 10 |

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|---|---|---|---|---|---|---|---|---|
| 1 | * UNIT | | | | | | | |
| 2 | MANUFACTURER | | | | | | | |
| 3 | * NUMBER REQUIRED | | | | | | | |
| 4 | TYPE OF REFORMER | | | | | | | |
| 5 | TOTAL HEATER ABSORBED DUTY, MW. | Radiant: | | Convection: | | Total: | | |
| 6 | **PROCESS DESIGN CONDITIONS (RADIANT SECTION)** | | | | | | | REV |
| 7 | * OPERATING CASE | | | | | | | |
| 8 | * PLANT CAPACITY, $Nm^3/hr$ $H_2$ | | | | | | | |
| 9 | HEAT ABSORPTION, MW. | | | | | | | |
| 10 | * PRESSURE DROP: ALLOWABLE , kPa. [1] | | | | | | | |
| 11 | PRESSURE DROP: CALCULATED, (CATALYST / TOTAL), kPa. | | | | | | | |
| 12 | AVERAGE HEAT FLUX, (INSIDE BASIS), $W/m^2$. | | | | | | | |
| 13 | | INLET | | | OUTLET | | | |
| 14 | * FLUID | | | | | | | |
| 15 | * FLOWRATE, DRY GAS, kg/s. | | | | | | | |
| 16 | STEAM, kg/s. | | | | | | | |
| 17 | TOTAL, kg/s. | | | | | | | |
| 18 | * AVERAGE MOLECULAR WEIGHT (WET) | | | | | | | |
| 19 | * TEMPERATURE, °C. | | | | | | | |
| 20 | * PRESSURE, (kPag): @ INLET MANIFOLD | | | | --- | | | |
| 21 | @ CATALYST TUBE | | | | | | | |
| 22 | @ EXIT TRANSFER LINE | --- | | | | | | |
| 23 | * COMPOSITION, (Mole %) (lb-mole/hr). | | | | | | | |
| 24 | $H_2$ | | | | | | | |
| 25 | $CH_4$ | | | | | | | |
| 26 | $C_2H_6$ | | | | | | | |
| 27 | $C_3H_8$ | | | | | | | |
| 28 | $C_4H_{10}$ | | | | | | | |
| 29 | $C_5H_{12}$ | | | | | | | |
| 30 | $H_2O$ | | | | | | | |
| 31 | CO | | | | | | | |
| 32 | $CO_2$ | | | | | | | |
| 33 | $N_2$ | | | | | | | |
| 34 | TOTAL | | | | | | | |
| 35 | | | | | | | | |
| 36 | APPROACH TO EQUILIBRIUM, °C. | | | | | | | |
| 37 | **CATALYST:** | | | | | | | |
| 38 | LOADING | TOP | | | BOTTOM | | | |
| 39 | PERCENT SPLIT BY VOLUME, %. | | | | | | | |
| 40 | HEATED VOLUME, $m^3$. | | | | | | | |
| 41 | TYPE / SHAPE | | | | | | | |
| 42 | SIZE | | | | | | | |
| 43 | MANUFACTURER | | | | | | | |
| 44 | **MECHANICAL DESIGN CONDITIONS FOR PRESSURE PARTS:** | | | | | | | |
| 45 | LOCATION | INLET | | CATALYST | OUTLET | | | |
| 46 | | PIGTAILS | MANIFOLDS | TUBE | PIGTAILS | MANIFOLDS | T.L. [2] | |
| 47 | * BASIS FOR TUBE WALL THICKNESS (CODE / SPEC.) | | | | | | | |
| 48 | * BASIS FOR RUPTURE STRENGTH (MIN. OR AVG.) | | | | | | | |
| 49 | * DESIGN LIFE, hr. | | | | | | | |
| 50 | DESIGN PRESSURE, kPag. | | | | | | | |
| 51 | * TEMPERATURE ALLOWANCE, °C. | | | | | | | |
| 52 | DESIGN METAL TEMPERATURE, °C. | | | | | | | |
| 53 | * CORROSION ALLOWANCE, mm. | | | | | | | |
| 54 | NOTES: | | | | | | | |
| 55 | 1. From inlet of inlet manifold to exit of transfer line. | | | | | | | |
| 56 | 2. Transfer line. | | | | | | | |
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| **REFORMING FURNACE DATASHEET** | | | | | **PROJECT No.:** | |
| | | | | | **ITEM No.:** | |
| | | | | | **REVISION No.:** | |
| **SI Units** | | | | | **SHEET NO.:** 3 of 10 | |

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|---|---|---|---|---|---|---|
| 1 | **PROCESS DESIGN CONDITIONS (CONVECTION SECTION)** | | | | | **REV** |
| 2 | * **OPERATING CASE** | | | | | |
| 3 | **COIL No.** | | | | | |
| 4 | * **SERVICE** | | | | | |
| 5 | **HEAT ABSORPTION, MW.** | | | | | |
| 6 | * **FLUID** | | | | | |
| 7 | **FLOW RATE, kg/s.** | | | | | |
| 8 | * **PRESSURE DROP: ALLOWABLE, kPa.** | | | | | |
| 9 | **PRESSURE DROP: CALCULATED, kPa.** | | | | | |
| 10 | **CONV. SECT. HEAT FLUX, (BARE TUBE), W/m$^2$.** | | | | | |
| 11 | **PROCESS FLUID MASS VELOCITY, kg/sec-m$^2$.** | | | | | |
| 12 | **MAX. CALCULATED INSIDE FILM TEMPERATURE, $^o$C.** | | | | | |
| 13 | * **FOULING FACTOR, m$^2$-$^o$K/W.** | | | | | |
| 14 | **INLET CONDITIONS:** | | | | | |
| 15 | * **TEMPERATURE, $^o$C.** | | | | | |
| 16 | * **PRESSURE, (kPag) (kPaa).** | | | | | |
| 17 | * **LIQUID FLOW, kg/s.** | | | | | |
| 18 | * **VAPOR FLOW, kg/s.** | | | | | |
| 19 | * **WEIGHT PERCENT VAPOR** | | | | | |
| 20 | * **LIQUID DENSITY, kg/m$^3$** | | | | | |
| 21 | * **LIQUID VISCOSITY, mPa.s.** | | | | | |
| 22 | * **LIQUID SPECIFIC HEAT, kJ/kg-$^o$K.** | | | | | |
| 23 | * **LIQUID THERMAL CONDUCTIVITY, W/m-$^o$K.** | | | | | |
| 24 | * **VAPOR MOLECULAR WEIGHT** | | | | | |
| 25 | * **VAPOR VISCOSITY, mPa.s.** | | | | | |
| 26 | * **VAPOR SPECIFIC HEAT, kJkg-$^o$K.** | | | | | |
| 27 | * **VAPOR THERMAL CONDUCTIVITY, W/m-$^o$K.** | | | | | |
| 28 | **OUTLET CONDITIONS:** | | | | | |
| 29 | * **TEMPERATURE, $^o$C.** | | | | | |
| 30 | * **PRESSURE, (psig) (psia).** | | | | | |
| 31 | * **LIQUID FLOW, kg/s.** | | | | | |
| 32 | * **VAPOR FLOW, kg/s.** | | | | | |
| 33 | * **WEIGHT PERCENT VAPOR** | | | | | |
| 34 | * **LIQUID DENSITY, kg/m$^3$** | | | | | |
| 35 | * **LIQUID VISCOSITY, mPa.s.** | | | | | |
| 36 | * **LIQUID SPECIFIC HEAT, kJ/kg-$^o$K.** | | | | | |
| 37 | * **LIQUID THERMAL CONDUCTIVITY, W/m-$^o$K.** | | | | | |
| 38 | * **VAPOR MOLECULAR WEIGHT** | | | | | |
| 39 | * **VAPOR VISCOSITY, mPa.s.** | | | | | |
| 40 | * **VAPOR SPECIFIC HEAT, kJkg-$^o$K.** | | | | | |
| 41 | * **VAPOR THERMAL CONDUCTIVITY, W/m-$^o$K.** | | | | | |
| 42 | **NOTES:** | | | | | |
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|---|---|---|---|---|---|---|
| | | ITEM No.: | | | | |
| | | REVISION No.: | | | | |
| | | SHEET NO.: 4 of 10 | | | | |
| 1 | **COMBUSTION DESIGN CONDITIONS** | | | | | REV |
| 2 | OPERATING CASE | | | | | |
| 3 | * TYPE OF FUEL | | | | | |
| 4 | EXCESS AIR, % | | | | | |
| 5 | CALCULATED HEAT RELEASE (LHV), MW. | | | | | |
| 6 | FUEL 1: | | | | | |
| 7 | FUEL 2: | | | | | |
| 8 | FUEL 3: | | | | | |
| 9 | TOTAL | | | | | |
| 10 | FUEL EFFICIENCY, CALCULATED, % (LHV). | | | | | |
| 11 | FUEL EFFICIENCY, GUARANTEED, % (LHV). | | | | | |
| 12 | RADIATION LOSS, % OF HEAT RELEASE (LHV). | | | | | |
| 13 | FLUE GAS TEMPERATURE PROFILE, $^{o}$C: | | | | | |
| 14 | EXIT RADIANT SECTION | | | | | |
| 15 | EXIT CONV. COIL: CC-1 | | | | | |
| 16 | CC-2 | | | | | |
| 17 | CC-3 | | | | | |
| 18 | CC-4 | | | | | |
| 19 | CC-5 | | | | | |
| 20 | CC-6 | | | | | |
| 21 | CC-7 | | | | | |
| 22 | CC-8 | | | | | |
| 23 | INLET SCR UNIT | | | | | |
| 24 | INLET AIR PREHEATER | | | | | |
| 25 | EXIT AIR PREHEATER / ID FAN INLET | | | | | |
| 26 | STACK | | | | | |
| 27 | FLUE GAS QUANTITY, kg/s. | | | | | |
| 28 | FLUE GAS MASS VELOCITY IN CONVECTION SECTION, kg/s-m$^{2}$. | | | | | |
| 29 | FLUE GAS PRESSURE PROFILE, Pa. | | | | | |
| 30 | ARCH | | | | | |
| 31 | EXIT CONVECTION SECTION | | | | | |
| 32 | INLET AIR PREHEATER | | | | | |
| 33 | INLET ID FAN | | | | | |
| 34 | INLET STACK | | | | | |
| 35 | COMBUSTION AIR QUANTITY, kg/s. | | | | | |
| 36 | AIR TEMPERATURE @ BURNER, $^{o}$C. | | | | | |
| 37 | COMBUSTION AIR PRESSURE PROFILE, Pa. : | | | | | |
| 38 | FD FAN INLET | | | | | |
| 39 | FD FAN OUTLET | | | | | |
| 40 | AIR PREHEATER OUTLET | | | | | |
| 41 | BURNER INLET | | | | | |
| 42 | * AMBIENT AIR TEMPERATURE, EFFICIENCY CALCULATION, $^{o}$C. | | | | | |
| 43 | * AMBIENT AIR TEMPERATURE, DRAFT CALCULATION, $^{o}$C. | | | | | |
| 44 | * ALTITUDE ABOVE SEA LEVEL, m. | | | | | |
| 45 | **FUEL DATA** | | | | | |
| 46 | * FUEL 1: TYPE | | | | | |
| 47 | * FUEL 2 :TYPE | | | | | |
| 48 | * FUEL 3 :TYPE | | | | | |
| 49 | COMPOSITION, TEMPERATURE & PRESSURE | SEE BURNER DATASHEET FOR DETAILS | | | | |
| 50 | **BURNER DATA** | | | | | |
| 51 | LOCATION | | | | | |
| 52 | ORIENTATION | | | | | |
| 53 | NUMBER OF ROWS | | | | | |
| 54 | NUMBER PER ROW | | | | | |
| 55 | TOTAL NUMBER | | | | | |
| 56 | HEAT RELEASE PER BURNER, DESIGN \| NORMAL, MW (LHV). | | | | | |
| 57 | MANUFACTURER, MODEL No., TYPE, ANCILLARIES | SEE BURNER DATASHEET FOR DETAILS | | | | |
| 58 | NOTES: | | | | | |
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| | | | | ITEM No.: |
| | | | | REVISION No.: |
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| # | | | | | REV |
|---|---|---|---|---|---|
| 1 | **SITE DATA** | | | | |
| 2 | * PLOT LIMITATIONS: | * MIN. STACK HEIGHT: | * NOISE LIMITATIONS, dBA.: | | |
| 3 | * STRUCTURAL DESIGN DATA: SEISMIC ZONE: | | * WIND VELOCITY, m/s. : | | |
| 4 | WIND EXPOSURE: | | * SNOW LOAD, kg/m$^3$: | | |
| 5 | * MIN. / NORMAL / MAX. AMBIENT AIR TEMPERATURE, $^o$C.: | | * RELATIVE HUMIDITY, %: | | |
| 6 | **MECHANICAL DESIGN CONDITIONS** | | | | |
| 7 | **REFORMER SECTION:** | RADIANT SECTION | | | |
| 8 | **CATALYST TUBES:** | | | | |
| 9 | TUBE ARRANGEMENT: IN LINE OR STAGGERED | | | | |
| 10 | NUMBER OF TUBES | | | | |
| 11 | NUMBER OF TUBE ROWS \| NUMBER OF TUBES PER ROW | | | | |
| 12 | HEATED TUBE LENGTH \| OVERALL TUBE LENGTH, mm. | | | | |
| 13 | EFFECTIVE INSIDE TUBE SURFACE, m$^2$. | | | | |
| 14 | TUBE MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 15 | TUBE INSIDE DIAMETER, mm. | | | | |
| 16 | TUBE WALL THICKNESS, (MINIMUM SOUND WALL), mm. | | | | |
| 17 | MAXIMUM CALC. TUBE WALL TEMPERATURE, $^o$C. | | | | |
| 18 | POST WELD HEAT TREATMENT (YES OR NO) | | | | |
| 19 | PERCENT OF WELDS FULLY RADIOGRAPHED | | | | |
| 20 | HYDROSTATIC TEST PRESSURE, kPag. | | | | |
| 21 | SPACING, mm. TUBE SPACING CENTER TO CENTER | | | | |
| 22 | ROW TO ROW | | | | |
| 23 | LAST ROW TO WALL | | | | |
| 24 | CATALYST SUPPORT GRID: MATERIAL | | | | |
| 25 | TUBE SUPPORT: TYPE \| LOCATION | | | | |
| 26 | **CATALYST TUBE TERMINALS:** | | | | |
| 27 | | INLET | OUTLET | | |
| 28 | LOCATION | | | | |
| 29 | END FLANGE, MATERIAL SPECIFICATION | | | | |
| 30 | SIZE & RATING | | | | |
| 31 | CAST REDUCER, TYPE / MATERIAL SPECIFICATION | ---- | | | |
| 32 | SIZE | ---- | | | |
| 33 | **PIGTAILS:** | | | | |
| 34 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 35 | SIZE (NPS OR OUTSIDE DIAMETER), mm. | | | | |
| 36 | WALL THICKNESS, (MINIMUM) (AVERAGE), mm. | | | | |
| 37 | PIGTAIL TO TUBE CONNECTION: TYPE | | | | |
| 38 | PIGTAIL LOCATION: TOP FLANGE OR SIDE INLET | | ---- | | |
| 39 | **INLET MANIFOLDS:** | | | | |
| 40 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 41 | SIZE (NPS OR OUTSIDE/INSIDE DIAMETER), mm. | | | | |
| 42 | WALL THICKNESS, (MINIMUM) (AVERAGE), mm. | | | | |
| 43 | PIGTAIL TO MANIFOLD CONNECTION: TYPE | | | | |
| 44 | **OUTLET MANIFOLDS:** | | | | |
| 45 | TYPE | HOT | COLD | TRANSFER LINE | |
| 46 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 47 | SIZE (NPS OR OUTSIDE/INSIDE DIAMETER), mm. | | | | |
| 48 | WALL THICKNESS, (MINIMUM) (AVERAGE), mm. | | | | |
| 49 | PIGTAIL TO MANIFOLD CONNECTION: TYPE | | | --- | |
| 50 | INTERNAL LINING: MATERIAL & THICKNESS, mm. | --- | | | |
| 51 | | --- | | | |
| 52 | TRANSFER LINE SHELL TEMPERATURE, $^o$C. | --- | | | |
| 53 | NOTES: | | | | |
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## REFORMING FURNACE DATASHEET

SI Units

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| PROJECT No.: | |
| ITEM No.: | |
| REVISION No.: | |
| SHEET No.: | 6 of 10 |

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|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | REV |
| 2 | **REFORMER SECTION:** | **CONVECTION SECTION** | | | | |
| 3 | SERVICE | | | | | |
| 4 | COIL NO. | | | | | |
| 5 | **COIL DESIGN:** | | | | | |
| 6 | * DESIGN BASIS: TUBE WALL THICKNESS (CODE / SPEC.) | | | | | |
| 7 | * RUPTURE STRENGTH (MINIMUM OR AVERAGE) | | | | | |
| 8 | * DESIGN LIFE, hr. | | | | | |
| 9 | * DESIGN PRESSURE, ELASTIC \| RUPTURE, kPag. | | | | | |
| 10 | * DESIGN FLUID TEMPERATURE, °C. | | | | | |
| 11 | TEMPERATURE ALLOWANCE, °C. | | | | | |
| 12 | * CORROSION ALLOWANCE, mm. | | | | | |
| 13 | HYDROSTATIC TEST PRESSURE, kPag. | | | | | |
| 14 | POST WELD HEAT TREATMENT (YES OR NO) | | | | | |
| 15 | PERCENT OF WELDS FULLY RADIOGRAPHED | | | | | |
| 16 | MAX. TUBE METAL TEMPERATURE, (CALCULATED), °C. | | | | | |
| 17 | INSIDE FILM COEFFICIENT, W/m²-°K. | | | | | |
| 18 | MAXIMUM TUBE METAL TEMPERATURE, (DESIGN), °C. | | | | | |
| 19 | **COIL ARRANGEMENT:** | | | | | |
| 20 | TUBE ORIENTATION: VERTICAL OR HORIZONTAL | | | | | |
| 21 | TUBE MATERIAL (ASTM SPEC. AND GRADE) | | | | | |
| 22 | TUBE OUTSIDE DIAMETER, mm. | | | | | |
| 23 | TUBE WALL THICKNESS, (MINIMUM) (AVERAGE), mm. | | | | | |
| 24 | NUMBER OF FLOW PASSES | | | | | |
| 25 | NUMBER OF TUBES | | | | | |
| 26 | NUMBER OF TUBES PER ROW \| NUMBER OF ROWS | | | | | |
| 27 | OVERALL TUBE LENGTH, mm. | | | | | |
| 28 | EFFECTIVE TUBE LENGTH, mm. | | | | | |
| 29 | BARE TUBES: NUMBER | | | | | |
| 30 | TOTAL EXPOSED SURFACE, m². | | | | | |
| 31 | EXTENDED SURFACE TUBE! NUMBER | | | | | |
| 32 | TOTAL EXPOSED SURFACE, m². | | | | | |
| 33 | TUBE ARRANGEMENT: IN LINE OR STAGGERED | | | | | |
| 34 | TUBE SPACING, CENTER TO CENTER HORIZONTAL, mm. | | | | | |
| 35 | DIAGONAL, mm. | | | | | |
| 36 | VERTICAL, mm. | | | | | |
| 37 | SPACING TUBE CENTER TO FURNACE WALL, mm. | | | | | |
| 38 | CORBEL (YES OR NO) | | | | | |
| 39 | CORBEL WIDTH, mm. | | | | | |
| 40 | **DESCRIPTION OF EXTENDED SURFACE:** | | | | | |
| 41 | TYPE: (STUDS) (SERRATED FINS) (SOLID FINS) | | | | | |
| 42 | MATERIAL | | | | | |
| 43 | DIMENSIONS: HEIGHT, mm. | | | | | |
| 44 | THICKNESS, mm. | | | | | |
| 45 | SPACING (FINS / m.) | | | | | |
| 46 | MAXIMUM TIP TEMPERATURE, (CALCULATED), °C. | | | | | |
| 47 | EXTENSION RATIO (TOTAL AREA / BARE AREA) | | | | | |
| 48 | **FLOW SEQUENCE:** | | | | | |
| 49 | FLUE GAS FLOW DIRECTION (UP / DOWN / HORIZONTAL) | | | | | |
| 50 | COIL ARRANGEMENT: COCURENT OR COUNTER CURRENT | | | | | |
| 51 | NOTES: | | | | | |
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| REFORMING FURNACE DATASHEET<br>SI Units | | | | | | PROJECT No.: |
|---|---|---|---|---|---|---|
| | | | | | | ITEM No.: |
| | | | | | | REVISION No.: |
| | | | | | | SHEET No.: 7 of 10 |
| 1 | MECHANICAL DESIGN CONDITIONS (Cont'd) | | | | | REV |
| 2 | **REFORMER SECTION:** | CONVECTION SECTION | | | | |
| 3 | SERVICE | | | | | |
| 4 | COIL NO. | | | | | |
| 5 | **RETURN BENDS:** | | | | | |
| 6 | TYPE | | | | | |
| 7 | MATERIAL (ASTM SPEC. AND GRADE) | | | | | |
| 8 | NOMINAL SIZE & SCHEDULE | | | | | |
| 9 | LOCATION (H.B.= HEADER BOX) | | | | | |
| 10 | **TERMINALS AND OR MANIFOLDS:** | | | | | |
| 11 | TYPE: MANIFOLD, BEVELED OR FLANGED | | | | | |
| 12 | INLET: PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 13 | SIZE (NPS OR O.D., mm.) | | | | | |
| 14 | SCHEDULE OR THICKNESS, mm. | | | | | |
| 15 | NUMBER OF TERMINALS | | | | | |
| 16 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 17 | FLANGE SIZE AND RATING | | | | | |
| 18 | OUTLET: PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 19 | SIZE (NPS OR O.D., mm.) | | | | | |
| 20 | SCHEDULE OR THICKNESS, mm. | | | | | |
| 21 | NUMBER OF TERMINALS | | | | | |
| 22 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 23 | FLANGE SIZE AND RATING | | | | | |
| 24 | MANIFOLD TO TUBE CONN. (WELDED, EXTRUDED, ETC.) | | | | | |
| 25 | MANIFOLD LOCATION (INSIDE OR OUTSIDE HEADER BOX) | | | | | |
| 26 | **CROSSOVERS:** | | | | | |
| 27 | WELDED OR FLANGED | | | | | |
| 28 | PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 29 | PIPE SIZE (NPS OR O.D., mm.) | | | | | |
| 30 | SCHEDULE OR THICKNESS | | | | | |
| 31 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 32 | FLANGE SIZE AND RATING | | | | | |
| 33 | LOCATION | | | | | |
| 34 | FLUID TEMPERATURE, °C. | | | | | |
| 35 | **TUBE SUPPORTS:** | | | | | |
| 36 | LOCATION (ENDS, TOP, BOTTOM) | | | | | |
| 37 | MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 38 | DESIGN METAL TEMPERATURE, °C. | | | | | |
| 39 | THICKNESS, in. | | | | | |
| 40 | INSULATION: THICKNESS, mm. | | | | | |
| 41 | MATERIAL | | | | | |
| 42 | ANCHOR (MATERIAL & TYPE) | | | | | |
| 43 | **INTERMEDIATE TUBE SUPPORTS:** | | | | | |
| 44 | MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 45 | DESIGN METAL TEMPERATURE, °C. | | | | | |
| 46 | THICKNESS, mm. | | | | | |
| 47 | SPACING, mm. | | | | | |
| 48 | **HEADER BOXES:** | | | | | |
| 49 | LOCATION: | | HINGED DOOR / BOLTED PANEL: | | | |
| 50 | CASING MATERIAL: | | THICKNESS, mm.: | | | |
| 51 | LINING MATERIAL: | | THICKNESS, mm.: | | | |
| 52 | ANCHOR (MATERIAL & TYPE): | | | | | |
| 53 | NOTES: | | | | | |
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| REFORMING FURNACE DATASHEET | |
|---|---|
| | PROJECT No.: |
| | ITEM No.: |
| | REVISION No.: |
| SI Units | SHEET No.: 8 of 10 |

| No. | | | | | | | REV |
|---|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | | REV |
| 2 | **REFRACTORY DESIGN BASIS:** | | | | | | |
| 3 | AMBIENT, °C.: | WIND VELOCITY, m/s.: | | CASING TEMP., WALLS \| FLOOR, °C.: | | | |
| 4 | **EXPOSED VERTICAL SIDE WALLS:** | | | | | | |
| 5 | LINING THICKNESS, mm.: | HOT FACE TEMPERATURE, DESIGN, °C.: | | | CALCULATED, °C.: | | |
| 6 | WALL CONSTRUCTION: | | | | | | |
| 7 | | | | | | | |
| 8 | ANCHOR (MATERIAL & TYPE): | | | | | | |
| 9 | CASING MATERIAL: | THICKNESS, mm.: | | | TEMPERATURE, °C.: | | |
| 10 | **EXPOSED VERTICAL END WALLS:** | | | | | | |
| 11 | LINING THICKNESS, mm.: | HOT FACE TEMPERATURE, DESIGN, °C.: | | | CALCULATED, °C.: | | |
| 12 | WALL CONSTRUCTION: | | | | | | |
| 13 | | | | | | | |
| 14 | ANCHOR (MATERIAL & TYPE): | | | | | | |
| 15 | CASING MATERIAL: | THICKNESS, in.: | | | TEMPERATURE, °F.: | | |
| 16 | **ARCH:** | | | | | | |
| 17 | LINING THICKNESS, mm.: | HOT FACE TEMPERATURE, DESIGN, °C.: | | | CALCULATED, °C.: | | |
| 18 | WALL CONSTRUCTION: | | | | | | |
| 19 | | | | | | | |
| 20 | ANCHOR (MATERIAL & TYPE): | | | | | | |
| 21 | CASING MATERIAL: | THICKNESS, mm.: | | | TEMPERATURE, °C.: | | |
| 22 | **FLOOR:** | | | | | | |
| 23 | LINING THICKNESS, mm.: | HOT FACE TEMPERATURE, DESIGN, °C.: | | | CALCULATED, °C.: | | |
| 24 | FLOOR CONSTRUCTION: | | | | | | |
| 25 | | | | | | | |
| 26 | CASING MATERIAL: | THICKNESS, mm.: | | | TEMPERATURE, °C.: | | |
| 27 | MINIMUM FLOOR ELEVATION, mm.: | | | | | | |
| 28 | **CONVECTION SECTION:** | | | | | | |
| 29 | LINING THICKNESS, mm.: | HOT FACE TEMPERATURE, DESIGN, °C.: | | | CALCULATED, °C.: | | |
| 30 | WALL CONSTRUCTION: | | | | | | |
| 31 | | | | | | | |
| 32 | ANCHOR (MATERIAL & TYPE): | | | | | | |
| 33 | CASING MATERIAL: | THICKNESS, mm.: | | | TEMPERATURE, °C.: | | |
| 34 | **RADIANT TO CONVECTION TRANSITION DUCTS:** | | | | | | |
| 35 | LOCATION: | FLOOR | | WALL | | ROOF | |
| 36 | LINING THICKNESS & MATERIAL, mm | | | | | | |
| 37 | | | | | | | |
| 38 | CASING MATERIAL \| THICKNESS, mm. | | | | | | |
| 39 | ANCHOR (MATERIAL & TYPE): | | | | | | |
| 40 | CASING TEMPERATURE, °C. | | | | | | |
| 41 | **FLUE GAS TUNNELS:** | | | | | | |
| 42 | LOCATION: | | MATERIAL: | | | | |
| 43 | INTERNAL DIMENSIONS: HEIGHT x WIDTH, mm.: | | | | | | |

| No. | | | | | | | | REV |
|---|---|---|---|---|---|---|---|---|
| 44 | **DUCTS:** | FLUE GAS | | | COMBUSTION AIR | | | |
| 45 | LOCATION | | | | | | | |
| 46 | NET FREE AREA, $m^2$. | | | | | | | |
| 47 | CASING MATERIAL | | | | | | | |
| 48 | CASING THICKNESS, mm. | | | | | | | |
| 49 | LINING: INTERNAL / EXTERNAL | | | | | | | |
| 50 | MATERIAL | | | | | | | |
| 51 | THICKNESS, mm. | | | | | | | |
| 52 | ANCHOR (MATERIAL & TYPE) | | | | | | | |
| 53 | CASING TEMPERATURE, °C. | | | | | | | |
| 54 | NOTES: | | | | | | | |
| 55 | | | | | | | | |
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# REFORMING FURNACE DATASHEET

SI Units

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| PROJECT No.: | |
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| REVISION No.: | |
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| | | | | | | REV |
|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | |
| 2 | **STACK:** | | | | | |
| 3 | NUMBER: | SELF-SUPPORTED OR GUYED: | | | | |
| 4 | LOCATION: | CASING MATERIAL: | | MIN. THICKNESS, mm. | | |
| 5 | INSIDE METAL DIAMETER, mm.: | HEIGHT ABOVE GRADE, mm.: | | STACK LENGTH, mm. | | |
| 6 | LINING THICKNESS, mm.: | LINING MATERIAL: | | | | |
| 7 | ANCHOR (MATERIAL AND TYPE): | | EXTENT OF LINING: | | | |
| 8 | INTERNAL OR EXTERNAL: | | EXIT FLUE GAS VELOCITY, m/s.: | | | |
| 9 | **DAMPERS:** | | | | | |
| 10 | LOCATION | | | | | |
| 11 | TYPE (CONTROL, TIGHT SHUT-OFF, ETC.) | | | | | |
| 12 | MATERIAL: BLADE | | | | | |
| 13 | SHAFT | | | | | |
| 14 | MULTIPLE / SINGLE LEAF | | | | | |
| 15 | PROVISION FOR OPERATION (MANUAL OR AUTO.) | | | | | |
| 16 | TYPE OF OPERATOR (CABLE OR PNEUMATIC) | | | | | |
| 17 | **PLATFORMS:** | | | | | |
| 18 | LOCATION: | WIDTH | LENGTH / ARC | STAIRS/LADDER | ACCESS FROM | |
| 19 | | | | | | |
| 20 | | | | | | |
| 21 | | | | | | |
| 22 | | | | | | |
| 23 | | | | | | |
| 24 | TYPE OF FLOORING: | | | | | |
| 25 | **DOORS:** | | | | | |
| 26 | TYPE: | NUMBER | LOCATION | SIZE | BOLTED/HINGED | |
| 27 | ACCESS | | | | | |
| 28 | | | | | | |
| 29 | OBSERVATION | | | | | |
| 30 | | | | | | |
| 31 | TUBE REMOVAL | | | | | |
| 32 | | | | | | |
| 33 | **MISCELLANEOUS:** | | | | | |
| 34 | INSTRUMENT CONNECTIONS: | | NUMBER | SIZE | TYPE | |
| 35 | COMBUSITON AIR: TEMPERATURE | | | | | |
| 36 | PRESSURE | | | | | |
| 37 | FLUE GAS: TEMPERATURE | | | | | |
| 38 | PRESSURE | | | | | |
| 39 | FLUE GAS SAMPLE | | | | | |
| 40 | SNUFFING STEAM / PURGE | | | | | |
| 41 | O2 ANALYZER | | | | | |
| 42 | VENTS / DRAINS | | | | | |
| 43 | PROCESS FLUID TEMPERATURE | | | | | |
| 44 | TUBESKIN THERMOCOUPLES | | | | | |
| 45 | EPA STACK SAMPLING PORTS | | | | | |
| 46 | CEMS | | | | | |
| 47 | PAINTING REQUIREMENTS: | | | | | |
| 48 | | | | | | |
| 49 | INTERNAL COATING: | | | | | |
| 50 | GALVANIZING REQUIREMENTS: | | | | | |
| 51 | PENTHOUSE: MATERIAL OF CONSTRUCTION | | | | | |
| 52 | AIR CIRCULATION REQUIREMENTS | | | | | |
| 53 | SPECIAL EQUIPMENT: AIR PREHEATER | | | | | |
| 54 | FD & ID FANS | | | | | |
| 55 | SCR / AUX. BOILER | | | | | |
| 56 | STEAM/AIR HEATER | | | | | |
| 57 | NOTES: | | | | | |
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| **REFORMING FURNACE DATASHEET** | **PROJECT No.:** |
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| **ENGINEERING NOTES** | **REV** |
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| PURCHASER / OWNER: | ITEM No.: |
|---|---|
| SERVICE: | LOCATION: |

# REFORMING FURNACE DATASHEET

**API STD. 561**

Note:
***** next to an API datasheet entry indicates purchaser required input.

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| **REV** | **DATE** | **REVISION LOG** | **BY** | **CHECKED** | **APP'D** | **APP'D** |

| | | | | |
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| **US CUSTOMARY UNITS** | **PROJECT NUMBER** | **DATASHEET NUMBER** | **SHEET** | **REV** |
| | | | 1 OF 10 | |

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## REFORMING FURNACE DATASHEET

**US Customary Units**

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| PROJECT No.: | |
| ITEM No.: | |
| REVISION No.: | |
| SHEET No.: | 2 of 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | * UNIT | | | | | | | |
| 2 | MANUFACTURER | | | | | | | |
| 3 | * NUMBER REQUIRED | | | | | | | |
| 4 | TYPE OF REFORMER | | | | | | | |
| 5 | TOTAL HEATER ABSORBED DUTY, MM Btu/hr. | Radiant: | | Convection: | | Total: | | |
| 6 | **PROCESS DESIGN CONDITIONS (RADIANT SECTION)** | | | | | | | REV |
| 7 | * OPERATING CASE | | | | | | | |
| 8 | * PLANT CAPACITY, MMSCFD $H_2$ | | | | | | | |
| 9 | HEAT ABSORPTION, MM Btu/hr. | | | | | | | |
| 10 | * PRESSURE DROP: ALLOWABLE , psi. [1] | | | | | | | |
| 11 | PRESSURE DROP: CALCULATED, (CATALYST / TOTAL), psi. | | | | | | | |
| 12 | AVERAGE HEAT FLUX, (INSIDE BASIS), Btu/hr-ft$^2$. | | | | | | | |
| 13 | | INLET | | | OUTLET | | | |
| 14 | * FLUID | | | | | | | |
| 15 | * FLOWRATE, DRY GAS, lb/hr. | | | | | | | |
| 16 | STEAM, lb/hr. | | | | | | | |
| 17 | TOTAL, lb/hr. | | | | | | | |
| 18 | * AVERAGE MOLECULAR WEIGHT (WET) | | | | | | | |
| 19 | * TEMPERATURE, °F. | | | | | | | |
| 20 | * PRESSURE, (psig) (psia): @ INLET MANIFOLD | | | | --- | | | |
| 21 | @ CATALYST TUBE | | | | | | | |
| 22 | @ EXIT TRANSFER LINE | --- | | | | | | |
| 23 | * COMPOSITION, (Mole %) (lb-mole/hr). | | | | | | | |
| 24 | $H_2$ | | | | | | | |
| 25 | $CH_4$ | | | | | | | |
| 26 | $C_2H_6$ | | | | | | | |
| 27 | $C_3H_8$ | | | | | | | |
| 28 | $C_4H_{10}$ | | | | | | | |
| 29 | $C_5H_{12}$ | | | | | | | |
| 30 | $H_2O$ | | | | | | | |
| 31 | CO | | | | | | | |
| 32 | $CO_2$ | | | | | | | |
| 33 | $N_2$ | | | | | | | |
| 34 | TOTAL | | | | | | | |
| 35 | | | | | | | | |
| 36 | APPROACH TO EQUILIBRIUM, °F. | | | | | | | |
| 37 | **CATALYST:** | | | | | | | |
| 38 | LOADING | TOP | | | BOTTOM | | | |
| 39 | PERCENT SPLIT BY VOLUME, % | | | | | | | |
| 40 | HEATED VOLUME, ft$^3$. | | | | | | | |
| 41 | TYPE / SHAPE | | | | | | | |
| 42 | SIZE | | | | | | | |
| 43 | MANUFACTURER | | | | | | | |
| 44 | **MECHANICAL DESIGN CONDITIONS FOR PRESSURE PARTS:** | | | | | | | |
| 45 | LOCATION | INLET | | CATALYST | OUTLET | | | |
| 46 | | PIGTAILS | MANIFOLDS | TUBE | PIGTAILS | MANIFOLDS | T.L. [2] | |
| 47 | * BASIS FOR TUBE WALL THICKNESS (CODE / SPEC.) | | | | | | | |
| 48 | * BASIS FOR RUPTURE STRENGTH (MIN. OR AVG.) | | | | | | | |
| 49 | * DESIGN LIFE, hr. | | | | | | | |
| 50 | DESIGN PRESSURE, psig. | | | | | | | |
| 51 | * TEMPERATURE ALLOWANCE, °F. | | | | | | | |
| 52 | DESIGN METAL TEMPERATURE, °F. | | | | | | | |
| 53 | * CORROSION ALLOWANCE, in. | | | | | | | |
| 54 | NOTES: | | | | | | | |
| 55 | 1. From inlet of inlet manifold to exit of transfer line. | | | | | | | |
| 56 | 2. Transfer line. | | | | | | | |
| 57 | | | | | | | | |
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| | **REFORMING FURNACE DATASHEET** | | | | **PROJECT No.:** | |
| | | | | | **ITEM No.:** | |
| | | | | | **REVISION No.:** | |
| | **US Customary Units** | | | | **SHEET NO.:** 3 of 10 | |
| 1 | **PROCESS DESIGN CONDITIONS (CONVECTION SECTION)** | | | | | **REV** |
| 2 | * **OPERATING CASE** | | | | | |
| 3 | **COIL No.** | | | | | |
| 4 | * **SERVICE** | | | | | |
| 5 | **HEAT ABSORPTION, MM Btu/hr.** | | | | | |
| 6 | * **FLUID** | | | | | |
| 7 | **FLOW RATE, lb/hr.** | | | | | |
| 8 | * **PRESSURE DROP: ALLOWABLE, psi.** | | | | | |
| 9 | **PRESSURE DROP: CALCULATED, psi.** | | | | | |
| 10 | **CONV. SECT. HEAT FLUX, (BARE TUBE), Btu/hr-ft$^2$.** | | | | | |
| 11 | **PROCESS FLUID MASS VELOCITY, lb/sec-ft$^2$.** | | | | | |
| 12 | **MAX. CALCULATED INSIDE FILM TEMPERATURE, $^o$F.** | | | | | |
| 13 | * **FOULING FACTOR, hr-ft$^2$-$^o$F/Btu.** | | | | | |
| 14 | **INLET CONDITIONS:** | | | | | |
| 15 | * **TEMPERATURE, $^o$F.** | | | | | |
| 16 | * **PRESSURE, (psig) (psia).** | | | | | |
| 17 | * **LIQUID FLOW, lb/hr.** | | | | | |
| 18 | * **VAPOR FLOW, lb/hr.** | | | | | |
| 19 | * **WEIGHT PERCENT VAPOR** | | | | | |
| 20 | * **LIQUID DENSITY, lb/ft$^3$** | | | | | |
| 21 | * **LIQUID VISCOSITY, cP.** | | | | | |
| 22 | * **LIQUID SPECIFIC HEAT, Btu/lb-$^o$F.** | | | | | |
| 23 | * **LIQUID THERMAL CONDUCTIVITY, Btu/hr-ft-$^o$F.** | | | | | |
| 24 | * **VAPOR MOLECULAR WEIGHT** | | | | | |
| 25 | * **VAPOR VISCOSITY, cP.** | | | | | |
| 26 | * **VAPOR SPECIFIC HEAT, Btu/lb-$^o$F.** | | | | | |
| 27 | * **VAPOR THERMAL CONDUCTIVITY, Btu/hr-ft-$^o$F.** | | | | | |
| 28 | **OUTLET CONDITIONS:** | | | | | |
| 29 | * **TEMPERATURE, $^o$F.** | | | | | |
| 30 | * **PRESSURE, (psig) (psia).** | | | | | |
| 31 | * **LIQUID FLOW, lb/hr.** | | | | | |
| 32 | * **VAPOR FLOW, lb/hr.** | | | | | |
| 33 | * **WEIGHT PERCENT VAPOR** | | | | | |
| 34 | * **LIQUID DENSITY, lb/ft$^3$** | | | | | |
| 35 | * **LIQUID VISCOSITY, cP.** | | | | | |
| 36 | * **LIQUID SPECIFIC HEAT, Btu/lb-$^o$F.** | | | | | |
| 37 | * **LIQUID THERMAL CONDUCTIVITY, Btu/hr-ft-$^o$F.** | | | | | |
| 38 | * **VAPOR MOLECULAR WEIGHT** | | | | | |
| 39 | * **VAPOR VISCOSITY, cP.** | | | | | |
| 40 | * **VAPOR SPECIFIC HEAT, Btu/lb-$^o$F.** | | | | | |
| 41 | * **VAPOR THERMAL CONDUCTIVITY, Btu/hr-ft-$^o$F.** | | | | | |
| 42 | **NOTES:** | | | | | |
| 43 | | | | | | |
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| REFORMING FURNACE DATASHEET | PROJECT No.: |
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| | REVISION No.: |
| US Customary units | SHEET NO.: 4 of 10 |

| | | | | | | REV |
|---|---|---|---|---|---|---|
| 1 | **COMBUSTION DESIGN CONDITIONS** | | | | | |
| 2 | OPERATING CASE | | | | | |
| 3 | * TYPE OF FUEL | | | | | |
| 4 | EXCESS AIR, % | | | | | |
| 5 | CALCULATED HEAT RELEASE (LHV), MM Btu/hr. | | | | | |
| 6 | FUEL 1: | | | | | |
| 7 | FUEL 2: | | | | | |
| 8 | FUEL 3: | | | | | |
| 9 | TOTAL | | | | | |
| 10 | FUEL EFFICIENCY, CALCULATED, % (LHV). | | | | | |
| 11 | FUEL EFFICIENCY, GUARANTEED, % (LHV). | | | | | |
| 12 | RADIATION LOSS, % OF HEAT RELEASE (LHV). | | | | | |
| 13 | FLUE GAS TEMPERATURE PROFILE, $^{o}$F: | | | | | |
| 14 | EXIT RADIANT SECTION | | | | | |
| 15 | EXIT CONV. COIL: CC-1 | | | | | |
| 16 | CC-2 | | | | | |
| 17 | CC-3 | | | | | |
| 18 | CC-4 | | | | | |
| 19 | CC-5 | | | | | |
| 20 | CC-6 | | | | | |
| 21 | CC-7 | | | | | |
| 22 | CC-8 | | | | | |
| 23 | INLET SCR UNIT | | | | | |
| 24 | INLET AIR PREHEATER | | | | | |
| 25 | EXIT AIR PREHEATER / ID FAN INLET | | | | | |
| 26 | STACK | | | | | |
| 27 | FLUE GAS QUANTITY, lb/hr. | | | | | |
| 28 | FLUE GAS MASS VELOCITY IN CONVECTION SECTION, lb/sec-ft$^2$. | | | | | |
| 29 | FLUE GAS PRESSURE PROFILE, in. $H_2O$. | | | | | |
| 30 | ARCH | | | | | |
| 31 | EXIT CONVECTION SECTION | | | | | |
| 32 | INLET AIR PREHEATER | | | | | |
| 33 | INLET ID FAN | | | | | |
| 34 | INLET STACK | | | | | |
| 35 | COMBUSTION AIR QUANTITY, lb/hr. | | | | | |
| 36 | AIR TEMPERATURE @ BURNER, $^{o}$F. | | | | | |
| 37 | COMBUSTION AIR PRESSURE PROFILE, in. $H_2O$: | | | | | |
| 38 | FD FAN INLET | | | | | |
| 39 | FD FAN OUTLET | | | | | |
| 40 | AIR PREHEATER OUTLET | | | | | |
| 41 | BURNER INLET | | | | | |
| 42 | * AMBIENT AIR TEMPERATURE, EFFICIENCY CALCULATION, $^{o}$F. | | | | | |
| 43 | * AMBIENT AIR TEMPERATURE, DRAFT CALCULATION, $^{o}$F. | | | | | |
| 44 | * ALTITUDE ABOVE SEA LEVEL, ft. | | | | | |
| 45 | **FUEL DATA** | | | | | |
| 46 | * FUEL 1: TYPE | | | | | |
| 47 | * FUEL 2 :TYPE | | | | | |
| 48 | * FUEL 3 :TYPE | | | | | |
| 49 | COMPOSITION, TEMPERATURE & PRESSURE | SEE BURNER DATASHEET FOR DETAILS | | | | |
| 50 | **BURNER DATA** | | | | | |
| 51 | LOCATION | | | | | |
| 52 | ORIENTATION | | | | | |
| 53 | NUMBER OF ROWS | | | | | |
| 54 | NUMBER PER ROW | | | | | |
| 55 | TOTAL NUMBER | | | | | |
| 56 | HEAT RELEASE PER BURNER, DESIGN \| NORMAL, MM Btu/hr (LHV). | | | | | |
| 57 | MANUFACTURER, MODEL No., TYPE, ANCILLARIES | SEE BURNER DATASHEET FOR DETAILS | | | | |
| 58 | NOTES: | | | | | |
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| | | | | | REV |
|---|---|---|---|---|---|
| 1 | SITE DATA | | | | |
| 2 | * PLOT LIMITATIONS: | * MIN. STACK HEIGHT: | * NOISE LIMITATIONS, dBA.: | | |
| 3 | * STRUCTURAL DESIGN DATA: SEISMIC ZONE: | | * WIND VELOCITY, mph. : | | |
| 4 | WIND EXPOSURE: | | * SNOW LOAD, lb/ft$^3$: | | |
| 5 | * MIN. / NORMAL / MAX. AMBIENT AIR TEMPERATURE, $^o$F.: | | * RELATIVE HUMIDITY, %: | | |
| 6 | MECHANICAL DESIGN CONDITIONS | | | | |
| 7 | REFORMER SECTION: | RADIANT SECTION | | | |
| 8 | CATALYST TUBES: | | | | |
| 9 | TUBE ARRANGEMENT: IN LINE OR STAGGERED | | | | |
| 10 | NUMBER OF TUBES | | | | |
| 11 | NUMBER OF TUBE ROWS \| NUMBER OF TUBES PER ROW | | | | |
| 12 | HEATED TUBE LENGTH \| OVERALL TUBE LENGTH, ft. | | | | |
| 13 | EFFECTIVE INSIDE TUBE SURFACE, ft$^2$. | | | | |
| 14 | TUBE MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 15 | TUBE INSIDE DIAMETER, in. | | | | |
| 16 | TUBE WALL THICKNESS, (MINIMUM SOUND WALL), in. | | | | |
| 17 | MAXIMUM CALC. TUBE WALL TEMPERATURE, $^o$F. | | | | |
| 18 | POST WELD HEAT TREATMENT (YES OR NO) | | | | |
| 19 | PERCENT OF WELDS FULLY RADIOGRAPHED | | | | |
| 20 | HYDROSTATIC TEST PRESSURE, psig. | | | | |
| 21 | SPACING, in. TUBE SPACING CENTER TO CENTER | | | | |
| 22 | ROW TO ROW | | | | |
| 23 | LAST ROW TO WALL | | | | |
| 24 | CATALYST SUPPORT GRID: MATERIAL | | | | |
| 25 | TUBE SUPPORT: TYPE \| LOCATION | | | | |
| 26 | CATALYST TUBE TERMINALS: | | | | |
| 27 | | INLET | OUTLET | | |
| 28 | LOCATION | | | | |
| 29 | END FLANGE, MATERIAL SPECIFICATION | | | | |
| 30 | SIZE & RATING | | | | |
| 31 | CAST REDUCER, TYPE / MATERIAL SPECIFICATION | ---- | | | |
| 32 | SIZE | ---- | | | |
| 33 | PIGTAILS: | | | | |
| 34 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 35 | SIZE (NPS OR OUTSIDE DIAMETER), in. | | | | |
| 36 | WALL THICKNESS, (MINIMUM) (AVERAGE), in. | | | | |
| 37 | PIGTAIL TO TUBE CONNECTION: TYPE | | | | |
| 38 | PIGTAIL LOCATION: TOP FLANGE OR SIDE INLET | | ---- | | |
| 39 | INLET MANIFOLDS: | | | | |
| 40 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 41 | SIZE (NPS OR OUTSIDE/INSIDE DIAMETER), in. | | | | |
| 42 | WALL THICKNESS, (MINIMUM) (AVERAGE), in. | | | | |
| 43 | PIGTAIL TO MANIFOLD CONNECTION: TYPE | | | | |
| 44 | OUTLET MANIFOLDS: | | | | |
| 45 | TYPE | HOT | COLD | TRANSFER LINE | |
| 46 | MATERIAL (ASTM SPECIFICATION AND GRADE) | | | | |
| 47 | SIZE (NPS OR OUTSIDE/INSIDE DIAMETER), in. | | | | |
| 48 | WALL THICKNESS, (MINIMUM) (AVERAGE), in. | | | | |
| 49 | PIGTAIL TO MANIFOLD CONNECTION: TYPE | | | --- | |
| 50 | INTERNAL LINING: MATERIAL & THICKNESS, in. | --- | | | |
| 51 | | --- | | | |
| 52 | TRANSFER LINE SHELL TEMPERATURE, $^o$F. | --- | | | |
| 53 | NOTES: | | | | |
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|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | |
| 2 | **REFORMER SECTION:** | CONVECTION SECTION | | | | |
| 3 | SERVICE | | | | | |
| 4 | COIL NO. | | | | | |
| 5 | **COIL DESIGN:** | | | | | |
| 6 | * DESIGN BASIS: TUBE WALL THICKNESS (CODE / SPEC.) | | | | | |
| 7 | * RUPTURE STRENGTH (MINIMUM OR AVERAGE) | | | | | |
| 8 | * DESIGN LIFE, hr. | | | | | |
| 9 | * DESIGN PRESSURE, ELASTIC \| RUPTURE, psig. | | | | | |
| 10 | * DESIGN FLUID TEMPERATURE, °F. | | | | | |
| 11 | TEMPERATURE ALLOWANCE, °F. | | | | | |
| 12 | * CORROSION ALLOWANCE, in. | | | | | |
| 13 | HYDROSTATIC TEST PRESSURE, psig. | | | | | |
| 14 | POST WELD HEAT TREATMENT (YES OR NO) | | | | | |
| 15 | PERCENT OF WELDS FULLY RADIOGRAPHED | | | | | |
| 16 | MAX. TUBE METAL TEMPERATURE, (CALCULATED), °F. | | | | | |
| 17 | INSIDE FILM COEFFICIENT, Btu/hr-ft$^2$-°F. | | | | | |
| 18 | MAXIMUM TUBE METAL TEMPERATURE, (DESIGN), °F. | | | | | |
| 19 | **COIL ARRANGEMENT:** | | | | | |
| 20 | TUBE ORIENTATION: VERTICAL OR HORIZONTAL | | | | | |
| 21 | TUBE MATERIAL (ASTM SPEC. AND GRADE) | | | | | |
| 22 | TUBE OUTSIDE DIAMETER, in. | | | | | |
| 23 | TUBE WALL THICKNESS, (MINIMUM) (AVERAGE), in. | | | | | |
| 24 | NUMBER OF FLOW PASSES | | | | | |
| 25 | NUMBER OF TUBES | | | | | |
| 26 | NUMBER OF TUBES PER ROW \| NUMBER OF ROWS | | | | | |
| 27 | OVERALL TUBE LENGTH, ft. | | | | | |
| 28 | EFFECTIVE TUBE LENGTH, ft. | | | | | |
| 29 | BARE TUBES: NUMBER | | | | | |
| 30 | TOTAL EXPOSED SURFACE, ft$^2$. | | | | | |
| 31 | EXTENDED SURFACE TUBES NUMBER | | | | | |
| 32 | TOTAL EXPOSED SURFACE, ft$^2$. | | | | | |
| 33 | TUBE ARRANGEMENT: IN LINE OR STAGGERED | | | | | |
| 34 | TUBE SPACING, CENTER TO CENTER HORIZONTAL, in. | | | | | |
| 35 | DIAGONAL, in. | | | | | |
| 36 | VERTICAL, in. | | | | | |
| 37 | SPACING TUBE CENTER TO FURNACE WALL, in. | | | | | |
| 38 | CORBEL (YES OR NO) | | | | | |
| 39 | CORBEL WIDTH, in. | | | | | |
| 40 | **DESCRIPTION OF EXTENDED SURFACE:** | | | | | |
| 41 | TYPE: (STUDS) (SERRATED FINS) (SOLID FINS) | | | | | |
| 42 | MATERIAL | | | | | |
| 43 | DIMENSIONS: HEIGHT, in. | | | | | |
| 44 | THICKNESS, in. | | | | | |
| 45 | SPACING (FINS / in.) | | | | | |
| 46 | MAXIMUM TIP TEMPERATURE, (CALCULATED), °F. | | | | | |
| 47 | EXTENSION RATIO (TOTAL AREA / BARE AREA) | | | | | |
| 48 | **FLOW SEQUENCE:** | | | | | |
| 49 | FLUE GAS FLOW DIRECTION (UP / DOWN / HORIZONTAL) | | | | | |
| 50 | COIL ARRANGEMENT: COCURENT OR COUNTER CURRENT | | | | | |
| 51 | NOTES: | | | | | |
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|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | |
| 2 | **REFORMER SECTION:** | CONVECTION SECTION | | | | |
| 3 | SERVICE | | | | | |
| 4 | COIL NO. | | | | | |
| 5 | **RETURN BENDS:** | | | | | |
| 6 | TYPE | | | | | |
| 7 | MATERIAL (ASTM SPEC. AND GRADE) | | | | | |
| 8 | NOMINAL SIZE & SCHEDULE | | | | | |
| 9 | LOCATION (H.B.= HEADER BOX) | | | | | |
| 10 | **TERMINALS AND OR MANIFOLDS:** | | | | | |
| 11 | TYPE: MANIFOLD, BEVELED OR FLANGED | | | | | |
| 12 | INLET: PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 13 | SIZE (NPS OR O.D., in.) | | | | | |
| 14 | SCHEDULE OR THICKNESS, in. | | | | | |
| 15 | NUMBER OF TERMINALS | | | | | |
| 16 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 17 | FLANGE SIZE AND RATING | | | | | |
| 18 | OUTLET: PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 19 | SIZE (NPS OR O.D., in.) | | | | | |
| 20 | SCHEDULE OR THICKNESS, in. | | | | | |
| 21 | NUMBER OF TERMINALS | | | | | |
| 22 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 23 | FLANGE SIZE AND RATING | | | | | |
| 24 | MANIFOLD TO TUBE CONN. (WELDED, EXTRUDED, ETC.) | | | | | |
| 25 | MANIFOLD LOCATION (INSIDE OR OUTSIDE HEADER BOX) | | | | | |
| 26 | **CROSSOVERS:** | | | | | |
| 27 | WELDED OR FLANGED | | | | | |
| 28 | PIPE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 29 | PIPE SIZE (NPS OR O.D., in.) | | | | | |
| 30 | SCHEDULE OR THICKNESS | | | | | |
| 31 | FLANGE MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 32 | FLANGE SIZE AND RATING | | | | | |
| 33 | LOCATION | | | | | |
| 34 | FLUID TEMPERATURE, °F. | | | | | |
| 35 | **TUBE SUPPORTS:** | | | | | |
| 36 | LOCATION (ENDS, TOP, BOTTOM) | | | | | |
| 37 | MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 38 | DESIGN METAL TEMPERATURE, °F. | | | | | |
| 39 | THICKNESS, in. | | | | | |
| 40 | INSULATION: THICKNESS, in. | | | | | |
| 41 | MATERIAL | | | | | |
| 42 | ANCHOR (MATERIAL & TYPE) | | | | | |
| 43 | **INTERMEDIATE TUBE SUPPORTS:** | | | | | |
| 44 | MATERIAL (ASTM SPEC. & GRADE) | | | | | |
| 45 | DESIGN METAL TEMPERATURE, °F. | | | | | |
| 46 | THICKNESS, in. | | | | | |
| 47 | SPACING, ft. | | | | | |
| 48 | **HEADER BOXES:** | | | | | |
| 49 | LOCATION: | HINGED DOOR / BOLTED PANEL: | | | | |
| 50 | CASING MATERIAL: | THICKNESS, in.: | | | | |
| 51 | LINING MATERIAL: | THICKNESS, in.: | | | | |
| 52 | ANCHOR (MATERIAL & TYPE): | | | | | |
| 53 | NOTES: | | | | | |
| 54 | | | | | | |
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| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | REV |
| 2 | **REFRACTORY DESIGN BASIS:** | | | | |
| 3 | AMBIENT, °F.: | WIND VELOCITY, mph.: | | CASING TEMP., WALLS \| FLOOR, °F.: | |
| 4 | **EXPOSED VERTICAL SIDE WALLS:** | | | | |
| 5 | LINING THICKNESS, in.: | HOT FACE TEMPERATURE, DESIGN, °F.: | | CALCULATED, °F.: | |
| 6 | WALL CONSTRUCTION: | | | | |
| 7 | | | | | |
| 8 | ANCHOR (MATERIAL & TYPE): | | | | |
| 9 | CASING MATERIAL: | THICKNESS, in.: | | TEMPERATURE, °F.: | |
| 10 | **EXPOSED VERTICAL END WALLS:** | | | | |
| 11 | LINING THICKNESS, in.: | HOT FACE TEMPERATURE, DESIGN, °F.: | | CALCULATED, °F.: | |
| 12 | WALL CONSTRUCTION: | | | | |
| 13 | | | | | |
| 14 | ANCHOR (MATERIAL & TYPE): | | | | |
| 15 | CASING MATERIAL: | THICKNESS, in.: | | TEMPERATURE, °F.: | |
| 16 | **ARCH:** | | | | |
| 17 | LINING THICKNESS, in.: | HOT FACE TEMPERATURE, DESIGN, °F.: | | CALCULATED, °F.: | |
| 18 | WALL CONSTRUCTION: | | | | |
| 19 | | | | | |
| 20 | ANCHOR (MATERIAL & TYPE): | | | | |
| 21 | CASING MATERIAL: | THICKNESS, in.: | | TEMPERATURE, °F.: | |
| 22 | **FLOOR:** | | | | |
| 23 | LINING THICKNESS, in.: | HOT FACE TEMPERATURE, DESIGN, °F.: | | CALCULATED, °F.: | |
| 24 | FLOOR CONSTRUCTION: | | | | |
| 25 | | | | | |
| 26 | CASING MATERIAL: | THICKNESS, in.: | | | |
| 27 | MINIMUM FLOOR ELEVATION, ft.: | | | TEMPERATURE, °F.: | |
| 28 | **CONVECTION SECTION:** | | | | |
| 29 | LINING THICKNESS, in.: | HOT FACE TEMPERATURE, DESIGN, °F.: | | CALCULATED, °F.: | |
| 30 | WALL CONSTRUCTION: | | | | |
| 31 | | | | | |
| 32 | ANCHOR (MATERIAL & TYPE): | | | | |
| 33 | CASING MATERIAL: | THICKNESS, in.: | | TEMPERATURE, °F.: | |
| 34 | **RADIANT TO CONVECTION TRANSITION DUCTS:** | | | | |
| 35 | LOCATION: | FLOOR | WALL | ROOF | |
| 36 | LINING THICKNESS & MATERIAL, in. | | | | |
| 37 | | | | | |
| 38 | CASING MATERIAL \| THICKNESS, in. | | | | |
| 39 | ANCHOR (MATERIAL & TYPE): | | | | |
| 40 | CASING TEMPERATURE, °F. | | | | |
| 41 | **FLUE GAS TUNNELS:** | | | | |
| 42 | LOCATION: | | MATERIAL: | | |
| 43 | INTERNAL DIMENSIONS: HEIGHT x WIDTH, ft. | | | | |
| 44 | **DUCTS:** | **FLUE GAS** | | **COMBUSTION AIR** | |
| 45 | LOCATION | | | | |
| 46 | NET FREE AREA, $ft^2$. | | | | |
| 47 | CASING MATERIAL | | | | |
| 48 | CASING THICKNESS, in. | | | | |
| 49 | LINING: INTERNAL / EXTERNAL | | | | |
| 50 | MATERIAL | | | | |
| 51 | THICKNESS, in. | | | | |
| 52 | ANCHOR (MATERIAL & TYPE) | | | | |
| 53 | CASING TEMPERATURE, °F. | | | | |
| 54 | NOTES: | | | | |
| 55 | | | | | |
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|---|---|---|---|---|---|---|
| 1 | **MECHANICAL DESIGN CONDITIONS (Cont'd)** | | | | | |
| 2 | **STACK:** | | | | | |
| 3 | NUMBER: | SELF-SUPPORTED OR GUYED: | | | | |
| 4 | LOCATION: | CASING MATERIAL: | | MIN. THICKNESS, in.: | | |
| 5 | INSIDE METAL DIAMETER, ft.: | HEIGHT ABOVE GRADE, ft.: | | STACK LENGTH, ft.: | | |
| 6 | LINING THICKNESS, in.: | LINING MATERIAL: | | | | |
| 7 | ANCHOR (MATERIAL AND TYPE): | | EXTENT OF LINING: | | | |
| 8 | INTERNAL OR EXTERNAL: | | EXIT FLUE GAS VELOCITY, ft/s.: | | | |
| 9 | **DAMPERS:** | | | | | |
| 10 | LOCATION | | | | | |
| 11 | TYPE (CONTROL, TIGHT SHUT-OFF, ETC.) | | | | | |
| 12 | MATERIAL: BLADE | | | | | |
| 13 | SHAFT | | | | | |
| 14 | MULTIPLE / SINGLE LEAF | | | | | |
| 15 | PROVISION FOR OPERATION (MANUAL OR AUTO.) | | | | | |
| 16 | TYPE OF OPERATOR (CABLE OR PNEUMATIC) | | | | | |
| 17 | **PLATFORMS:** | | | | | |
| 18 | LOCATION: | WIDTH | LENGTH / ARC | STAIRS/LADDER | ACCESS FROM | |
| 19 | | | | | | |
| 20 | | | | | | |
| 21 | | | | | | |
| 22 | | | | | | |
| 23 | | | | | | |
| 24 | TYPE OF FLOORING: | | | | | |
| 25 | **DOORS:** | | | | | |
| 26 | TYPE: | NUMBER | LOCATION | SIZE | BOLTED/HINGED | |
| 27 | ACCESS | | | | | |
| 28 | | | | | | |
| 29 | OBSERVATION | | | | | |
| 30 | | | | | | |
| 31 | TUBE REMOVAL | | | | | |
| 32 | | | | | | |
| 33 | **MISCELLANEOUS:** | | | | | |
| 34 | INSTRUMENT CONNECTIONS: | | NUMBER | SIZE | TYPE | |
| 35 | COMBUSITON AIR: TEMPERATURE | | | | | |
| 36 | PRESSURE | | | | | |
| 37 | FLUE GAS: TEMPERATURE | | | | | |
| 38 | PRESSURE | | | | | |
| 39 | FLUE GAS SAMPLE | | | | | |
| 40 | SNUFFING STEAM / PURGE | | | | | |
| 41 | O2 ANALYZER | | | | | |
| 42 | VENTS / DRAINS | | | | | |
| 43 | PROCESS FLUID TEMPERATURE | | | | | |
| 44 | TUBESKIN THERMOCOUPLES | | | | | |
| 45 | EPA STACK SAMPLING PORTS | | | | | |
| 46 | CEMS | | | | | |
| 47 | PAINTING REQUIREMENTS: | | | | | |
| 48 | | | | | | |
| 49 | INTERNAL COATING: | | | | | |
| 50 | GALVANIZING REQUIREMENTS: | | | | | |
| 51 | PENTHOUSE: MATERIAL OF CONSTRUCTION | | | | | |
| 52 | AIR CIRCULATION REQUIREMENTS | | | | | |
| 53 | SPECIAL EQUIPMENT: AIR PREHEATER | | | | | |
| 54 | FD & ID FANS | | | | | |
| 55 | SCR / AUX. BOILER | | | | | |
| 56 | STEAM/AIR HEATER | | | | | |
| 57 | NOTES: | | | | | |
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# Annex C
(informative)

# Purchaser's Checklist

This checklist (Table C.1) is used to record the specific requirements the purchaser makes in response to the sections and subsections in this standard where bullets (●) are used to indicate that more information is required, or it is necessary to make a decision.

Completion of the checklist is the responsibility of the purchaser.

**Table C.1---Checklist for Reforming Furnaces**

<table>
<tr><th>Section</th><th>Requirement</th><th colspan="6">Action / Selection</th></tr>
<tr><td>4.2.1 e)</td><td>Completed noise data sheet with proposal</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.2.1 h)</td><td>A purchaser's list of vendors and fabricators proposed for the materials, fabrication, and equipment within the supplier's scope included with purchaser specification</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.2.1 k)</td><td>Supplier's experience and reference list for the applicable system with proposal</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.2.1 l)</td><td>Spare parts lists for commissioning, start-up, and two years of operation</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.3.3.1 f))</td><td>Noise data sheet for purchaser's review</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.3.3.1 g))</td><td>Tube-support design calculations for purchaser's review</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.3.3.1 i)</td><td>Provide preliminary results from CFD or cold flow modeling for purchaser's review</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.4.1.1</td><td>A performance test performed</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>4.5.1 b)</td><td>Update of final records (drawings and datasheets) for field changes</td><td colspan="6">Decision required between purchaser and supplier</td></tr>
<tr><td>5.1.1</td><td>Pressure design code specified by licensor</td><td colspan="6">Agreed between licensor and purchaser</td></tr>
<tr><td>5.1.3</td><td>Structural design code specified or agreed by purchaser</td><td colspan="3">Specified</td><td colspan="3">Agreed</td></tr>
<tr><td>5.1.6</td><td>Measures required to conform with all local and national regulations</td><td colspan="6">Decision required between purchaser and supplier</td></tr>
<tr><td>5.3.7</td><td>Design margin added to the calculated structural steel loads</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>6.3.1</td><td>Stress-rupture testing shall be performed in accordance with this standard</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>8.1.1</td><td>Any special welding procedures, testing, and other requirements of dissimilar metal welds.</td><td colspan="6">Agreed between purchaser and supplier</td></tr>
<tr><td>8.2.3</td><td>Purchaser specified information for the piping flexibility analysis</td><td colspan="6">Per project specification</td></tr>
<tr><td>10.1</td><td>Direct use of the normative statements in Annex D</td><td colspan="2">With mod.</td><td colspan="2">Without mod.</td><td colspan="2">Alternate</td></tr>
<tr><td>15.1.11</td><td>Purchaser specification of welding consumables for thermocouples or other non-pressure retaining attachments to pressure parts</td><td colspan="6">Per project specification</td></tr>
<tr><td>15.8.1</td><td>Equipment prepared and suitable for a minimum of six months of outdoor storage from the time of shipment</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>15.8.3</td><td>Purchaser approval of catalyst tube packing before shipment</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>16.1.3</td><td>Pre-inspection meetings between the purchaser and the supplier before the start of fabrication</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
</table>

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| Section | Requirement | Action / Selection | |
|---|---|---|---|
| 16.3.3 | Centrifugally cast tees and cones shall be examined in accordance with this standard | Yes | No |
| 16.5.2 | An equivalent alternative pressure testing procedure of a field assembled reforming furnace process circuit | Decision required between purchaser and supplier | |
| D.4.9.1 | Pressure relief door | Yes | No |

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# Annex D
(informative)

# Reformer Refractory Lining System

## D.1 Scope

NOTE 1 This annex provides refractory details unique to hydrogen and synthesis gas reforming furnaces in refineries and petrochemical plants and is intended to complement and supplement owner/purchaser specifications.

NOTE 2 When this annex is specified for normative use by the purchaser, suppliers should identify any exceptions or proposed alternative in their proposal. See 10.1.

NOTE 3 API standards referenced in Section 2 governing the installation quality control for three basic refractory forms; monolithic, brick, and fibers are intended to be used in combination with this annex relative to the refractory forms being used.

## D.2 Lining System Design - General

NOTE 1 The function of refractory linings in reforming furnaces is to provide thermal protection of structures on the flue gas side and of pressure boundaries on the process gas side. The refractory lining system design on the flue gas is similar to fired process heaters except the refractory hot face temperatures in the radiant section and tunnel walls are normally higher.

NOTE 2 Multiple refractory forms are used in different applications on the flue gas side. While similar higher operating temperature apply to the process gas side, unique process gas conditions preclude the use of brick and fiber refractories and defer to dual layer and/or alloy shrouded systems designed to prevent hot gas bypassing and avoid problems such as silica transport and cold side acid dew point corrosion.

## D.3 Material Temperature Requirements

NOTE The flue gas side of the furnace provides heat to the process side which flows through the tubes in the furnace. While radiant section temperatures are generally 150 °C to 165 °C (270 °F to 300 °F) higher than a common fired process heater, much of the refractory practice as defined in API 560 is similar, if not the same other than selecting refractories with higher use temperature ratings.

**D.3.1** The design temperature of hot-face linings shall be determined by the maximum operating temperature that the specific area of the refractory lining will be continuously exposed plus a temperature margin of 165 °C (300 °F). The design temperature shall be used for the selection of refractory material based on the continuous use temperature as defined by the refractory manufacturer.

**D.3.2** The maximum hot-face temperature for use of fiber shall not exceed a material classification temperature of 1426 °C (2600 °F) or continuous use temperature limit of 1343 °C (2450 °F).

NOTE Unless specified by the technology provider, the application of polycrystalline wool (PCW) fiber is not normally considered for hot-face linings in reforming furnaces designed and specified within the scope of this standard.

**D.3.3** The design temperature for backup layers of refractories shall be determined by calculation of the interface temperature between the hot and cold face of the lining plus 50 °C (90 °F). The calculated design temperature shall be used for selection of refractory material based on continuous-use temperature as defined by the refractory manufacturer.

NOTE The continuous use temperature for a refractory may not be the same as the maximum service temperature stated on the refractory manufacturer's product datasheet.

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## D.4 Lining System Design – Flue Gas Side

### D.4.1 General

Unless otherwise specified, the design and application of refractory lining systems for the flue gas side of hydrogen and synthesis gas reforming furnaces shall be in accordance with the requirements of API 560 as herein noted or amended.

### D.4.2 Radiant Section

Radiant section refractory lining systems shall be in accordance with API 560 with the following exceptions:

a) sidewall construction with exception to burner walls;

b) roof/bullnose construction with exception to handling high duty firebrick (HDFB) roofs.

### D.4.3 Convection Section

**D.4.3.1** Convection section refractory lining systems, including breeching, ducting and anchorage, shall be in accordance with API 560 with the following exceptions:

a) material selection and design for sidewall refractory, corbelling and tube sheet protection in consideration of the higher flue gas temperature and flue gas velocity;

b) material selection and design for header boxes in consideration of the potential for erosion due to flue gas velocity and/or tube leakage.

**D.4.3.2** The refractory contractor responsible for shop installed convection section modules shall address and document a plan to alleviate issues from possible alkali hydrolysis.

NOTE Plans may include controlled refractory dry-out, selection of monolithic materials less prone to alkali hydrolysis and/or possible coatings, or alternate refractory material lining system options.

### D.4.4 Flue Gas Tunnel Walls and Subfloor

**D.4.4.1** Refractory materials shall be selected for the calculated flue gas temperatures from the radiant section or maximum temperature due to flame impingement from tunnel burners where applicable,

**D.4.4.2** Walls shall be constructed with brick that has dimensional tolerances to within +/-1.6 mm (1/16 in.) on all nominal dimensions. Specification shall be at least HDFB, or appropriate grade insulating firebrick (IFB).

NOTE 1 Higher temperature grade brick may be required when tunnel burners are used.

NOTE 2 Other special designs may apply with approval from owner/purchaser.

**D.4.4.3** The dimensional tolerance for tunnel wall brick shall be +/-1.6 mm (1/16 in.) on all nominal dimensions.

NOTE Tongue and grove brick or other special/proprietary design brick constructions may be used when approved by the owner.

**D.4.4.4** Air set mortal shall be used in the wall construction with bricks.

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**D.4.4.5** Mortar joint shall be no greater than 3.2 mm (1/8 in.) for HDFB and no greater than 1.6 mm (1/16 in.) for IFB.

**D.4.4.6** When leveling is required, it shall be done using bedding placed gradually over the length of the wall to prevent distortion. Bedding shall be limited to the thickness of one brick.

**D.4.4.7** Shimming shall not be permitted.

**D.4.4.8** Buttress side walls or gussets shall be considered for lateral support and improved wall stability.

**D.4.4.9** Expansion joints shall be used between calculated wall sections to allow for reversible thermal expansion with a typical size of 12 mm to 19 mm (½ in.to ¾ in.). These joints shall not contain any mortar.

NOTE Expansion joints may contain fiber.

**D.4.4.10** Tunnel covers/slabs shall be extruded or precast and pre-fired shapes of proper refractory grade.

NOTE 1 Tunnel covers/slabs may incorporate tongue and groove or other joint design between pieces.

NOTE 2 Other special designs for tunnel covers/slabs may apply when approved by the owner.

**D.4.4.11** Tunnel covers/slabs shall be laid dry without mortar and capable of reversible expansion and contraction.

NOTE Alumina grain between the tunnel wall and cover may be required to provide unrestrained movement.

### D.4.5 Tunnel Wall Footer

**D.4.5.1** Castable or firebrick (HDFB or IFB) shall be used below the flue gas tunnel walls with material selection and construction evaluated to prevent overheating of the furnace floor and support structure.

### D.4.6 Radiant Section Burner Walls

NOTE 1 Refer to Figure D.1 illustrating an arrangement using radiant wall burners for a side wall fired reforming furnace.

NOTE 2 Other typical burner wall arrangements for reformer furnaces include side wall arrangements with multiple up-fired rows of burners, roof burner in a down fired reformer and floor burners in and up-fired reformer.

**D.4.6.1** Radiant section hot face refractory materials shall be designed with a minimum temperature rating of 1426 °C (2600 °F).

**D.4.6.2** Backup layers shall not be mineral wool.

NOTE Backup layers may be insulation board, block, or blanket.

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**Figure D.1—Side Wall Fired Reformer Furnace in Operation**

NOTE Refractory lined burner wall on left. Sight ports on opposite refractory lined end wall. Radiant tubes on right.

## D.4.7 Physical Openings

### D.4.7.1 Tube and Nozzle Penetrations

**D.4.7.1.1** Tube seals/seal boots for tube and nozzle penetrations shall be designed for the specific thermal movements, pressure, and temperature of the reformer furnace. Refer to Figure D.2. and Figure D.3 for example arrangements.

**D.4.7.1.2** Tube seals/seal boots shall be flexible and leak resistant.

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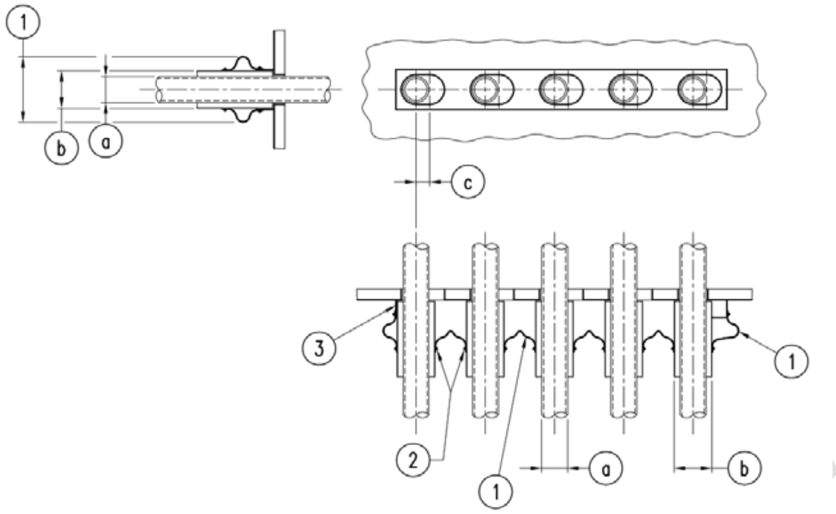


### Key

1 seal bag

2 type 304 clamps

3 type 304 flat bar with self-drilling screw

### Notes

[a] pipe outside diameter

[b] external insulation outside diameter

[c] lateral movement

**Figure D.2 – Gang Nozzles Tube Seals**

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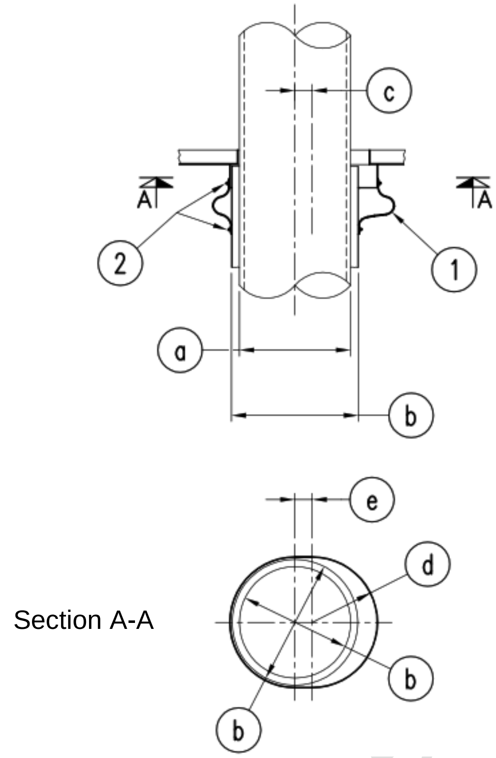


**Key**

1 seal bag

2 type 304 clamps

3 type 304 flat bar with self-drilling screw

**Notes**

[a] pipe outside diameter

[b] external insulation outside diameter

[c] lateral movement

[d] radius collar plate

[e] axial + lateral movement

**Figure D.3 –Nozzle Seal Boot**

## D.4.8 Access Doors and Observation Ports

**D.4.8.1** Material selection for the access doors, observation ports, and the refractory lining system surrounding access doors and observation ports (surrounds) shall consider the material compatibility and anchorage requirements of the related furnace setting.

**D.4.8.2** Material selection for the access door and observation port surrounds shall have a similar minimum service temperature rating to the furnace setting however can differ due to construction and exposure considerations. Refer to Table D.1 for consideration for such factors.

NOTE Fiber modules used for access door and observation port surrounds may have rigidizer applied after installation for additional surface durability and shape restraint.

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**Table D.1 – Relative Refractory Resistance to Key Parameters**

| | Flame Impingement | Excessive Temperture | Constructability | Thermal Shock Resistance | Water Intrusion | | |
|---|---|---|---|---|---|---|---|
| Vacuum formed ceramic fiber | - | + | + | + | - | | |
| Precast/prefired castable | + | + | + | - | + | | |
| Cast in place | + | + | - | - | + | | |
| Brick | + | + | - | + | + | | |
| Ceramic fiber modules | - | + | + | + | - | | |

**D.4.8.3** Access door and observation port surrounds construction shall be stable and not rely on door materials for anchorage.

**D.4.8.4** For access doors that swing open, the refractory material weight of shall be considered in design.

**D.4.8.5** For access doors using fiber modules, castable, or brick, a metallic retainer shroud on the door shall be used for added protection of refractory from mechanical abuse during removal and installation.

**D.4.8.6** Observation port plugs shall be custom shaped to fit the geometry of port closure.

**D.4.8.7** Access doors shall be located above tunnels and sized large enough for material and personnel ingress/egress for standard maintenance.

### D.4.9 Pressure Relief Doors

● **D.4.9.1** When specified by the licensor/owner, a pressure relief door shall be provided.

NOTE API 560 does require the use of pressure relief doors.

### D.4.10 Instrument Penetrations

The refractory lining system and anchorage shall be designed to accommodate any instrument connection penetrations without interference.

## D.5 Lining System Design – Process Gas Side

NOTE 1 The refractory lining system design of the process side of the hydrogen and synthesis gas reforming furnaces is very different from that on the flue gas side and not addressed in API 560.

NOTE 2 Refractory lining systems are often used in the process gas outlet collection system downstream of the reformer radiant section. The collection system components typically include outlet headers, a process gas transfer line, and a process gas boiler. The internal refractory lining protects the metallic pressure boundary from overheating/high-temperature corrosion, dew point of process gas at the cold face refractory lining systems are considered critical to the pressure integrity of the reforming furnace.

NOTE 3 Refractory lined process gas collection systems are typically referred to as cold or warm wall design.

NOTE 4 When refractory lining of collection headers is impractical due to size, a hot wall header design with external insulation is used.

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NOTE 5 Process gas going to other types of equipment, e.g. secondary reformer in an ammonia plant are beyond the scope of this standard.

**D.5.1.1** Unless otherwise specified by the technology provider, the refractory hot face temperature shall not be lower than the maximum process outlet temperature and in no case less than 871 °C (1600 °F).

NOTE The hydrogen content of the process gas, typically more than 50 %, can cause deterioration of refractories containing $SiO_2$ by volatilization of $SIO_2$ to a gas and increases the thermal conductivity of refractory material as a function of the refractory porosity.

**D.5.1.2** Refractory linings shall be thermally designed to provide a shell temperature at least 10 °C (18 °F) above the acid dew point of the process gas based on local ambient conditions.

NOTE The increased thermal conductivity of the refractory material due to the hydrogen content as noted in 5.1.1 is an important consideration for the heat transfer calculations and the overall design of the refractory lining system by the supplier/refractory contractor

**D.5.1.3** No castable lining or layer in the main transfer line shall be less than 75 mm (3 in.) in thickness.

NOTE 1 Refractory thickness may be adjusted for reducing cone, branches, nozzles etc.

**D.5.1.4** Unless otherwise specified, when a dual layer lining is used, the range of physical properties as shown in Table D.2 shall be used for refractory material selection.

**Table D.2 –Physical Property Requirements for Dual Layer Lining Systems in Cold Wall Outlet Headers and Transfer Lines**

| | **Hot Face Castable** | **Back-up Castable** |
|---|---|---|
| Density kg/m$^3$ (lb/ft$^3$) after firing to 815 °C (1500 °F) | 2400 -2725 (150 170) | not specified |
| Permanent Linear Change (PLC) after firing to 815 °C (1500 °F) | 0.3 % max. shrinkage | 0.8 % max. shrinkage |
| Cold Crushing Strength MPa (psi) per ASTM after firing to 815 °C (1500 °F) | 27 (4000) min. | 2 (300) min. |
| Use Temperature Rating | 1540 °C (2800 °F) min. | 1150 °C (2100 °F) min. |
| Iron Oxide | 0.5 % max. | 1.5 % max. |
| Silica | 0.5 % max. | not specified |

**D.5.1.5** Refractory material selections shall balance purity, maximum silica content, and potential carbonic acid dew point.

**D.5.1.6** The variation in local ambient conditions shall be taken into account in the thermal design of linings, including the use of a rain shield to avoid the potential for carbonic acid dew point.

## D.5.2 Refractory Design

**D.5.2.1** The refractory lining system in the headers and transfer line shall be one of the following, unless otherwise specified by the licensor:

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a. dual layer castable with low silica in the hot face layer;
b. single layer low silica insulating refractory;
c. alloy shrouded hot face with insulating castable behind the shroud;
d. water jacketed single layer dense hot face.

**D.5.2.2** Collection headers shall be either hot wall with external insulation or internally lined with refractory.

**D.5.2.3** Refractory linings shall not be used in headers with a final inside diameter less than 510 mm (20 in.) due to access restrictions. Design options for internal refractory linings are covered in D.4.2.1.

**D.5.2.4** The transfer line between the headers and the transition/inlet channel into the process gas boiler shall be internally refractory lined. Design options for the internal refractory linings are covered in D.4.2.1.

**D.5.2.5** Unless otherwise specified, the process gas boiler tube sheet refractory thickness shall be 75 mm to 100 mm (3 in.to 4 in.)

NOTE 1 Tubesheet refractory thickness and ferrules are typically specified by the process licensor.

NOTE 2 High alloy grade materials are typically specified for the tube sheet refractory lining and installed with a pressure or thermal fit.

**D.5.2.6** Tubesheet refractory material shall be low in iron and low in silica.

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## D.5.3 Additional Considerations

NOTE 1 For dual layer, cold wall refractory lining systems as illustrated in Figure D.4, there are two basic methods for placement; cast in place or precast.

**Figure D.4 – Cold Wall Process Gas Outlet Header**

NOTE 2 With a cast in place design, hot and cold face refractories are individually cast in place and thermally dried together.

NOTE 3 With a pre-cast design, high alumina castable hot face shapes are cast in forms and thermally dried before placement. The pre-cast and pre-fired shapes are placed in the pipe sections with lighter weight insulating castable installed behind to support and center the hot face shapes. Metallic anchors are used in the backup insulating lining.

NOTE 4 Refer to Figure D.5 for an illustration of the refractory configuration typical for a cold wall header with dual layer lining and a catalyst tube pigtail inlet.

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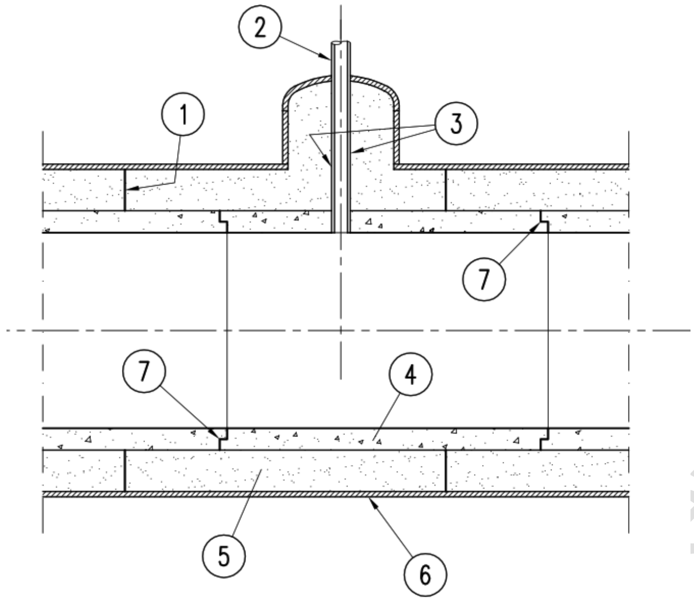


**Key**

1 backup cold joint
2 pigtail
3 ceramic fibre paper
4 refractory hot face layer
5 refractory backup layer
6 steel shell
7 stepped joint

**Figure D.5 –Typical Cold Wall Header with Dual Layer Lining and a Pigtail Inlet from Catalyst Tubes**

NOTE 5 Single layer lighter weight refractory linings are used successfully in specific process licensor designs. Traditional material specified is a low silica bubbled alumina castable. However, newer formulations using calcium aluminate low silica aggregate have also been used successfully

**D.5.3.1** Insulating castable material selection and anchorage for dual layer lining systems shall be designed to avoid cracks in the refractory, in particular, the dense hot face layer.

**D.5.3.2** Ceramic fiber used for nozzle sleeve wrapping shall be high alumina fiber to avoid silica volatilization problems.

**D.5.3.3** Alloy ferrules shall be used on the process gas boiler tube sheet refractory lining system.

NOTE Alloy ferrules are preferred for this application compared to ceramic ferrules due to their high temperature material properties and the thin wall design that minimizes process side pressure drop.

**D.5.3.4** Alloy sleeves/liners in headers and the transfer line shall be tight to the refractory to prevent process gas behind the liner.

**D.5.3.5** Seal cones shall be provided at transitions in the alloy sleeves/liners, particularly at locations when there are changes in direction or cross-section with respect to gas flow through the pipe

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NOTE 1 Process gas behind the sleeves/liners may cause deterioration of the refractory materials with potential for creating hot spots at the cold face of headers and the transfer line.

NOTE 2 Alloys that are not well matched in thermal expansion to the base metal may require bi-metallic welds in the more flexible portions of the cones to improve reliability.

## D.6 Refractory Dryout, Startup, and Shutdown

### D.6.1 Monolithic Refractory Dry Out

D.6.1.1 In some cases, process side refractory may be dried out with pressurized nitrogen using heat from the reformer furnace. In these situations, dryout heating schedules should be adjusted to account for differences in steam temperature.

NOTE 1 For dry out of monolithic refractory systems, see API 936.

### D.6.2 Brick, Fiber, and Previously Dried Refractory

**D.6.2.1** For previously dried out refractory linings, the heating rate shall not exceed 110 °C/h (200 °F/hr). When shutting down a unit, the cooling rate should not exceed 56 °C/hr (100 °F/h).

**D.6.2.2** Cooling down a refractory lined unit shall be done in a controlled manner to prevent thermal mechanical spalling, loosening, or shifting of the refractory especially the brick lining portion.

NOTE 1 Faster heating and cooling rates may be applied to fiber linings but only if there are no brick or castable refractories affected in the area.

NOTE 2 Heating the refractory too fast, before the shell reaches equilibrium, can add stress to the refractory lining resulting in thermal mechanical spalling of the refractory.

## D.7 Quality Control and Assurance

### D.7.1 Procedures

NOTE The purpose of QC provided by the refractory installer is to oversee and ensure all owner approved design and API specifications during installation are followed. The purpose of QA is to provide the owner with the assurance that the work being performed and documented is meeting owner's approved designs and specifications.

QC and QA procedures shall use owner specifications, project execution plan, API 936, API 975, and API 976, as reference documents for installation and material requirements.

### D.7.2 Inspection

**D.7.2.1** For brick installation, mortar shall not be used to change the taper of a brick.

**D.7.2.2** Expansion joints shall be verified with design drawings.

**D.7.2.3** Cutting of brick shapes shall only be allowed provided, the installation is periodically checked during installation.

**D.7.2.4** Installation of refractory for the tube sheet shall be monitored to verify proper installation.

**D.7.2.5** Ferrule fit up into the process gas boiler tubes shall be verified in accordance with the manufacturer's installation procedures.

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**D.7.2.6** Refractory linings shall be examined throughout for thickness variations during application and for cracks after curing in accordance with the following.

a) total refractory thickness tolerance:

- castable for process gas sections: -0/+5 mm (- 0/+3/16 in.);
- bricks, and slabs: +/- 1.5 mm (+/- 1/16 in.)
- castable for flue gas sections: -0/+6 mm (- 0/+1/4 in.);
- ceramic fiber: -0/+6 mm (- 0/+1/4 in.).

b) cracks:

- cracks in monolithic linings that are 3 mm (1/8 in.) or greater in width and penetrate more than 50 % of the castable thickness shall be repaired.

**D.7.2.7** Monolithic ling repairs shall be in accordance with the following:

a) Repairs shall be made by chipping out the unsound refractory to the backup layer interface or casing and exposing a minimum of three tieback anchors, or to sound metal.

b) Repair joints shall abut sound refractory that has a minimum inward slope of 25 mm (1 in.) to the base surface, i.e. dove-tail construction.

c) Refractory repairs shall be gunning, casting, or hand-packing.

## D.8 Inspection and Maintenance Requirements

### D.8.1 Tunnel Wall Inspection

NOTE 1 Ensure walls are within lateral movement tolerances specified by the purchaser/designer.

NOTE 2 Ensure expansion joints areas are open and free of interference and locations are within tolerance from the original placement.

NOTE 3 Confirm that covers/slabs do not have any cracks or defects.

CAUTION Do not step on tunnel slabs unless suitably covered by plywood to distribute the load.

NOTE 4 Ensure the floor and walls are level and plumb, within specified tolerances.

NOTE 5 Check brick for cracks, spalling, or defects.

NOTE 6 Ensure brick openings are in the correct location and free of debris.

NOTE 7 Ensure that the lateral restraint of the tunnel walls and bullnose is within design tolerances.

NOTE 8 Verify that the mortar joints are within tolerance and that dry joints are free of mortar.

NOTE 9 Ensure that tunnel wall slab expansion joints are installed correctly and do not contain mortar.

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# Annex E
(informative)

# Pre-commissioning Inspection—Catalyst Tubes and Convection Coil

NOTE This annex is provided as guidance to an owner for pre-commissioning inspections as part of an asset integrity program for pressure components in a reforming furnace.

## E.1 General

**E.1.1** Following mechanical completion of pressure parts, inspection of all catalyst tubes and convection section coils shall be conducted to establish a baseline record for future remaining life and fitness for service calculations.

**E.1.2** Baseline inspection data shall be used in fitness for service assessments to remove possible errors due to material thickness tolerances.

## E.2 Reformer Catalyst Tubes Inspection

NOTE After fabrication, an inspection is typically conducted from the outside diameter (OD) and/or inside diameter (ID) surfaces for future remaining life and fitness for service calculations.

**E.2.1** Inspection of reformer catalyst tubes prior to placing them into service shall be performed to detect manufacturing flaws such as over boring, gouges, excessive root penetration, etc. All flaws shall be accepted/rejected by the owner.

**E.2.2** OD/ID Based Inspection:

a) The application of automated/manual methods employing ultrasonic or eddy current crack detection technologies, laser or other profilometry methods, proximity sensors, individually or a combination thereof, to gather data relating to physical changes of the tube material shall be utilized for the inspection from the OD/ID.

b) The location specific baseline data shall be retained for comparison with the same location for physical changes during operation.

c) Any deviation in the diameter of tube sections both within and outside of the allowable machining tolerances existing on the various tube assemblies shall be accepted/rejected by the owner.

NOTE Refer to Table E 1 for reformer catalyst tube inspection requirements.

## E.3 Convection Coil Inspection

NOTE 1 Automated intelligent pigs or manual techniques can be used to map baseline data on convection coils for dimensional and wall thickness documentation.

NOTE 2 Refer to Table E.1 for convection section coil and header inspection requirements.

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**Table E.1—Catalyst Tubes and Convection Coil Inspection**

| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| 1.0. | Radiant section tubes and risers | | | | | |
| a. | Conduct external or internal scan using ultrasonic, eddy current, laser, profilometry dimensional measurements, or a combination utilizing automated/manual method. | | | | | |
| b. | Record data for future tube life assessment. | | | | | |
| 1.1 | Collection headers | | | | | |
| a. | Conduct OD measurements. | | | | | |
| b. | Record information for future remaining life assessment. | | | | | |
| 2.0 | Convection section coils and headers. | | | | | |
| a. | Record locations of tubes splice joints, if any. | | | | | |
| b. | Conduct outside diameter tube and wall thickness measurements. | | | | | |
| c. | Conduct header OD and wall thickness measurements. | | | | | |
| d. | Conduct pressure fitting (return bends/elbows) OD and wall thickness measurements. | | | | | |
| e. | Record information for future remaining life assessment. | | | | | |

a A = Acceptable
b U = Unacceptable
c NA = Not Applicable
d NI = Not Inspected

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# Annex F
(informative)

# On-stream Inspection and Testing

NOTE This annex is provided as guidance to an owner for on-stream inspection and testing as part of an asset integrity program for pressure components in a reforming furnace.

## F.1 Infrared Examination of High Temperature Surfaces

F.1.1 External surface temperature scan using infrared examinations for the integrity of the internal refractory and thermal lining systems are best conducted while the reformer and its components are in operation. The owner should specify frequency, procedures, and practices.

NOTE Areas scanned typically include furnace wall, floor, and arch panels; transition and convection sections; stack; and water jacketed components as applicable.

**F.1.2** A hot spot map shall be created, and appropriate action(s) taken during maintenance opportunities.

NOTE Refer to Table F.1 for guidance on on-stream inspection and testing.

## F.2 Visual Inspection and On-stream Monitoring of Reformer Components

**F.2.1** Routine, on-stream monitoring/inspection shall be performed. The owner shall specify frequency, procedures, and practices.

**F.2.2** All identified issues shall be documented, with actions taken in accordance with owner procedures and practices.

NOTE Recommendations for visual Inspection and on-stream monitoring of reformer components include the following:

- Observe internal refractory condition and appearance to identify problems with burner tiles, refractory, insulation modules, and floors.

- Observe burner flame pattern and appearance for proper operation including flame shape and size, burner component (e.g. fuel tips, air register, etc.) condition, no flame impingement on catalyst tubes and flame stability.

- Monitor temperature of the catalyst tubes with infrared, visual, or other applicable technologies. Accuracy of remaining life assessment depends on tube metal temperature measurement accuracy. Catalyst tube skin thermocouples are not considered to be reliable for reformer applications due to extremely high temperature.

- Observe catalyst tube condition and appearance such as bowing, hot spots, scaling, etc. Tube condition may provide indication of catalyst degradation.

- Monitor catalyst tube suspension system condition and appearance for uneven position, which may indicate differential tube growth, imbalances, binding, mechanical support problems, etc.

- Monitor external structures, transitions and convection sections, stack, and other reformer component condition and appearance for abnormalities.

NOTE Refer to Table F.1 for guidance on visual inspection and on-stream monitoring of reformer components.

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**Table F.1—On-stream Monitoring**

| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| 1.0. | Visual inspection of fired components | | | | | |
| a. | Perform visual inspection of the firebox and burner flame pattern regularly. | | | | | |
| b. | Monitor/record tube metal temperatures regularly. | | | | | |
| | | | | | | |
| 2.0 | Visual structural inspection. | | | | | |
| a. | Complete an external inspection to determine condition of the structure to look for signs of expansion/buckling, high temperature exposure & corrosion. | | | | | |
| b. | Inspect external equipment, blowdown valves, level gauges, external hangers/rods, insulation. | | | | | |
| c. | Inspect radiant tube hangers and/or counterweight systems for proper balance, clearance, and operation. | | | | | |
| d. | Inspect all load carrying structural steel members for observable deflection. | | | | | |
| e. | Conduct external infrared inspections of areas including but not limited to furnace wall panels, arch panels, floor panels, transition sections, and water jacketed components. | | | | | |
| f. | Inspect concrete foundations supporting the structures for damage. | | | | | |
| g. | Perform leak detection for air ingress or loss of draft. | | | | | |

a A = Acceptable
b U = Unacceptable
c NA = Not Applicable
d NI = Not Inspected

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# Annex G

(informative)
## Turnaround Reformer Inspections

NOTE This annex is provided as guidance to an owner for turnaround inspections of a reforming furnace.

## G.1 General

**G.1.1** The owner shall specify frequency, procedures, and practices for inspections in accordance with owner's mechanical integrity program.

**G.1.2** Observations shall be documented with actions taken in accordance with owner procedures and practices.

NOTE 1 Refer to Table G.1 lists damage mechanisms and specifies, examination options available for inspection of pressure part welds in reformers.

NOTE 2 Refer to Table G.2 for a list of recommended inspections to be performed during turnaround and serves as a record of inspection.

**G.1.3** During performance of internal firebox inspection, the catalyst tubes shall be protected from surface contaminates (e.g. zinc, sulfur, chloride, metals) to prevent associated damage mechanisms.

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**Table G.1—Weld Damaging Mechanisms and Inspection Options**

| Components | Weld Description | Damage Mechanism | Mechanical Completion Exam. [1] | Turnaround Exam. [1] | Repair Exam. [1] |
|---|---|---|---|---|---|
| Radiant Tubes | Tube to tube butt welds | Creep, weld defects, cracking | 1,2,3,5,6,7 | 1 | 1,2,3,5,6,7 |
| | Dissimilar tube to tube butt welds | Creep, ID cracking | 1,2,3,5,6,7 | 1, 2, and 3 or 4 | 1,2,3,5,6,7 |
| | Weldolet/support trunnion penetration welds | ID cracking | 1,4, 5, 6,7 | 1, 2 | 1,2,3,5,6,7 |
| | | | | | |
| Inlet/Outlet Pigtails | Butt welds to tube reducer | Creep / weld defects / cracking | 1,2,3,5,6,7 | 1,2 | 1,2,3,5,6,7 |
| | Butt/sockolet welds to headers | Creep / weld defects / cracking | 1,2,3,5,6,7 | 1,2 | 1,2,3,5,6,7 |
| | Tube to tube butt welds | Creep / cracking | 1,2,3 | 1,2 | 1,2,3,5,6,7 |
| | | | | | |
| Outlet Hot Collection Headers | Butt welds | Creep, OD, volumetric cracking | 1,2,3,5,6,7 | 1,2, and 3 or 4 | 1,2,3,5,6,7 |
| | Weldolet | Creep, OD, volumetric cracking | 2,3,4 | 1,2,4 | 1,2,4,6,7 |
| | Dissimilar metal welds | Creep/weld defects/ cracking | 1,2,3,5,6,7 | 1, 2, and 3 or 4 | 1,2,3,5,6,7 |
| Refractory Lined Transfer Line | Butt Welds | weld defects / cracking | 1,2,3,5,6,7 | 1, 2 and 3, or 1, 2 and 4 | 1,2,3,5,6,7 |
| Convection Shock Tubes | Butt welds (Closure joints) | Weld defects | 1,2,3,5,6,7 | 1,2 | 1,2,3,5,6,7 |

NOTE 1 Inspection/NDE Techniques: 1-Visual (VT), 2-Penetrant Examination (PT), 3-Radiographic Examination (RT)[a], 4-Ultrasonic Examination (UT)[b], 5 – PMI, 6 – Ferrite (if required by WPS), 7 – Leak Test

[a] -Includes conventional RT and digital / computerized methods
[b] -Includes computerized and UT TOFD and phased array methods

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## Table G.2—Turnaround Reformer Inspections

| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| 1.0 | Radiant Section - Refractory: | | | | | |
| a. | Inspect tunnel walls and covers for damage including leaning walls and broken tunnel covers. | | | | | |
| b. | Inspect walls for damaged or missing refractory anchor components, or damaged refractory lining | | | | | |
| c. | Inspect arch (internal ceiling for radiant section) for damaged or missing refractory modules. | | | | | |
| d. | Inspect transition section refractory to convection section. | | | | | |
| e. | Inspect auxiliary boiler and gas baffles behind boiler coils. | | | | | |
| f. | Inspect tunnel openings to ensure they match the design drawings. | | | | | |
| g. | Inspect refractory expansion joints to ensure foreign materials have been removed prior to placing reformer back into service. Tunnels covers should also be inspected. | | | | | |
| h. | Inspect tube seals where radiant tubes transition between penthouse and radiant box to ensure proper clearance/gaps. Improper gap or clearance will restrict tube axial movement to accommodate axial expansion. | | | | | |
| 2.0 | Burners: | | | | | |
| a. | Inspect position. | | | | | |
| b. | Inspect wind box, and instrument mountings. | | | | | |
| c. | Inspect burner tips. | | | | | |
| d. | Inspect burner tiles. | | | | | |
| e. | Burner view port. | | | | | |
| f. | Inspect air registers and expansion joints | | | | | |
| | | | | | | |
| 3.0 | Spring hangers supports and counterweights | | | | | |
| a. | Ensure all are in serviceable condition are not restricted. | | | | | |
| b. | Ensure that the radiant harp hangers are balanced. | | | | | |
| c. | Ensure all spring supports are not corroded, missing, or damaged. | | | | | |
| | | | | | | |
| 4.0 | Radiant Section | | | | | |

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| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| a. | Turnaround – Collect tube diameter data. | | | | | |
| b. | Record data into catalyst tube life assessment software for review. | | | | | |
| c. | Conduct collection header dimensional & weld examination. | | | | | |
| d | Inspect for distortions, warpage, bulging, dimensional changes, and surface condition of the system. | | | | | |
| e | Dye penetrant examination of the riser tube, if any, to collection header “O-Let” welds. | | | | | |
| f. | Inspect hot collection header insulation, if any, for damage prior to removal of insulation. | | | | | |
| g. | Dissimilar metal welds shall be examined by dye penetrant or other applicable methods. | | | | | |
| h. | Inspect all Bi-Metallic welds at the tube top if catalyst is removed using available technology. | | | | | |
| i. | Inlet pigtail visual examination. Dye penetrant examination of pigtail and tube top if required | | | | | |
| j. | Outlet Pigtail (if configured) visual examination, dimensional examination, dye penetrant examination of welds. | | | | | |
| k. | Internal inspection of catalyst tubes using video and other available technologies. | | | | | |
| l. | Prior to start up leak test shall be carried out (NOTE 1) | | | | | |
| m. | Random PT examination on catalyst tube outlets. | | | | | |
| n. | External scale. | | | | | |
| o. | External/Internal cleanliness. | | | | | |
| p. | External corrosion, pitting (describe location/depth/appearance) | | | | | |
| | | | | | | |
| 5.0 | Transfer Line | | | | | |
| a. | Inspect internal metal liner (if applicable) observe for damaged expansion joints and warped liner plates. | | | | | |
| b. | Inspect for exposed Internal refractory & pressure shell. | | | | | |
| c. | Inspect water jacket (if applicable) for corrosion and leaking. | | | | | |
| d. | Inspect support straps at top of transfer line for corrosion. | | | | | |
| e. | Inspect for corrosion on pressure shell at end of water jacket through temporary window cut in water jacket (if applicable) near entry flat cap. | | | | | |
| | | | | | | |
| 6.0 | Convection Section: | | | | | |

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| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| a. | Thermowells. | | | | | |
| b. | Internal refractory. | | | | | |
| c. | Flue gas deflection plates. | | | | | |
| d. | Individual headers, welds, dimensional changes, thickness | | | | | |
| e. | Individual coils - Welds, dimensional changes, thickness. | | | | | |
| f. | Inspect coil supports for damage | | | | | |
| g. | Individual finned components - check for fouling and fin damage. | | | | | |
| h. | OD measurements. | | | | | |
| i. | Pressure test for leaks if indicated | | | | | |
| j. | Dissimilar metal welds shall be examined by dye penetrant or other methods. | | | | | |
| | | | | | | |
| 7.0 | Radiant Section – External | | | | | |
| a. | Casing condition. | | | | | |
| b. | Coating condition. | | | | | |
| c. | Structural steel. | | | | | |
| | | | | | | |
| 8.0 | Convection Section - External | | | | | |
| a. | Casing condition. | | | | | |
| b. | Coating condition. | | | | | |
| c. | Structural steel | | | | | |
| | | | | | | |
| 9.0 | Other | | | | | |
| a. | | | | | | |
| b. | | | | | | |
| c. | | | | | | |
| d. | | | | | | |
| | | | | | | |
| 10.0 | Stack Assembly | | | | | |
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| | | | | | | |
| 11.0 | Foundation Bolts | | | | | |
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| | | | | | | |
| | | | | | | |
| 12.0 | Blower / ID Fan | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| 13.0 | Air Preheaters and Expansion Joints | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| 14.0 | SCR | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

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| # | Item Description | A [a] | U [b] | NA [c] | NI [d] | Comments |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| NOTE 1 Air or gas is hazardous when used as a testing medium. Refer to ASME PCC-2, Article 5.1, Appendix 2 & ASME PCC-2 Article 5.1, Appendix 3 for guidance on pressure testing and to ensure protection of personnel from the release of the total internal energy of the piping and other pressure components, including the use of a safe distance perimeter zone | | | | | | |
| a A = Acceptable<br>b U = Unacceptable<br>c NA = Not Applicable<br>d NI = Not Inspected | | | | | | |

## G.2 Reformer Catalyst Tubes Inspection

**G.2.1** Inspection of catalyst tubes shall be performed in accordance with G.1.2 for creep damage. Frequency of this inspection shall be determined by the owner's mechanical integrity program.

**G.2.2** External visual inspection of catalyst tubes shall be performed for bulging, scaling, bowing, and abnormalities.

**G.2.3** Catalyst tubes inspection for creep/stress rupture damage shall include dimensional change in diameter.

NOTE Recommendations for turnaround inspection of reformer components include the following:

- Inspect catalyst tubes for tube bowing for indication of tube support malfunction and for hindrance to thermal expansion of tubes or pigtails.

- Internal surfaces of catalyst tubes shall be inspected for surface flaws, weld defects, metal loss, fouling, and abnormalities using remote video equipment during catalyst replacement.

- Inspect the ID section of the reformer tube in the short length of catalyst tube above the side inlet pigtails, see Figure A.4, to detect ID initiated cracks due to thermal fatigue resulting from cyclic condensation and evaporation of water in syngas.

NOTE The condensation of the syngas gas inside the tube is caused by the insufficient insulation thickness at the top ends and/or insulation is not extended till top flange. This is observed typically in geographical areas with extreme cold and/or rain.

## G.3 Convection Coil Inspection

**G.3.1** Inspection of accessible section of convection coils shall include visual inspection and collection of dimensional and wall thickness data to assess the degree of thinning/deterioration.

**G.3.2** External visual inspection of the convection tubes shall be performed for surface flaws, scaling, bowing, sagging and abnormalities.

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# Annex H
(informative)

# Fitness for Service and Remaining Life Assessment

NOTE This annex is provided as guidance to an owner for fitness for service and remaining Life assessment of reforming furnace tube and pressure components operating in the creep rupture range.

## H.1 General

**H.1.1** Guidance on fitness for service and remaining life assessment of convection section coils, inlet headers, inlet pigtails, reformer catalyst tubes, outlet pigtails, and outlet manifolds is provided in this annex. The types of damage typically experienced by this equipment are indicated.

**H.1.2** When an unexpected type of damage is experienced, root-cause analysis should be performed to provide a sound basis for corrective measures and ensure that the applicable damage model is used for remaining life assessment.

**H.1.3** The owner should specify frequency, procedures, and practices. Fitness for service and remaining life assessments should be documented and action(s) taken in accordance with owner procedures and industry practices, which should be in accordance with the procedures in the API 579-1/ASME FFS-1 standard where applicable. Parts of that standard applicable to a specific type of assessment are indicated throughout this annex.

## H.2 Convection Coil Assessment

**H.2.1** Convection section coils may be subjected to high-temperature corrosion, which results in general or local metal loss. When this type of damage is identified, the fitness for service and remaining life of the coils should be assessed using the procedures of Part 4 and Part 5 of API 579-1/ASME FFS-1.

**H.2.2** Some coils in the convection section may be exposed to temperatures high enough to cause creep damage. The potential for creep damage and remaining creep life, should be assessed using methods provided in Part 10 of API 579-1/ASME FFS-1.

**H.2.3** API 579-1/ASME FFS-1 provides two methods for evaluating remaining creep life:

1) Larson-Miller parameter relationships of WRC Bulletin 541, and

2) MPC Omega method. API 579-1/ASME FFS-1 also provides procedures for assessing less common types of convection coil damage including pitting corrosion, fire, crack-like flaws, and thermal fatigue.

**H.2.4** Some coils in the convection section may have extended surfaces to enhance heat transfer. Damage to the fins, such as corrosion, fouling, or mechanical failure, typically results in loss of heat transfer capability. In this case, their suitability for service is measured by the ability to provide the minimum amount of required heat transfer.

## H.3 Inlet Header Assessment

**H.3.1** Inlet headers typically operate at temperatures and stress levels where significant creep damage does not occur. Potential damage includes general corrosion, local corrosion, crack-like flaws, thermal fatigue, and overheating.

**H.3.2** Fitness for service and remaining life for these types of damage should be assessed using the procedures included in API 579-1/ASME FFS-1. If overheating should occur, creep damage should be assessed using the methods provided in Part 10 of API 579-1/ASME FFS-1.

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**H.3.3** Due to the complex configuration, attachments, and supports, a detailed stress analysis of the inlet manifold system is often required for assessing inlet header and pigtail fitness for service and remaining life.

## H.4 Inlet Pigtail Assessment

**H.4.1** Inlet pigtails typically operate at temperatures and stress levels where significant creep damage does not occur unless improper supporting adds additional stresses.

**H.4.2** Fatigue cracking at the welded connections to the inlet header or radiant tube is a potential damage mechanism.

**H.4.3** Fatigue cracking at the welded connection also can be caused by high local cyclic stresses that result from thermally induced movement of the inlet header and/or radiant tube resulting from cyclic operation.

**H.4.4** Fitness for service and remaining life because of fatigue cracking should be assessed using the procedures provided in Part 14 of API 579-1/ASME FFS-1.

**H.4.5** Other types of damage, such as corrosion, creep, and exposure to overheating, should be assessed using procedures in API 579-1/ASME FFS-1.

## H.5 Catalyst Tube Assessment

**H.5.1** Catalyst tubes are made of cast heat-resistant alloys and operate at temperatures where creep damage typically limits their useful service life.

**H.5.2** Catalyst tube failures are typically the result of through-wall axial creep-rupture cracks in the base metal, indicating normal end-of-life behavior. Non-standard failures, such as circumferential cracking at girth butt welds, metal dusting, or stress corrosion cracking, are typically addressed following recommendations and corrective action from root cause analysis and by ensuring that the applicable damage model is used for fitness for service and remaining life assessment.

**H.5.3** Both experimental and analytical methods are used to assess tube fitness-for-service and remaining life. These methods are summarized as follows:

a) Experimental Assessment Methods

  i) Experimental assessment methods rely on destructive examination and testing of samples of a tube or tubes that have been removed from the reformer.

  ii) Metallographic examination can be used to estimate creep damage while creep-rupture testing can be used to measure creep behavior.

  iii) Creep-rupture tests of specimens taken from the regions of highest operating temperature and highest heat flux along the length of the tube can be used to measure the creep behavior.

b) Analytical Assessment Methods

  i) Except for the HK-40 (UNS J94204) alloy, catalyst tube alloys are typically proprietary materials for which creep properties are not available in API 579-1/ASME FFS-1.

  ii) Larson-Miller parameter stress-rupture relationships and the MPC Omega Creep relationships for the HK-40 (UNS J94204) alloy are provided in API 579-1/ASME FFS-1.

  iii) The following material properties as a function of temperature should be obtained for use in such assessments:

    - Elastic modulus / Poisson’s ratio

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- Yield strength/ultimate strength
- Stress-strain curve
- Coefficient of thermal expansion/thermal conductivity
- Creep stress-strain/stress-rupture relationship

**H.5.4** Data from an experimental assessment method of paragraph H.5.3 a) and/or an on-stream inspection are used to establish the initial condition and level of creep damage of the catalyst tube material for creep remaining life calculations.

**H.5.5** The analytical method should compute creep stress and/or strain as a function of operating history considering the stress relaxation and redistribution that occurs during high-temperature creep.

**H.5.6** Creep damage should be estimated using an accepted damage criterion. The criterion may be based on stress, strain, energy, or some other parameter that has been documented to provide an estimate of creep damage in the material being evaluated. Tube life is estimated based on the damage reaching a limiting value.

## H.6 Outlet Pigtail Assessment

**H.6.1** Outlet pigtails operate at temperatures where creep damage typically limits their useful life.

**H.6.2** End-of-life tube failures are usually the result of through-wall axial creep-rupture cracks in the base metal or through-wall circumferential creep-fatigue cracks at attachments to the radiant tube or the outlet header.

**H.6.3** Procedures for assessing remaining creep-rupture and creep-fatigue life that are applicable to outlet pigtails are provided in Part 10 of API 579-1/ASME FFS-1.

**H.6.4** Larson-Miller parameter relationships and MPC Omega Creep relationships for commonly used outlet pigtail materials are provided in API 579-1/ASME FFS-1.

## H.7 Outlet Manifold Assessment

**H.7.1** Outlet manifolds may have a hot-wall or cold-wall design. Cold-wall manifolds are made of refractory lined carbon/low alloy steel.

**H.7.2** Hot-wall outlet manifolds operate at temperatures where creep damage is the normal limitation on their useful service.

**H.7.3** End-of-life manifold failures are usually the result of through-wall axial creep-rupture cracks in the base metal of a header section or through-wall circumferential creep-fatigue cracks at girth welds between header sections, girth welds at tees, welds at weldolet to header or welds at pigtail to header attachments.

**H.7.4** Analytical methods are typically used to assess outlet headers because it is impractical to remove material samples for experimental methods.

**H.7.5** Inspection data are used to establish the initial condition and level of creep or creep-fatigue damage of the outlet manifold material for remaining life calculations.

**H.7.6** The calculations should be based on expected operating conditions, including but not limited to, outlet manifold metal temperature, internal pressure, startup and shutdown cycles, and operating trips. Calculations should also include the effects of manifold supports and attachments.

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**H.7.7** The analytical method should compute creep stress and/or strain as a function of operating history considering the stress relaxation and redistribution that occurs during high-temperature creep. Creep damage should be accounted for using a method that accounts for accumulation of damage as a function of the variation of stress, strain and temperature. Refer to Part 10 of API 579-1/ASME FFS-1.

**H.7.8** Creep damage should be estimated using an accepted damage criterion. The criterion may be based on stress, strain, energy or some other parameter that has been documented provide an estimate of creep damage in the material being evaluated. Component life should be estimated per Part 10 of API 579-1/ASME FFS.

## H.8 Transfer Lines Assessment

**H.8.1** Refer to API 941 for details regarding high temperature hydrogen attack (HTHA) damage and the limits proposed by the Nelson curves. Refractory damage can lead to exposure to HTHA.

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# Bibliography


[1] API Recommended Practice 579-1/ASME FFS-1, *Fitness-For-Service*

[2] API Recommended Practice 941, *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*

[3] API Technical Report 942-A, *Materials, Fabrication, and Repair Considerations for Hydrogen Reformer Furnace Outlet Pigtails and Manifolds*

[4] API Technical Report 942-B, *Materials, Fabrication, and Repair Considerations for Austenitic Alloys Subject to Embrittlement and Cracking in High Temperature 565 °C to 760 °C (1050 °F to 1400 °F) Refinery Services*

[5] API Standard 975, *Refractory Installation Quality Control—Inspection and Testing, Brick Systems and Materials*

[6] API Standard 976, *Refractory Installation Quality Control—Inspection and Testing, AES/RCF Fiber Linings*

[7] ASME Boiler and Pressure Vessel Code (BPVC), *Section I: Rules for Construction of Power Boilers 1*[8]

[8] ASME BPVC, *Section II: Materials, Part D*

[9] ASME BPVC, *Section VIII*: *Rules for Construction of Pressure Vessels; Division1*

[10] ASME BPVC, *Section VIII, Div. 1, Appendix 8, Methods for Liquid Penetrant Examination (PT)*

[11] ASME BPVC, *Section IX, Welding and Brazing Qualifications*

[12] ASME B31.1, *Steam Piping*

[13] ASME PCC-2, [2022] *Repair of Pressure Equipment and Piping, Article 5.1: Appendix 2, Stored Energy Calculations for Pneumatic Pressure Test, Appendix 3, Safe Distance Calculations for Pneumatic Pressure Test*

[14] ASNT-TC-1A[9] – *Personnel Qualification and Certification in Nondestructive Testing*

[15] ASME B36.10, *Welded and Seamless Wrought Steel Pipe*

[16] ASTM A608 / A608M, *Standard Specification for Centrifugally Cast Iron-Chrome-Nickel High Alloy Tubing for Pressure Application at High Temperatures*

[17] ASTM A193 / A193M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

[18] ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry*


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[8] ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

[9] The American Society for Nondestructive Testing, 1201 Dublin Road, Suite #G04, Columbus, OH 43215-1045, USA, www.asnt.org

[19] EN 12952 [10] (all parts), *Water-tube boilers and auxiliary installations*

[20] EN 13445 (all parts), *Unfired pressure vessels*

[21] EN 13480 (all parts), *Piping*

[22] WRC Bulletin 541 [11], *Evaluation of Material Strength Data for Use in API Std 530*

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[10] European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

[11] Welding Research Council, P.O. Box 201547, Shaker Heights Ohio 44122, www.forengineers.com