

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

API 534 – Draft Rev 10

March 16, 2023

(clean copy)

API STANDARD 534

Proposed NEXT EDITION, XXX, 202X

Editor's Notes:

- 1) This revision of the draft document includes the technical ballot resolution decisions made during the Fall 2022 meeting, actions from the meeting including subsequent clarification edits between the Chairman and Editor, API format and style revisions, and overall editorial update in preparation for an approval ballot.
- 2) Both “track change” and “clean” (with all changes accepted) copies are being provided.
- 3) Section 2 and the Bibliography does not show track changes.
- 4) Annex G fully reformatted with no technical changes (with all format changes accepted).

[Revision Record](#)

2023 Mar 16 – Submission for Approval Ballot (changes accepted)

2023 Mar 15 – Final edit before submission to API for Approval Ballot (with track change)

2023 Feb 17 – Revisions Post Fall 2022 Technical Ballot comment resolutions and overall editorial cleanup.

2022 Sep 30 – Submitted to API for Technical Ballot

2022 Sep 09 – Version 9a.1 with technical / editorial review of the full document by R Wey

[older versions](#) on [SharePoint](#)

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Introduction

Heat recovery steam generators for combustion turbine exhaust applications are used in oil and gas applications typically for power generation, process heating or both. Designs often include provisions for combustion of fuel in duct burners to supplement the energy provided from turbine exhaust gas. This document defines common terms and requirements for the design, fabrication, inspection, testing, preparation for shipment and erection of heat recovery steam generators.

Once through type heat recovery steam generators without a steam drum and forced circulation type are not specifically covered in this standard. However, many of the requirements contained in this standard are considered applicable to those designs. The users of this standard should assess to what extent this standard may be applied to other types of heat recovery steam generators.

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 should 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 (USC) 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 the purchaser's checklist (see Annex B) or stated in the inquiry or purchase order.

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

1 Scope

This standard specifies minimum requirements and provides guidance for the design, materials, fabrication, inspection, testing, preparation for shipment, and erection of heat recovery steam generators (HRSG) downstream of combustion turbines in oil and gas application.

The scope of this standard covers water tube drum type HRSGs with typical operating conditions up to 1400 kPa(g) (2030 psi) and 565 °C (1050 °F) and using a natural circulation evaporator system.

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 536, *Post-Combustion NO_x Control for Fired Equipment in General Refinery Services*

API Recommended Practice 582, [Fourth Edith \(2022\)](#), *Welding Guidelines for the Chemical, Oil, and Gas Industries* >>>RW - pending publication

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

API TR 938-B, First Edition (2008), *Use of 9CR-1Mo-V (Grade 91) Steel in the Oil Refining Industry*

ANSI S1.4-1983 (R2006), *Specifications for Sound Level Meters*

ASME Boiler and Pressure Vessel Code (BPVC), Section I¹, *Rules for Construction of Power Boilers*

ASME BTH-1, *Design of Below-the-Hook Lifting Device*

ASME B30.20, *Below-the-Hook Lifting Devices*

ASME CRTD-81 - *Consensus on Operating Practices for the Sampling and Monitoring of Feed Water and Boiler Water Chemistry in Modern Industrial Boilers*

ASME PTC 4.4, *Gas Turbine Heat Recovery Steam Generators*

ASME PTC 19.11-2008, *Steam and Water Sampling, Conditioning, and Analysis in the Power Cycle*

ASME STS-1, *Steel Stacks*

¹ American Society of Mechanical Engineers, 3 Park Avenue, New York, NY, 10016-5990, www.asme.org.

ASTM A123/A123M², *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

ASTM A143/A143M, *Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*

ASTM A182/182M, *Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*

ASTM A153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A384/A384M, *Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies*

ASTM A385/A385M, *Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)*

ASTM B633/B633M, *Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Testing for General Industry*

EN 10204³, *Metallic products - Types of inspection documents*

IAPWS-IF97⁴, *Industrial Formulation by The International Association for the Properties of Water and Steam*

IEC 60534⁵, *Industrial-process control valves*

IEC-61511, *Functional safety - Safety instrumented systems for the process industry sector*

IEC 61672-1:2002, *Electroacoustics - Sound level meters*

ISO 1461⁶, *Hot dip galvanized coatings on fabricated iron and steel articles—Specifications and test methods*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness—Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 9001, *Quality management systems - Requirements*

ISO 10005, *Quality management - Guidelines for quality plans*

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

³ European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.

⁴ The International Association for the Properties of Water and Steam, <http://www.iapws.org/>

⁵ International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland, www.iec.ch.

⁶ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

ISO 10474, *Steel and steel products - Inspection documents*

ISO 10684, *Fasteners - Hot dip galvanized coatings*

NB-27⁷ - *A Guide for Blowoff Vessels, 2012 Edition*

NFPA 85⁸, *Boiler and Combustion Systems Hazards Code*

SSPC SP 6⁹/NACE No. 3, *Joint Surface Preparation Standard: Commercial Blast Cleaning*

UNS¹⁰, N06625

UNS R3006

3 Terms, Definitions, and Abbreviations

3.1 General Terms and 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 fabricator is 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

owner

purchaser

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

NOTE The owner or purchaser may often be represented by an engineering contractor (contractor), as an agent undertaking owner's requirement for the engineering, procurement and construction phase of work including

⁷ The National Board of Boiler and Pressure Vessel Inspectors (NBBI) The National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue Columbus, OH 43229, www.nationalboard.org.

⁸ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, USA 02169-7471 www.nfpa.org.

⁹ The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

¹⁰ SAE International, 400 Commonwealth Drive, Warrendale, PA 15096, www.sae.org.

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.

3.1.3

supplier

The supplier is 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 thermal design, detailed engineering, material procurement, project management and manufacturing processes involved in the physical supply of the HRSG 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.

3.1.4

vendor

The vendor is 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, have responsibility for the quality of the product to either recognized industry or other standards as directed by the purchaser, whomever they may be. Vendors typically supply sub-components such as; burners, fans, dampers, instrumentation, pipe hangers, castings, refractory, pipe / tubes, and fittings etc. A vendor may also provide specialty engineering services such as finite element analysis (FEA). 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 – Heat Recovery Steam Generator

3.2.1

alkaline earth silicate fiber

AES fiber

Manmade vitreous fiber (MMVF) composed of at least 18 % alkaline earth oxides developed for their low bio-persistence.

NOTE Also known as bio-fiber, bio-soluble, or low bio-persistence fiber.

3.2.2

atmospheric blowdown tank

Atmospheric vessel that receives all drains and blowdown from the HRSG where water is flashed to ambient pressure with steam relieved to atmosphere and water drained to a blowdown treatment system or sewer.

NOTE The water may be cooled or uncooled.

3.2.3

attemperator

A piece of equipment to control the steam outlet temperature to a maximum temperature. It is often also referred to as de-superheater.

3.2.4

augmenting air

Supplemental air typically introduced at the duct burner element.

NOTE 1 Used to increase the TEG O₂ levels to promote more stable combustion and for cooling the burner elements.

NOTE 2 Cooling may be needed in consideration of the fuel being applied, e.g. has a coking tendency.

3.2.5

blowdown flash vessel

Pressurized vessel where blowdown water is flashed to a lower level and the steam is reclaimed in lower pressure system, with water directed to an atmospheric blowdown tank.

3.2.6

burner

duct burner

Device that introduces fuel into the exhaust system at the desired velocities, turbulence, and concentration to supplement heat to the flue gas.

NOTE 1 This definition differs from API 560 definition.

NOTE 2 Duct burners, also referred to as supplemental firing burners, are different in construction and design compared to typical fired heater burners.

3.2.7

burner element

A component of a duct burner.

3.2.8

cold casing design

An internally insulated casing. The casing is at low temperature, exposed to the ambient.

3.2.9

corrosion allowance

Material thickness added to allow for material loss during the design life of the component.

3.2.10

damper

Device for introducing a variable resistance or an obstruction to regulate or isolate the flow of flue gas or air.

3.2.11

dead space

An area above and below (for horizontal HRSG) or at the tube end (vertical HRSG) that can be accessed for inspecting tube ends or headers.

NOTE Also referred to as crawl space.

3.2.12

distribution grid

Flow conditioning device located upstream of the fired equipment to ensure acceptable uniform turbine exhaust gas distribution at the burner plane.

3.2.13

duct

Conduit for air or flue gas flow.

3.2.14

erosion

Reduction in material thickness due to mechanical attack from a solid or fluid.

3.2.15

excess air

The amount of air above the stoichiometric requirement for complete combustion, expressed as a percentage.

3.2.16

flame impingement

Any visible part of the flame or any part of the flame envelop touching or engulfing the identified surface.

NOTE Applied to natural gas and typical fuel gas.

3.2.17

flue gas

Gaseous product of combustion including excess air.

NOTE Gas leaving the gas turbine it is also referred to as turbine exhaust gas (TEG).

3.2.18

fouling factor

Additional heat transfer resistance used in heat transfer calculation.

NOTE The inside fouling factor is used to calculate the maximum metal temperature for design. The external fouling factor is used to compensate the loss of performance due to external fouling on the external surface of the tubes or surface extension.

3.2.19

fuel efficiency

Total heat absorbed duty divided by the total input of heat derived from the combustion of fuel only (lower heating value basis).

NOTE This definition excludes sensible heat of the fuels and applies to the net amount of heat exported from the HRSG.

3.2.20

gas turbine

A turbine driven by expanding hot gases produced by burning fuel.

NOTE Also known as a gas turbine engine, combustion turbine, or combustion gas turbine.

3.2.21

guillotine

Single-blade device that is slid into the flue gas path for the purpose of isolating the equipment or HRSG.

3.2.22

harp

A section of a heating surface consisting of a top and bottom header.

NOTE 1 Other terminology used for harp is rack.

NOTE 2 A functional heat transfer component, e.g. a superheater, can consist of more than one harp.

NOTE 3 Some designs make use of return bends in which the terminology of harp may not be so obvious.

3.2.23

header

A distributing or collecting manifold to which the heating surface tubes are attached.

3.2.24

higher heating value

HHV

gross heating value

Total heat obtained from the combustion of a specified fuel at 15°C (60°F).

NOTE The higher heating value includes the latent heat of vaporization of water in the combustion products including any water present in the fuel.

3.2.25

hot casing design

Casing design that is externally insulated or has a combination of internal and external insulation for the purpose of creating a higher metal temperature.

NOTE A stack may be externally insulated however this would not be regarded as a hot casing design.

3.2.26

isosurface

A three-dimensional surface representation of points of a constant value within a volume of space.

3.2.27

lower (net) heating value

LHV

net heating value

Higher heating value minus the latent heat of vaporization of the water formed by combustion of hydrogen in the fuel.

3.2.28

multiple burner operation

Burner elements in a duct burner having individual shutoff valves that can be turned on and off individually without affecting the other burner elements.

NOTE 1 These burner systems can act as "single burners" lighting off and modulating in unison, controlled by a single fuel flow control valve.

NOTE 2 The multiple burner system has the flexibility to operate with one or more burners out of service.

3.2.29

Nernst equation

Relates the effective concentrations of the components of a cell reaction to the standard cell potential used in pH measurements.

3.2.30

pressure design code

Recognized boiler design code or standard specified or agreed by the purchaser.

EXAMPLES ASME BPVC Section I, EN 12952 (all parts) for boilers, ASME B31.1; ISO 15649, or EN 13480 (all parts) for piping.

3.2.31

pressure drop

Difference between the inlet and the outlet static pressure between termination points, excluding the static differential head.

3.2.32

single burner operation

Burner elements in a duct burner that light-off together, modulate together and shut down in unison.

NOTE These modulate firing rate in response to a single fuel flow control valve.

3.2.33

stack

Vertical conduit used to discharge flue gas to the atmosphere.

3.2.34

structural design code

Recognized structural code or standard specified or agreed by the purchaser.

EXAMPLE International Building Code (IBC)

3.2.35

structural welding code

Recognized structural welding code specified or agreed by the purchaser.

EXAMPLES ANSI/AWS D 1.1

3.2.36

sky vent

A controlled vent on the steam system, typically used during start-up to control the steam pressure.

3.2.37

temperature allowance

Number of degrees Celsius (Fahrenheit) to be added to the process fluid temperature to account for flow maldistribution and operating unknowns.

NOTE The temperature allowance is added to the calculated maximum tube metal temperature or the equivalent tube metal temperature to obtain the design metal temperature.

3.2.38

thermal efficiency

Total heat absorbed divided by the total input of heat derived from the combustion of fuel (h_L) plus sensible heats from air, fuel, and any atomizing medium.

3.2.39

total pressure

Static plus dynamic pressure.

3.2.40

total temperature

Static temperature plus kinetic impact.

NOTE also called stagnation temperature.

3.2.41 vapor barrier

Metallic foil or a PTFE foil placed between layers of insulation as a barrier to flue gas flow.

NOTE This barrier protects the steel shell from corrosion caused by condensing acids.

3.2.42 velocity

Rate of movement of flue gas, air, steam, or water.

NOTE For gas turbine exhaust, typically three velocity directions are defined as:

- a. radial velocity
radial component of the flue gas velocity
- b. tangential velocity
tangential component of the flue gas velocity
- c. axial velocity
axial component of the flue gas velocity

NOTE As an alternative, a gas turbine supplier may provide velocity expressed in x, y, and x components.

3.3 Abbreviations

AVT(O)	all volatile treatment (oxidizing)
AVT(R)	all volatile treatment (reducing)
BFW	boiler feedwater
BMS	burner management system
CC	combined cycle
CCR	center control room
CFD	computational fluid dynamics
CHP	combined heat and power
CO	carbon monoxide
CSO	car-sealed open
CT	caustic treatment
DCS	distributed control system
DNB	departure from nucleate boiling
FAC	flow accelerated corrosion
FAF	fresh air firing
GT	gas turbine
HAZOP	hazard and operability study

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

HHV	higher heating value
HIC	hydrogen induced cracking
HRSG	heat recovery steam generator
ITP	inspection and test plan
IPF	instrumented protective functions
LHV	lower heating value
MECL	minimum emissions compliant load
MCR	maximum continuous rating
MIC	microbiologically influenced corrosion
MMVF	man made vitreous fiber
MP	magnetic particle testing
NDE	non-destructive examination
NDT	non-destructive testing
NEMA	<i>National Electrical Manufacturers Association</i>
NPSH	net positive suction head
NO _x	nitrogen oxide
NWL	normal water level
ORP	oxygen reduction potential
PAW	plasma arc welding
P&ID	piping and instrument diagram
PMI	positive material identification
ppm	parts per million
PT	phosphate treatment
RMS	root mean square
RT	radiographic testing
SCC	sulfide stress corrosion cracking
SCE	safety critical elements
SCR	selective catalytic reduction
SDS	safety data sheet
SOHIC	stress oriented hydrogen induced cracking
SSOV	safety shut off valve

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

STC	solution temperature compensation
TEG	turbine exhaust gas
TSOV	tight shut off valve
UNS	<i>Unified Numbering System</i>
UT	ultrasonic testing
VOC	volatile organic compound
WPS	weld procedure specification

4 Proposal and 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 from the purchaser's perspective.

NOTE 1 The purchaser should complete, as a minimum, those items on the data sheet that are designated by an asterisk (*). Refer to Annex B.

NOTE 2 The purchaser should refer to the checklist in Annex E for further information to be provided by the purchaser in the inquiry documents or during design development.

4.1.2 The purchaser shall identify the HRSG orientation at an early stage of request for project proposal.

NOTE Information on capital and operating cost criteria used for project evaluations should also be provided at an early stage of request for project proposal.

4.1.3 The purchaser shall define operating conditions such as steam pressure, flow, and temperature at battery limit of HRSG supplier's scope of supply.

4.1.4. Steam purity requirements at the HRSG battery limit shall be provided by the owner based on steam turbine and/or process specifications.

4.1.5 The purchaser shall inform/specify how the HRSG will be operated, e.g. base load, variable load based on power and process demand, cycling mode (on/off frequency) etc.

4.1.6 The gas turbine (GT) ramp rates shall be specified by the purchaser. This includes any fast start-up requirement for cold, warm, and hot start-up.

4.1.7 The purchaser shall specify start-up philosophy with respect to using steam bypass and or start-up sky vent.

4.1.8 The purchaser shall consider the emission of fuels combustion products to meet jurisdictional, local emission, and final user's requirements.

4.1.9 The purchaser shall specify fuel emission requirements.

4.1.10 The purchaser shall specify fuel over-firing margin in sizing of the duct burner if any.

4.1.11 The purchaser shall specify mechanical design requirements, regulatory codes of practice, and any purchaser standards and specifications that supplement this standard.

4.1.12 The purchaser shall define the supplier's scope of supply and responsibilities relative to the application of this standard.

4.1.13 The purchaser shall provide a list of approved sub-suppliers, fabricators, or component vendors.

4.1.14 The purchaser shall specify the hazardous area classification.

4.1.15 The purchaser shall identify all terminal point requirements including type/rating and full scope of supply for the HRSG including the responsible party, i.e. supplier or contractor. See

4.2 Supplier's Responsibilities

4.2.1 Suppliers shall provide detailed description of the proposed scope of supply including completed datasheets.

4.2.2 The supplier's proposals shall include a schedule for the work after receipt of a purchase order for engineering, drawings, data, documents, procurement of materials, manufacturing, testing, and delivery date including the specified time for purchaser's review of information and drawings subject to approval by purchaser.

4.2.3 The supplier's proposals shall include:

- a) general arrangement drawings, outline drawing showing overall dimensions, arrangement of any internal components, ladders and platforms, equipment weights; location of supports, nozzle list and overall dimensions and weights of any provided skids;
- b) full definition of the extent of shop assembly including the number, size and mass of prefabricated parts, skids, and location of any field welds;
- c) detailed description of any exceptions to the specified requirements;
- d) when specified by the purchaser, a completed noise datasheet representative of the supplier's experience and reference list for the applicable system;
- e) detailed schedule for engineering, drawings, data, documents, procurement of materials, manufacturing, testing, and delivery date including the specified time for purchaser's review of information and drawings;
- f) a list of utilities and quantities required;
- g) a proposed list of vendors, sub-contractors/sub-suppliers;
- h) guarantees and warranties;
- i) process & instrumentation diagram (P&ID);
- j) operation and maintenance manual;
- k) safety lifecycle support and engineering deliverables in accordance with the requirements of IEC-61511.

4.3 Documentation for Purchaser's Review

4.3.1 The supplier shall submit design drawings and specified detailed equipment drawings for approval after award and before start of work for the required scope of work. The design and detail drawings shall include, but not limited to, the following information:

- a) equipment tag number(s), project name and location, purchaser's order number, supplier's project number, and any other special identification numbers;
- b) design pressure, test pressure (when applicable), design temperature, minimum design metal temperature;

- c) connection sizes, location, orientation, projection, flange rating and facing and weld bevel preparation as applicable for welded connections;
- d) dimensions, orientation, and location of supports, including bolt holes and slots, sliding support details, and direction and maximum growth from any fixed support;
- e) overall equipment dimensions, location and orientation of nameplates, lifting lugs, grounding clips, surface temperature thermocouples, and any other attachments, equipment slope, and clearance requirements for any removal components;
- f) weight of the equipment by major component in the “as shipped” condition for lifting and setting on supports and “in service” condition inclusive of refractory lining systems;
- g) location of the center of gravity for lifting modules;
- h) references to the applicable codes and the purchaser’s specifications;
- i) material specifications and grades for all materials;
- j) weld map for the pressure boundary;
- k) requirements for non-destructive examination (NDE);
- l) requirements for surface preparation and painting;
- m) nameplate drawing(s).

4.3.2 The supplier shall submit design and detail instrumentation, control, and protective systems drawings for approval after award and before start of work for the instrumentation and control, or otherwise defined scope of work. The design and detail drawings shall include, but not limited to, the following information:

- a) P&ID for the HRSG;
- b) P&ID for the igniter and any fuel gas system/fuel gas train;
- c) control and protective function narrative;
- d) cause and effect diagram;
- e) recommended alarm and trip setpoints.

4.3.3 The supplier shall submit for purchaser’s review foundation-loading diagrams. 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;

e) center of gravity;

f) seismic code.

4.3.4 Individual stages of the equipment mechanical design and fabrication shall not proceed until the relevant document has been reviewed and confirmed as being accepted by the purchaser. The supplier shall submit the following documents for review and comment:

- a) fireside CFD when specified;
- b) an engineering quality plan for the design phase of work that addresses quality assurance for the coordination of the multi-disciplined elements of work either performed directly by the primary supplier or subcontracted in part or in whole in execution of the design and specification phase of the work.
- c) pressure design code calculations;
- d) structural design code calculations;
- e) inspection and test plan covering all phases of supply, fabrication and construction including that of all vendors;
- f) all other test documents (material test, NDE reports etc.), including all signed-off inspection test reports;
- g) weld procedure specification (WPS) and procedure qualification records (PQR), examination, test procedures and welder qualification record (WQR) for pressure boundary welding.
- h) WPS and PQR records, examination, test procedures, and welder and welding operator qualification records for structural welding including anchor welding.
- i) material mill test reports and certifications.

4.3.5 The supplier shall provide a 3D model to be checked versus rest of the plant to minimize misfit on terminal points. A 3D model shall also be suitable to evaluate accessibility of equipment.

4.3.6 Individual stages of the design, fabrication, testing, and supply of instrumentation, control, and protective systems components shall not proceed until the relevant document has been reviewed and confirmed as being accepted by the purchaser. The supplier shall submit the following documents for review and comment:

- a) instrument data sheets; (including control valves and analyzer)
- b) wiring diagram (if in scope)

4.4 Approved for Construction Documentation

4.4.1 After receipt of the purchaser's comments on the general arrangement drawings and diagrams, the supplier shall furnish, as a minimum, the following approved for construction documentation:

- 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) erection drawings including erection sequence;

e) drawings of all auxiliary equipment;

f) the following instrumentation and electrical drawings:

1) a P&ID with instrument symbols and identification;

EXAMPLE 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,

4) all instrumentation data sheets for each tagged instrument item,

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

4.5 Performance Tests and Guarantees

4.5.1 Performance Tests

- **4.5.1.1** When specified by the purchaser, performance test(s) shall be performed by the supplier.

4.5.1.2 A mutually agreed performance test procedure shall be developed based on ASME PTC 4.4.

4.5.1.3 All steam properties shall be based on IAPWS-IF97.

4.5.1.4 Guarantees shall be provided for the specified boundary conditions (e.g. ambient condition, GT exhaust flow and temperature).

4.5.1.5 If the conditions of 4.5.1.4 cannot be met, corrections shall be applied, based on supplier's correction curves (or computerized model) for test conditions other than the specified guaranteed conditions. The supplier and purchaser shall agree upfront on the details of such correction curves/programs.

4.5.2 Performance Guarantees

4.5.2.1 The following shall be guaranteed as specified in the purchase order or contract documents:

- a) energy output detailed relative to specific streams of a specific value to the different energy streams;
- b) steam production or hot water production;
- c) steam temperature;

- d) steam purity requirements including, as a minimum, cation conductivity, silica, iron, copper, and sodium;
- e) stack flue gas emission levels;
- f) sound pressure levels;
- g) startup ramp rate and maximum load change rates;
- h) utilities consumption;
- i) flue gas pressure drop across the HRSG (from GT outlet to atmosphere);
- j) reheater pressure drop;
- k) burner heat release;
- l) burner turndown rate.

4.5.2.2 Guarantees shall be provided for the specified boundary conditions (e.g. GT exhaust flow, temperature, flue gas composition etc.).

4.5.2.3 The purchaser shall specify the fuel composition to be fired and expected mode of operation and rate of change between fuels and possible mixing modes of fuels.

4.6 Final Records

4.6.1 Within a specified time after completion of construction or shipment, the supplier shall provide the purchaser with the following documents:

- a) all pressure part registration certificates, e.g. National Board Inspection Code Data Reports;
- b) all electrical part compliance certifications;
- c) installation, operation, and maintenance instructions
- d) all other test documents (material test, NDE reports etc.), including all signed-off inspection test reports;
- e) data sheets and drawings representing the as built condition;
- f) material test certificates for all pressure parts;
- g) installation, operation, and maintenance instructions for the system and auxiliary equipment;
- h) performance curves or as built data sheets for fans, drivers, duct burners, and other auxiliary equipment;
- i) bill of materials;
- j) noise data sheets when specified by the purchaser;
- k) factory acceptance test certifications;

- l) as built SRS and SIL calculations;
- m) test procedures.

5 Design Requirements – General

5.1 HRSG Gas Path Orientation

5.1.1 The HRSG orientation (horizontal or vertical flue gas path) shall be as specified. The following shall be considered in the selection of the HRSG orientation (horizontal or vertical gas flow):

- a) accessibility;
- b) plot space limitation;
- c) ease of access and tube replacement;
- d) any future additions e.g. future post combustion NO control, when specified.

NOTE If not specified, the supplier may propose their preference.

5.2 Steam Capacity and Pressure

5.2.1 Unless otherwise specified, the design pressure shall be determined by the pressure design code with enough margin to prevent simmering of safety valves.

5.2.2 The design shall meet the performance requirements specified by the purchaser.

5.2.3 The purchaser minimum specifications shall include the following:

- a) MCR;
- b) any margin greater than MCR;
- c) the lowest steam capacity at the rated steam temperature.

5.3 Operating Philosophy

5.3.1 Cycling vs. Base Load

- **5.3.1.1** The required operating philosophy (cycling vs. base load) shall be specified by the purchaser.

5.3.1.2 Operating philosophy shall be considered when determining the number of cold, warm, and hot starts, and load variations. If the number of cold, warm and hot starts per year is not specified by the purchaser, the following, as minimum, shall be used for the design:

- two cold starts a year;
- 10 warm starts, and;
- 10 hot starts.

- **5.3.1.3** The purchaser shall specify the GT ramp rates.

NOTE This includes any fast start-up requirement for cold, warm and hot start-up.

5.3.2 Operating Cycle – Period of Time

The design of the HRSG provides a minimum of 24 months of continued operation between planned outages unless otherwise specified.

5.4 Fuel Type

5.4.1 The purchaser shall specify the fuels to be burned in the gas turbine (GT) and/or supplemental firing burners. As a minimum fuel data shall include, for all fuels used:

- a) fuel composition (including sulfur components);
- b) supply pressure at the inlet flange to the gas train;
- c) fuel temperature and pressure at the inlet flange to the gas train;
- d) LHV.

5.4.2 The purchaser shall specify any requirements for emission control equipment.

5.5 Gas Turbine Operating Data

5.5.1 The HRSG specification shall include a representative range of operating conditions from the gas turbine including mass flow, exhaust gas temperatures, molecular composition of the exhaust gas, and the required exhaust gas pressure into the HRSG.

5.5.2 The minimum representative range of gas turbine operating conditions shall, as minimum, cover the load range from the minimum emissions compliant load (MECL) to base load.

NOTE The purchaser may specify additional load cases or load range.

5.5.3 Gas turbine operating data shall include the following data for the exhaust gas flow profiles, normalized to ambient ISO conditions for the specified fuels and various loads:

- a) total pressure (P_t/P_{tavg});
- b) total temperature (T_t/T_{tavg});
- c) velocity (V_{tot}/V_{totavg});
- d) radial velocity (V_{rad}/V_{totavg});
- e) tangential velocity (V_{tan}/V_{totavg} ; and
- f) axial velocity (V_{ax}/V_{totavg}).

NOTE: The flow profile data is used to assist proper design and determine need for any flow distribution grids or other means of assuring proper operation of the HRSG. Alternative to using radial, tangential and axial velocity a X, Y, Z system may be used.

where:

- P_t is total pressure
- P_{tavg} is average total pressure
- T_{tot} is total temperature
- T_{totavg} is average total temperature
- V_{rad} is radial velocity
- V_{tan} is tangential velocity
- V_{ax} is axial velocity
- V_{totavg} is average total velocity

5.5.4 Other items of importance that shall be provided and agreed to between the purchaser and supplier include:

- a) interface flange dimensions;
- b) interface location;
- c) interface characteristics and displacement;
- d) interface acceptable stresses and moments at the interface flange;
- e) volume of the exhaust plenum (gas turbine ducting up to scope limit HRSG);

NOTE: Volume is used in purging calculations / considerations and NFPA compliance.

- f) sound power levels and sound pressure levels;
- g) flow distribution;
- h) centerline position reference.

NOTE Position based to either the centerline of the gas turbine or the HRSG.

5.6 Noise Control

5.6.1 General

5.6.1.1 The design shall comply with local regulatory and specified noise requirements.

5.6.1.2 The HRSG supplier shall analyze and provide any necessary measures to reduce near field and far field sound pressure level for the complete scope of supply. For workers safety near field shall not exceed 85 dB(A) (or lower if specified) at 1 m 3 ft) from any surface of the HRSG, even if purchaser requirements are less strict.

5.6.1.3 Purchaser shall provide enough information and specifications for the HRSG supplier to accurately develop an HRSG noise model.

5.6.1.4 The purchaser shall provide sound power levels from the GT broken down by octave band center frequencies as defined in Table 1.

Table 1—Sound Power Levels

Octave Band Center Frequency, Hz	31.5	63	125	250	500	1000	2000	4000	8000
Sound Power Level (L _{WA}) dB(A) reference 10 ⁻¹² Watts									

5.6.2 Noise Specifications and Tests

5.6.2.1 As required by federal, local or national regulations, the HRSG supplier shall guarantee environmental (far field), occupational (near field) and intermittent noise emissions.

5.6.2.2 Noise guarantees shall be verified using a mutually agreed test procedure based upon recognized acoustical standards.

EXAMPLE ANSI S12.56 – 1999 / ISO 3746 – 1995 (R2004) or ISO 3746:2010

5.6.2.3 All sound pressure level measurements shall be performed with an ANSI S1.4-1983 (R2006) or an IEC 61672-1:2002 class 1 meter or purchaser approved equivalent.

5.6.2.4 The HRSG supplier shall design so that acoustic wave damage is prevented including acoustic baffles if required.

5.6.2.5 The material of acoustic baffles shall comply with Table 2.

Table 2--Acoustic Baffle Material Design Temperature

Type or Grade	Maximum Temperature
Carbon Steel	450 °C (842 °F)
409 SS	650 °C (1200 °F)
410 SS	705 °C (1300 °F)
304 SS	815 °C (1500 °F)
309 SS	870 °C (1600 °F)
310 SS	870 °C (1600 °F)
NOTE 1 Type 410 SS is not recommended for welded parts. NOTE 2 Additional guidance on material selection may be found in API 560 Table 10	

5.6.2.6 Baffles and supports shall be designed considering expansion of the baffle or support and any heat transfer coils they are attached to.

6 Design Requirements – Pressure Parts (steam/water system)

6.1 Pressure Parts General

- **6.1.1** The pressure design code shall be specified by the purchaser.
 - 6.1.2** Pressure components shall comply with the pressure design code, local or national regulations and the normative requirements of this standard. When there is conflict between standards the pressure design code shall take precedence.
 - **6.1.3** The purchaser shall specify any local or national regulation applicable to the supplied equipment.
 - 6.1.4** The heating surface for horizontal type HRSG shall be top supported.
- NOTE A bottom supported HRSG is acceptable if such design is unavoidable due to size of the HRSG, e.g. with a bi-drum design.
- 6.1.5** All heating surface tubes, headers/manifolds, and piping shall be seamless tubes/pipe.
 - 6.1.6** Tubes shall be one piece from tube inlet to outlet excluding header-manifold stubs.
 - 6.1.7** Tube wall thickness shall not be less than 2.6 mm (0.102 in.)
 - 6.1.8** When heating surface tubes need to be bent, the resulting minimum thickness shall be in accordance with the applicable design code considering the corrosion allowance. The minimum wall thickness after bending shall not be less than 2.4 mm (3/32 in.).
 - 6.1.9** When ovality is not addressed in the specified pressure design code, the requirements of ASME BPVC Section I shall apply.

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

6.1.10 The tube arrangement (staggered or in-line) shall consider both the primary and secondary fuels fired. In general, the arrangement will be staggered. When fouling and cleaning requires in-line arrangement, purchaser shall clearly specify.

6.1.11 Heat transfer calculations shall include external / internal fouling factors as specified by the purchaser.

6.1.12 If no fouling factors are specified, the supplier shall use external fouling factors based on the fuel(s) used with a minimum in accordance with Table 3. The higher of minimum and supplier internal standards shall be used and be indicated on the datasheet by the supplier.

6.1.13 Internal fouling factors shall be based on expected water and steam quality, with a minimum in accordance with Table 3. The higher of minimum and supplier internal standards shall be used and be indicated on the datasheet by the supplier.

Table 3--Fouling Factors

	Fouling Factor	
	m ² K/W	hr ft ² °F / Btu
External Fouling:		
Natural gas	0.0000176	0.0010
No 1 and No 2 Oil (also when oil is used during commissioning)	0.000352	0.0020
No 6. oil	0.00088	0.005
Internal Fouling:		
Economizer	0.00025	0.00140
Evaporator	0.00016	0.00095
Superheater	0.00008	0.00048

6.1.14 No restriction orifices or reduced drilling shall be used in the heating surface pipes and tubes or harps.

- **6.1.15** Corrosion allowance for headers and piping (water/steam) shall be specified by the purchaser. If not specified for CS, a minimum of 1 mm (0.04 in.) shall be used on piping and headers. A minimum of 0.5 mm (0.02 in.) shall be used on heating surface tubes.

6.1.16 Coarse grain steel intended for intermediate/high temperature service shall not be used due to risk of brittle fracture.

EXAMPLE ASMESA-515/SA 515M Grades 60/65/70

6.1.17 The applied piping shall use standardized sizes/schedules except where calculations show that non-standard schedules are required.

NOTE If the required minimum wall thickness and or pipe size cannot be covered by standardized seamless piping, rolled pipe can be used. (e.g. 760 mm (30 in.), $t_{min} > 16$ mm (5/8 in.)

6.1.18 Swaged tubes shall not be used.

6.1.19 All pressure parts shall be fully drainable without dismantling of the pressure parts.

6.1.20 As a minimum vent/drain valve size shall not be smaller than DN 50 (2 in.).

6.1.21 Drains/vents required for operation, e.g. automatic drains/vents, shall be sized to not limit normal operation and the startup/shutdown of the HRSG.

6.1.22 The maximum number of rows of tubes per heating surface banks shall be 12.

NOTE The maximum tube row specification is in consideration of maintenance, inspection, and to reduce sensitivity to flow induced vibration.

6.1.23 The minimum distance between two tube banks, i.e. cavity, shall not be less than 800 mm (32 in.).

6.1.24 A minimum of one access door to each cavity shall be provided.

6.1.25 Piping in dead space shall be designed based on flue gas temperature upstream of the related bank.

6.2 Heating Surface Extension

6.2.1 Tube surface extensions shall be helically wound high-frequency fins continuously resistant welded to the tube.

6.2.2 Only one type of surface extension shall be used in each harp.

6.2.3 Tubes in each harp shall have consistent surface extension details throughout, i.e. the same fin height, fin thickness, fin density, and fin type.

6.2.4 The surface extension design shall be suitable for the fuels applied in the gas turbine and auxiliary fuel firing, where applicable. Both normal and back-up fuels shall be considered.

6.2.5 The maximum fin density shall not exceed 275 fins/m (7 fins/in.) for clean gaseous fuel. For other fuels, the maximum fin density shall be agreed between supplier and purchaser.

6.2.6 The minimum fin thickness to be applied shall be 1.0 mm (0.039 in.) for clean fuels. When fuels contain corrosive components, the minimum shall be 1.25 mm (0.050 in.).

6.2.7 The design of finning shall be suitable to comply with selected lifetime and operating time in between maintenance turnarounds. Unless otherwise approved by purchaser, finning shall comply with maximum and minimum as specified in Table 4.

Table 4--Tube Finning

	Fin Density fins / m (fins / in.)	Fin Thickness mm (in.)	Fin Height mm (in.)
Clean Gaseous Fuel ^a	Max 275 (7)	>1.0 (0.039)	<19 (0.75)
Light Oil / Distillates	Max 160 (4)	>1.25 (0.050)	<12.7 (0.50)
Heavy Fuel Oil ^b	Bare Tubes		
^a Clean gas = Sulfur free (less than 20 ppm sulfur), sales quality gas, free of solids with atmospheric dew point < -20 °C (-4 °F). This includes light oil distillate max. 30 days a year. ^b Heavy fuel is rarely used in GT applications			

- **6.2.8** When specified by the purchaser, the normative statements contained in Annex G for the fabrication and testing of high-frequency resistance welded fins shall be used directly, with or without modification or alternate specifications and requirements provided.

6.2.9 When the purchaser does not specify the use of Annex G, the fabrication tolerances for high-frequency resistance welded fins shall comply with Table 5. The Supplier shall include the same tolerance criteria in the inspection and test plan (ITP) for tube finning.

Table 5--Fin Manufacturing Tolerances

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

6.3 Superheater

6.3.1 For tube to header connections, full penetration seated type tube to header weld shall be used. Stick through type of tube-header weld shall not be used.

6.3.3 Dissimilar welds between tube and header shall be avoided. Where dissimilar welds between tube to header are required, a stub or nipple between tube and header shall be used. The stub or nipple and header shall be the same material.

6.3.4 Welding and material selection, as a minimum shall comply with API RP 582 and API TR 938.

6.3.5 The supplier shall perform life-time analysis for fatigue and creep life assessments based on the pressure design code.

EXAMPLE EN12952-3 for fatigue assessment, EN12952-4 for creep life assessment.

6.3.6 The number of tube rows on a superheater harp directly downstream the GT or facing an auxiliary fuel fired duct burner shall be a maximum of two rows per header.

NOTE Superheater sections that are not directly downstream GT and are not facing an auxiliary fuel fired duct burner may be designed with a maximum of three rows per header.

6.3.7 When a superheater section is applied directly downstream of a supplemental fuel firing duct burner with firing temperatures greater than 700 °C (1290 °F), as a minimum, the first two rows shall be bare tubes for staggered tube arrangement and four rows of tubes for inline arrangement.

NOTE It may be necessary to apply more layers of bare tubes or low finning to limit heat input to the tubes. This consideration, however, is left to the experience of the designer/supplier, who would be expected to clarify the selected design details.

6.3.8 The maximum steam side maldistribution between parallel tubes on a harp shall be so that temperature distribution side to side is less than 5 %.

6.3.9 The mechanical design of the superheater harp shall take into account maximum possible differential temperature between tube rows on one header, considering both stationary and dynamic operation. (start/stop, part loads, normal loads etc.).

6.3.10 No multiple pass superheater harps, i.e. up and down flow in one harp, shall be used.

6.3.11 The minimum tube diameter used for a superheater shall not be less than 31.8 mm (1.25 in.) nominal.

6.4 Evaporator

6.4.1 Bi-drum type evaporators shall not be used.

NOTE A bi-drum type evaporator may be used with purchaser approval for an HRSG with a design pressure < 7000 kPa (ga) (1000 psig).

6.4.2 For horizontal gas path HRSGs with vertical tubes, no multiple pass evaporator shall be used.

NOTE For vertical gas path HRSGs with horizontal tubes multiple pass evaporators are rather common and it is acceptable to apply.

6.4.3 The supplier shall provide the circulation ratios of the evaporator. As a minimum, 5:1 ratio shall be used. Deviations require departure from nucleate boiling (DNB) calculations.

6.4.4 The design of the circulation system shall be so that water velocity at the inlet shall be minimum 1.0 m/s (3.3 ft/sec.)

6.4.5 The maximum heat flux shall not exceed 250 kW/m² (79,250 btu/hr-ft²)

6.4.6 The designer shall design the HRSG to avoid flow accelerated corrosion (FAC).

6.4.7 For evaporator system operated below 3500 kPa(g) (508 psig), the risers shall be made of P11 or similar or higher grade to prevent FAC and/or erosion corrosion.

6.4.8 For evaporator system operated below 3500 kPa(g) (508 psig), bent tubes (tube outlet) shall be made of T11/P11 or similar or higher grade to prevent FAC and/or erosion/corrosion.

6.4.9 No heated downcomers shall be used.

NOTE Large size downcomers without any surface extension that pass through the flue gas path may be regarded as unheated when the temperature rise of the water will be such that there is no notable heat input to the water, i.e. the inside film temperature of the downcomer water remains subcooled over the complete length of the down comer.

6.4.10 The supplier shall demonstrate by calculation that the inside film temperature of any downcomer remains subcooled using at least three times the expected heat flux.

6.4.11 Downcomers shall be equipped with minimum DN 50 (2 NPS) inspection nozzles placed in a horizontal orientation at the low point of the downcomer.

NOTE The horizontal orientation of inspection nozzles is intended to avoid deposit accumulation.

- **6.4.12** The purchaser shall specify that the inspection nozzles be capped or flanged.

6.5 Economizer / Feedwater Preheater

6.5.1 Economizer sections shall be provided with enough drains and vents to be able to fully drain and vent the economizer system.

6.5.2 Vents and drains shall be placed so that the economizer can be completely filled with boiler feedwater (BFW) without any trapping of air or any non-condensable gas.

6.5.3 Economizers shall not generate steam, i.e. steaming economizers shall not be used.

NOTE Steaming may be prevented either by selecting a sufficiently large temperature approach or applying anti-steaming features.

6.5.4 Anti-steaming features shall be agreed between the purchaser and supplier before implementing. The design features shall be supported with demonstrated success-based experience in a comparable system.

6.5.5 The design of the economizer shall be so that any steaming would occur in only upward flow sections of the economizer with steam completely relieved to the steam drum. The amount of steaming allowed shall be agreed with the purchaser prior to finalizing the economizer design.

NOTE Some steaming may be expected during upset and transitional operating cases, e.g. startup.

6.5.6 Economizer bypass systems are allowed as a solution to prevent steaming however shall have a pilot operated safety relief valve in accordance with pressure design code.

6.5.7 The last economizer pass shall always have unrestricted upward flow to the steam drum.

6.5.8 The velocity in downward flow tubes shall be so that there are no downward flow instabilities.

6.5.9 The water velocity in economizer tubes and connecting piping shall be designed to avoid FAC and or erosion corrosion. The supplier shall provide the maximum calculated velocity for each specified operating case.

6.5.10 Design of the economizer piping shall be such that FAC is prevented. If operated between 75 °C to 240 °C (165 °F to 465 °F) piping shall be made of P11 or alternative shall be clearly communicated.

6.5.11 Materials for economizers with a fluid design temperature between 75 °C to 240 °C (165 °F to 465 °F) shall, as a minimum, be T11 or P11 alloy steel or purchaser approved alternate.

6.5.12 Economizers shall be thermally designed to prevent acid dew point corrosion for the specified range of operation. The minimum fluid temperature shall be 15 °C (27 °F) above the calculated acid dew point and provide a calculated metal temperature above the water dew point.

NOTE If the SO₃ content of the flue gas is less than 300 ppb, acid dew point should not need to be considered.

6.5.13 Temperature of the flue gas, as a minimum, shall be 15 °C (27 °F) above the acid dew point.

6.5.14 The calculated acid dewpoint shall be determined considering all the fuels used for the gas turbine and the auxiliary fuel firing and possible SO₂ to SO₃ conversion due to NO_x control catalysts.

6.5.15 The supplier shall specify the methods used to calculate the acid dew point.

6.5.16 When applying condensate recirculation, the design of the condensate recirculation pumps and associated control valve(s) for temperature control shall be such that all operating cases are covered maintaining water temperature 15 °C (27 °F) above the dewpoint.

NOTE To limit the size of the condensate recirculation pump(s) a condensate preheater bypass may be used for extreme dew point situations.

6.5.17 When condensate recirculation is used, the pump configurations shall include redundancy to maintain full capacity on loss of a single pump, e.g. two 100 % or three 50 % capacity pumps.

6.5.18 When external condensate preheating is used, the heat exchangers shall be designed in accordance with the pressure design code.

NOTE Shell and tube or plate type heat exchangers may be used.

6.6 Steam Drums, Headers, and Manifolds

6.6.1 Headers and or manifolds shall be made of seamless pipe. Welding and material selection, as a minimum, shall comply with API RP 582 and API TR 938.

6.6.2 Unless otherwise specified, steam drums, headers and manifolds shall include 1 mm (1/16 in.) corrosion allowance.

6.6.3 Flat heads or covers on headers shall be full penetration welded. And the design shall be in accordance with the pressure design code.

6.6.4 Steam drum(s) shall be designed with a minimum retention, i.e. liquid hold-up, to prevent damage to the evaporator tubes and starvation of steam to the superheater tubes in case of feedwater supply failure. The minimum retention time between normal water level (NWL) and low-level trip/cut out shall be three minutes for high pressure and five minutes for intermediate and low-pressure steam drums.

6.6.5 Unless otherwise specified, steam drum sizing shall include the following drum level criteria in design:

- a) The distance between NWL and the high-level trip or critical alarm shall be not less than one minute of feedwater supply at maximum steam flow rate without any flow leaving the drum.
- b) The distance between NWL and first alarm level shall be minimum of 100 mm (4 in.); applicable to both high and low alarm level.

6.6.6 Steam drum(s) shall be designed so that there is enough volume available in the drum to facilitate startup swell/surge between a defined start level and high-level alarm, without using a startup or intermittent blow down. The start level shall be above the low-level trip.

6.6.7 Steam drum(s) shall be equipped with separate nozzles for safeguarding and control instrumentation.

NOTE The minimum number of steam drum nozzles is determined from the instruments selected and the requirements of the pressure design code.

6.6.8 Steam drum shall be equipped with internals to assure sufficient high-water steam separation efficiency to comply with the specified steam purity requirements.

6.6.9 In the absence of purchaser specified steam separation efficiency, the supplier shall design the steam drum internals and separation efficiency in consideration of the requirements appropriate for the steam system consumers, e.g. process steam, steam turbines, etc. following industry recognized criteria and guidelines.

EXAMPLE VGB Standard, EPRI guidelines or other.

6.6.10 For steam drums with an integral deaerator, deaerator design requirements shall be in accordance with 6.9.

6.6.11 There shall be no welding of any kind to the drum shell after heat treatment.

6.6.12 Shop welded nozzles shall be of sufficient length so that welding of tube/pipe to the nozzle will not adversely affect the steam drum nozzle weldments. The same requirement applies for welding internal or external drum attachments relative to steam drum attachment weldment.

6.6.13 The drum internal diameter shall be large enough to ensure proper function. If the purchaser requires a minimum internal size, it shall be clearly stated on the data sheet or in the specification.

6.6.14 The steam drum shall be equipped with two manholes; one on each steam drum head, with manhole covers that open to the inside.

NOTE Steam drum pressure will assist in the closure of inside opening manhole covers.

6.6.15 Steam drums manhole cover shall be properly hinged.

6.6.16 Steam drums shall have an internal and external handgrip above the manholes for ease of personal entry and egress.

6.6.17 The manholes shall be elliptical with a minimum size of 360 mm x 460 mm (14 in. x 18 in.)

6.6.18 Manhole gaskets shall be one of the following types unless otherwise specified by the purchaser:

- a) spiral wound, Type 304 SS, graphite filled with inner and outer rings;
- b) serrated metal Type 304 SS with graphite facing, or;
- c) corrugated metal Type 304 SS with graphite facing.

6.6.19 All steam drum internals subjected to maintenance shall be designed to be removed from the drum without cutting.

6.6.20 All internal bolted constructions shall have bolts that cannot loosen in service.

NOTE Example methods include double nutted, tack welded, with locking devices such as a tab washer, locking plates, split pins/cotter pins, etc.

6.6.21 The boiler feedwater supply to the drum shall be uniformly distributed over drum length.

6.6.22 All chemical injection facilities into a vessel shall have a distribution header of compatible material with the chemical added.

6.6.23 Downcomer inlets from drums shall be either flush with drum bottom or include drain features, e.g. slots or holes, in the lip of the downcomer when it is not flush with steam drum bottom, i.e. protrudes into the steam drum.

6.6.24 Downcomers shall be equipped with vortex breakers.

6.6.25 Downcomer position shall be arranged so that it will not lead to false level readings or vapor from being sucked into the downcomer.

6.6.26 Manifolds shall be supplied with a flanged end nozzle to allow for internal inspection. Nozzles shall be minimum size 100 mm (4 in.)

6.6.27 All drums shall be designed for full vacuum.

6.7 Blowdown System

6.7.1 Each pressure level of the HRSG shall be equipped with continuous blowdown and intermittent blowdown systems.

6.7.2 Continuous blowdown shall be taken from the steam drum. Intermittent blowdown shall be taken from the lowest point of the evaporator.

NOTE When the LP drum also acts as feedwater tank/integral deaerator and supplies BFW to other systems, this drum does not require continuous blowdown.

6.7.3 Blowdown water shall be routed to an atmospheric blowdown tank (or separator) unless used in a cascading blowdown design.

NOTE Cascading blowdown may be, from drum to drum or from drum to a blowdown flash vessel. Blowdown from the last flash vessel would be sent to an atmospheric blowdown tank.

6.7.4 The continuous blowdown system shall be designed for a maximum continuous blowdown as specified with a minimum capacity of 3 %.

NOTE If the supplier believes that the specified continuous blowdown system capacity is too small, this issue should be brought to the attention of the purchaser.

6.7.5 The intermittent blowdown system, for removal of sludge and reducing high water level, shall be designed with a minimum capacity of 10 %, or higher based on the supplier's experience.

6.7.6 The supplier shall specify any need for separate startup blowdown.

NOTE If a separate startup blowdown is not specified, this capability should be included in the intermittent blowdown system.

6.7.7 Operation of blowdown shall not impact evaporator circulation.

6.7.8 The continuous, intermittent and startup blowdown shall not share lines or connection to the blowdown tank.

6.7.9 Erosion resistant piping materials shall be used down stream of blowdown valves due to the high turbulence/velocity caused by water flashing and resultant two-phase flow. As a minimum, P11 piping materials shall be used.

NOTE When blowdown valves are placed directly on a header with sizing in consideration of stable two-phase flow, carbon steel materials may be used for this header if agreed by the purchaser.

6.7.10 Blowdown tanks shall use an internal wear plate to protect the tank shell against erosion due to flashing of blowdown into two phases; liquid and vapor.

6.7.11 If a pressurized flash tank is used in the blowdown system design, the tank shall include a liquid level control system to ensure that no flash steam cascades through the blowdown system drain.

6.7.12 The atmospheric blowdown tank, as a minimum, shall be designed following the guidance provided in NB-27 and in accordance with the pressure design code.

6.7.13 The atmospheric blowdown tank shall be adequately sized to accommodate all flows from blowdown and operational drains at the same time.

EXAMPLE Opening of intermittent and continuous blowdown at the same time, will not lead to water carry over into the blow down tank steam vent.

6.8 Attemperators

6.8.1 The supplier shall inform the purchaser of the proposed attemperator design and the expected maintenance frequency and means of inspection.

NOTE 1 An attemperator should be designed to minimize number of inspections and maintenance.

NOTE 2 A surface temperature reading of downstream pipe may assist to determine the operating condition of the attemperator.

6.8.2 The maximum attemperator spray water flow shall not exceed 15 % of the steam flow on a mass basis.

6.8.3 The attemperator steam inlet and outlet steam temperature shall be measured for the purposes of temperature monitoring and control.

6.8.4 The minimum degree of superheat downstream the attemperator before entering the next heating surface or main steam system shall be 25 °C (45 °F). The location of the temperature measuring point downstream of the attemperator shall be in line with the recommendation of the attemperator supplier.

6.8.5 Attemperator installations shall include a liner in the steam pipe from the spray point and extending a length following the attemperator vendor recommendations.

NOTE Liners protect the piping from thermal shock and erosion due to water droplet impingement.

6.8.6 The attemperator vendor shall provide a CFD model indicating droplet distribution and the point where full evaporation is expected.

6.8.7 Attemperator spray water line shall contain a strainer.

6.8.8 Attemperator spray water shall be treated condensate or demineralized boiler feedwater in line with the selected water treatment standard and steam requirements.

6.8.9 An inspection nozzle minimum DN 50 (2 NPS) shall be placed downstream of the internal for internal inspection of the liner and steam pipe.

6.8.10 To prevent upstream flow disturbance, e.g. bends, thermowells, etc. adversely affecting the attemperator operation, the upstream straight length shall comply with attemperator vendor's design recommendations, with the minimum being five inside pipe diameters.

6.8.11 To prevent downstream impingement, the downstream straight length shall comply with attemperator vendor's design recommendations, with the minimum being five inside pipe diameters.

6.8.12 There shall be a drain pot installed downstream the attemperator, as described in ASME BPVC.I – PHRSG-4.

6.8.13 Temperature measurement elements shall be provided directly upstream and downstream of the attemperator point to monitor and control steam temperature.

6.8.14 The minimum distance between attemperator point and temperature measurement element shall be 10 m (33 ft) or at minimum distance as required by the attemperator vendor, with a minimum distance of 5 m (16.5 ft).

6.8.15 Attemperator design shall be optimized to enable complete evaporation. The vendor data shall also include the length of downstream piping required to have complete atomization and steam temperature at the required set point.

6.8.16 Attemperator design shall be capable of providing complete evaporation within the length of the internal liner.

6.8.17 Attemperator shall have nozzle design to minimize droplet size.

6.8.18 The attemperator vendor data sheet shall include the following information for each of the specified operating cases:

- a) spray water droplet size and evaporation rates;
- b) the length of piping downstream of the attemperator where atomization is complete and the corresponding steam temperature.

6.8.19 The attemperator vendor shall specify the required spray water inlet pressure to achieve the attemperator design performance.

6.9 Integral Deaerators

NOTE External deaerators are not considered in this standard.

6.9.1 The deaerator shall be designed to meet specified requirements over the complete operating range of the HRSG.

- **6.9.2** The purchaser shall specify the quality of water supplied to the deaerator.
- **6.9.3** The purchaser shall specify the deaerator performance requirements.

6.9.4 When pegging steam is required in the design of an integral deaerator, the maximum pegging steam flow shall be considered for the sizing of the steam drum, levels, and internals.

6.9.5 Pegging steam shall be introduced into either the steam space or below the normal water level as determined by the supplier, unless otherwise specified.

6.9.6 When pegging steam is injected below the water level, this addition of steam shall not lead to excessive liberation speed, i.e. steam escaping the water level to disturb the level control. Liberation speed shall not exceed 0.3 m/s (1 ft/s).

6.9.7 When pegging steam is introduced below the water level, a distribution device shall be used.

6.9.8 Integral deaerators shall be equipped with a manually adjustable non-condensable vent to allow optimizing the deaerator process and energy consumption.

6.9.9 The location of the feedwater pump suction from the integral deaerator shall be optimized to prevent short-circuiting of non-deaerated water to the pumps.

6.9.10 Feedwater pumps shall be located below the deaerator in consideration of optimizing the available net positive suction head (NPSH) for the pump design.

6.9.11 Deaerator storage time between the normal liquid level and the low-level trip at design steam flow, shall, as a minimum, be 5 minutes unless otherwise specified by purchaser.

6.9.12 The corrosion allowance for the pressure boundary if an integral deaerator shall be the same as specified for the steam drum. No corrosion allowance for the internal is required unless otherwise specified by the purchaser.

6.9.13 Minimum temperature difference between the feedwater to the deaerator and saturation temperature shall be 10 °C (5.6 °F)

6.9.14 Integral deaerator shall be designed with a minimum operating pressure of 500 kPa(ga) (72.5 psig).

6.10 Piping

6.10.1 Piping shall always slope towards the low point drain.

NOTE If possible, downward sloping should be in the normal direction of flow.

6.10.2 Attenuator piping, as a minimum, shall slope towards the drain pot with a minimum slope of 0.5 degrees.

6.10.3 Piping shall be seamless and made of standardized pipe sizes and schedules.

NOTE If the required minimum wall thickness (t_{min}) and or pipe size cannot be covered by standardized seamless piping, rolled pipe, e.g. DN 750 (30 NPS) with $t_{min} > 16$ mm (5/8 in.), may be used when agreed by the purchaser.

6.10.4 Piping shall include drains and vents to facilitate start up and shutdown.

6.10.5 A steam warm-up line to the HRSG shall be provided to prevent excessive thermal stress, malfunctioning or damage to valves and piping.

6.11 Drains and Vents for Pressure Parts

6.11.1 There shall be drains and vents on the HRSG to allow complete drainage and venting of all heating surface and piping.

6.11.2 The minimum nozzle size for drains and vents shall be DN 50 (2 NPS).

6.11.3 All valve bodies shall be made with forged material in accordance with the pressure design code.

6.11.4 The superheater drains shall be of adequate size and number to drain condensate formed during the startup of the HRSG with the superheater drained completely prior to ignition of the GT.

6.11.5 The drain nozzles shall be properly positioned to drain all tubes evenly and completely with the design premise being gravity feed. A minimum of two drains on the outer ends of the harp shall be provided.

NOTE It is not necessary that a drain is at the outer end, but rather they are properly distributed, e.g. at position 25 % and 75 % of the header.

- **6.11.5** The purchaser shall specify the extent of automation, if any, for drains and vents.

6.11.6 The drain time for the complete HRSG assembly shall not exceed four hours unless otherwise specified.

6.11.7 The flexibility and spacing of drain and vent lines shall be designed in consideration of the largest degree of thermal expansion for the design service conditions.

6.11.8 Drain and vent lines shall be labeled.

6.11.9 Supplier shall properly review operating conditions and choice of material for drains and vents, including atmospheric sections.

6.11.10 Drains shall be accessible from grade or an operating platform for operation.

6.11.11 Two valves in series shall be provided for each drain or vent connection and located as close as possible to the drum, header, or any other HRSG pressure part.

6.12 Safety Relief Valves

6.12.1 The rating, sizing, number and testing of safety relief valves shall be in accordance with the specified pressure design code.

6.12.2 Steam safety relief valves shall be spring loaded.

6.12.3 All safety relief valves shall be designed for hydrostatic test value of 1.5 times the design pressure.

6.12.4 Safety relief valve sizing, as a minimum, shall be in accordance with the pressure design code for boilers unless the purchaser specifies a more stringent design code.

EXAMPLE ASME BPVC Section I; EN 12952 (all parts)

6.12.5 The required safety relief valve capacity shall be based on the maximum possible heat input.

6.12.6 The superheater safety relief valve capacity shall be such that the tubes of the superheater will not be excessively overheated during blowing safety situation, i.e. lifting of safety relief valves.

EXAMPLE API Standard 530 / ISO 13704, using elastic allowable stress with design life of 20,000 hr.

- **6.12.7** The purchaser shall specify flanged or welded connections for safety relief valves.

6.12.8 Safety relief valves shall have vertical discharge pipe of sufficient sizing, with the minimum being DN 200 (NPS 8).

6.12.9 Safety relief valves shall discharge to a safe area. The minimum height of the discharge point above the highest platform shall be 2 m (6.5 ft).

6.12.10 A safety relief valve and outlet shall have a drain of adequate size to avoid plugging and designed to prevent water accumulation in the outlet pipe. The drain lines shall be protected from freezing in consideration of the site minimum ambient conditions.

- **6.12.11** The purchaser shall specify any requirement for redundancy in the number of safety relief valves.

6.12.12 The safety relief valve outlet shall be equipped with a silencer to comply with the specified noise requirements.

6.12.13 The safety relief valve outlet piping supports shall be designed to withstand the mechanical forces and moments of the discharge piping under relieving conditions without transmitting these mechanical loads back to the valve.

6.12.14 The safety relief valve shall have a lever handle.

6.12.15 A test gag shall be supplied with each safety relief valve.

6.12.16 A factory test pressure report shall be supplied with each safety relief valve.

6.12.17 Each safety relief valve shall be supplied with one lower and upper adjusting ring pins.

6.12.18 All safety relief valve materials shall be readily identifiable and mill test reports provided with each valve.

6.12.19 Safety relief valves shall be designed for the designed lifetime of the HRSG.

- **6.12.20** Safety valves shall have valid factory test and tested on site during commissioning if required by code or when specified by the purchaser.

6.12.21 Outdoor HRSGs shall be equipped with weather hood/protection.

6.12.22 Commissioning shall consider the type of economizer safety relief valve and prevent chattering when a spring-loaded safety relief valve is applied.

NOTE A pilot operated safety relief valve may be used as solution to prevent chattering.

6.12.23 Only certified safety relief valves shall be used.

6.13 Startup Vent Valves, Sky Vent, and Electronic Relief Valves

6.13.1 The HRSG shall be equipped with an automated steam startup valve unless otherwise specified.

6.13.2 The startup vent shall support the following functions:

- a) Relieve steam until the steam header pressure is achieved.
- b) Allow adequate cooling of the superheater during startup.
- c) Control of steam drum pressure transients during startup to prevent damage to drum.

6.13.3 The startup vent shall have a minimum capacity of 30 % of maximum unfired steam production of the HRSG while at the minimum operating pressure, i.e. minimum floor pressure.

6.13.4 The startup vent shall have a vertical discharge pipe adequately sized to avoid reducing the design capacity of the vent valve.

6.13.5 As a minimum, a manual block valve shall be located upstream of the startup vent valve. The purchaser shall specify any supplemental requirements regarding block valve actuation, e.g. motor, or pneumatic, and the type of control, e.g. remote, local, or automatic.

6.13.6 The piping between block valve and startup vent valve shall have drain; minimum size DN 50 (2 NPS).

6.13.7 Startup vent valves shall discharge to a safe area. The minimum height of the discharge point above highest local platform shall be 2 m (6.5 ft)

6.13.8 A startup vent valve and outlet shall have drain of adequate size to avoid plugging and designed to prevent water accumulation in the outlet pipe. The drain shall be protected from freezing in consideration of the site minimum ambient conditions.

6.13.9 The startup vent valve outlet shall be equipped with silencer to comply with the specified normal operation noise requirements.

6.13.10 The startup vent valve outlet piping supports shall be designed to withstand the mechanical forces and moments of the discharge piping under relieving conditions without transmitting these mechanical loads back to the valve.

6.14 Valves

6.14.1 Valves shall meet the requirements of the pressure design code.

6.14.2 Each valve shall be designed to the specific application and designed for 25 years operating lifetime.

6.14.3 All valves shall be designed to a hydrostatic test pressure of 1.5 times the design pressure and be capable of opening and closing at the test pressure.

6.14.4 Valve design shall be such that it allows trouble free operation, e.g. no pressure locking or thermal binding.

6.14.5 The feedwater shut-off (stop) valve and non-return valve shall be as close as possible to the economizer inlet.

6.14.6 The steam shut-off (stop) valve and non-return valve shall be as close as possible to the superheater outlet.

6.14.7 When automatic startup is required, automated valves shall be used with preferred selection of motor operated or pneumatically operated valves specified by the purchaser.

NOTE The safeguarding philosophy applied may impact the selection of the actuator.

6.14.8 Valve selection and design shall be such that pressure locking will not occur.

6.14.9 The valve vendor shall provide manufacturing technical reports including mill certificates, NDE reports and materials datasheets.

6.14.10 All valves shall be supplied with permanently attached tags.

6.14.11 For valves DN 100 (4 NPS) and larger, the valve shall be provided with some type of pressure/temperature equalizing, to reduce differential pressure/temperature.

- **6.14.12** The purchaser shall specify when a shut-off valve bypass is required for warmup of downstream piping.

6.14.13 The maximum valve noise shall be SPL 85 dBA at 1 m (3 ft) from the valve, or the purchaser specification, whichever is less.

6.14.14 Forged materials shall be used for PN 260 (ANSI Class 1500) valves with a temperature rating greater than 480° C (900° F).

6.14.15 Valve applications above PN 420 (ANSI Class 2500), shall use an intermediate design unless otherwise specified by the purchaser.

6.14.16 The supplier shall provide chemical cleaning/acid wash trim kits for all HRSG valves in water or steam-side services.

6.14.17 The flow direction by design, where applicable, shall be clearly marked on all valves.

6.14.18 All valves shall be hydrotested in the shop and dried prior to shipment. Hydrotest reports shall be provided by the supplier/vendor.

- **6.14.19** When specified by the purchaser, vents and drains shall be suitable for throttling.

6.14.20 All operational vent and drain valves of the HRSG shall have a wear resistant cobalt alloy seat and plug, e.g. Unified Numbering System (UNS) R30006, or higher-grade material with demonstrated wear and leak tightness experience.

6.14.21 HRSG vent and drain valves shall be forged globe or gate valves with a minimum size of DN 50 (2 NPS).

6.14.22 All pressure retaining parts of the valve shall be made of materials, including specific limitations on various materials that are in full compliance with the pressure design code.

6.14.23 Only materials listed and rated in accordance with the pressure design code, e.g. ASME B16.34, appropriate to the design and service conditions listed shall be offered.

6.14.24 All materials shall be readily identifiable, including the country of origin. Mill test reports shall be obtained for all pressure boundary parts and included in the supply for all valves.

6.14.25 For high temperature applications >565 °C (1050°F) forged material shall be used instead of cast to ensure high quality and lasting reliability.

6.14.26 Economizer isolation valves shall be parallel slide type.

6.14.27 Gate valves PN 150 (ANSI Class 900) and higher, shall be flexible split wedge or parallel slide type with advanced pressure seal design. Pressure seal design shall be executed, with a ring allowing the opening without pushing down the bonnet for easy dismantling and avoiding damages on the tightness gasket area in the body.

6.14.28 Gate valves shall be of the outside screw and yoke construction including a yoke nut with bearing to lower the stem torque.

6.14.29 Calculations for internal valve trim (stem etc.) and all the internal parts shall be based on full differential pressure no matter the differential pressure for actuator sizing purpose.

6.14.30 Wedge guide shall be integral to the body and shall be machined to ensure smooth action across the valve stroke.

- 6.14.31** Valve stem shall be designed with integral anti-blowout.
- 6.14.32** Applied valve gasket shall be reinforced graphite rings, covered jacketed with a layer of 18.8 grade stainless steel on both sides (anti-extrusion). Metallic gaskets shall not be acceptable.
- 6.14.33** Valve stem packing or gaskets shall not contain asbestos.
- 6.14.34** Packing chamber shall be short and narrow with maximum six rings.
- 6.14.35** The rings on the top and on the bottom of the packing shall have UNS N06625 wire reinforcing overlay for guiding and with splinter-proof function.
- 6.14.36** The materials for yoke nuts shall be anti- friction.
- 6.14.37** Valve larger than DN 150 (6 NPS) shall be provided with two needle bearings. Every yoke shall have a lubrication nipple.
- 6.14.38** The yokes shall be equipped with a connecting flange on the top, ready to assemble gear, motor devices and other accessories.
- 6.14.39** All welding shall be provided with WPS and PQR records following authorized third-party industry standards.
- 6.14.40** Parallel slide valves shall be one-piece forged body.
- 6.14.41** Parallel slide valves shall include an anti-rotation device to prevent disks from rotating.
- 6.14.42** All stems shall be stainless steel with back seat designs.
- 6.14.43** All water/steam valves shall be full bore design unless otherwise agreed by the purchaser.
- 6.14.44** The valve supplier shall include as a minimum, the following NDE, with written reports:
- a) 100 % visual examination of forgings;
 - b) 100 % UT on bodies and pre-machined bonnets;
 - c) 100 % UT on welding of upper/lower bodies;
 - d) 100 % liquid penetrant testing on:
 - 1) 100 % wear resistant cobalt alloy and all the other hard facing;
 - 2) 100 % seats to body fillet;
 - 3) 100 % full penetration welding on bypass or warm up line (on the valve body).

NOTE Optional x-ray examination for any discontinuity.

6.14.45 When using ASTM A182/A182M or SA Grade F91 (ASME Specification) for valves, as a minimum, welding and material selections shall comply with API RP 582 and API TR 938 with the following amendments:

- a) The aluminum content shall be limited to ≤ 0.02 %wt.
- b) The ratio of nitrogen content to aluminum content shall be ≤ 2.5 .
- c) Forgings shall be supplied with 100% liquid penetrant examination for 10% of the forgings, as per ASTM E165/E 165M. Acceptance criteria as per ASME VIII Div. 1.
- d) Hardness shall be tested on minimum frequency of one per charge and per size. Maximum hardness 220 BHN, minimum hardness 190 BHN.
- e) Hot yield test at 538 °C (1000 °F). Acceptance criteria 277 MPa (40.2 ksi) yield strength minimum. Extent of testing shall be same as for the tension tests required by ASTM A182/A182M.
- f) Transverse V-Notch impact test.
- g) Micro examinations which indicate a structure of 100% tempered martensite required.

NOTE These amendments may be waived after approval by purchaser modified with purchaser approval.

6.14.46 PWHT shall not be done in a furnace, but by electric resistance heating mats.

6.14.47 Hard facing of alloy F91 material shall comply with the following requirements:

- a) UNS N06625 buttering layer mandatory for high temperature application with WPS and approved PQR for each step and NDE to ensure the results;
- b) UNS R3006 overlay with plasma arc welding (PAW) is preferred. No other procedures are acceptable for integral hard facing in the body and with proven quality record.

6.14.48 Alloy 91 welding shall be pre and post heat treated with recorded temperature levels.

6.14.49 Cast Materials ASTM A217 Grade C12A shall not be used unless it has been inspected with 100 % NDE, to check for any voids. The manufacturer shall include a report of factory repairs in the final acceptance test report.

6.15 Control Valves

6.15.1 When the steam drum level control valve is located downstream of the economizer, the valve internals and downstream piping shall be designed in consideration of steam flashing conditions.

6.15.2 Suppliers shall design and select control valves considering all operating conditions. This includes pressure testing, flushing, startup, normal operation, shutdown, maintenance etc. If certain conditions cannot be included, special trim, trim protection or other solutions shall be provided, and the purchaser shall be properly informed. Control valves shall have removable trim.

NOTE Replacement trim/spare may be included.

6.15.3 Control valve design shall comply with ANSI/ISA 75 (all parts) or purchaser approved equivalent.

6.15.4 Control valves shall be supplied with upstream and downstream block valves, a drain valve, and a bypass valve.

6.15.5 Control valve bypass valve shall have a nominal capacity equal to the control valve.

NOTE Operation may be manual if no actuator is specified.

6.15.6 A control valve bypass valve shall be suitable for throttling conditions.

6.15.7 Block valves around control valves shall be full bore.

6.15.8 Block valves shall, as a minimum, be the same line size as the control valve.

6.15.9 Valve bodies shall not be smaller than DN 50 (2 NPS).

6.15.10 Control valves shall be minimum PN 50 (ANSI Class 300) design class rating.

6.15.11 Control valve bodies shall not be fitted with bottom drain plugs or other wetted threaded connections.

6.15.12 Material selection of body, bonnet, bolts, nuts etc., shall be in accordance with the requirements of the applied piping classes.

6.15.13 Trim with passages smaller than 6 mm (1/4 in.) shall be protected with an upstream filter or strainer with mesh size less than 50 % of smallest valve trim passage.

6.15.14 Strainer design shall not cause control limitations.

6.15.15 On-off control valves for protective applications shall not be fitted with hand-wheels.

6.15.16 Only single acting actuators using a return spring shall be used for protective applications.

6.15.17 All non-hand operated valves shall be automatically controlled through the purchaser's distributed control system (DCS).

6.15.18 All non-hand operated valves shall have position indicators that are connected to a DCS or programmable logic controller (PLC).

6.15.19 All hand operated valves shall have position indicators connected to DCS, when their position is relevant for the process conditions and/or safety reasons.

6.16 Sampling

6.16.1 Supplier shall provide the HRSG with separate sample connections for:

- a) boiler feedwater (after pumps and after chemical injection point (if applicable) and downstream preheater/economizers);
- b) drum water (for each steam generating drum);
- c) saturated steam;
- d) superheated steam;
- e) deaerator (possible upstream of location of oxygen scavenger injection).

6.16.3 Drum water sampling shall be taken from a separated connection and not from the blow down lines.

6.16.4 Sampling of boiler water and steam shall be in accordance with relevant codes.

EXAMPLE ASTM D3370, ASTM D1066-11, and VGB-S-006-00.

6.16.5 When included in the supplier's scope, sampling lines shall be stainless steel pipe, Type 316, equivalent or higher grade.

EXAMPLE ASTM A312/A312M Grade 316.

6.16.6 The sample connection shall be same material as the line from which the sample is taken.

6.16.7 Sampling lines shall be self draining in the direction of flow.

6.16.8 Samples lines shall be designed for continuous flow.

6.16.9 For sampling of saturated and superheated steam supplier shall supply isokinetic sampling nozzles and associated valves.

EXAMPLE ASTM D1066-11

6.16.10 All chemical injection locations that are in a line shall have a quill of compatible material for the chemical used.

6.17 Water Quality and Steam Purity

6.17.1 The design of the HRSG shall be suitable for the specified water chemistry, specified water qualities and steam purity requirements, e.g. material selection, drum internals etc.

- **6.17.2** The purchaser shall specify which water treatment standard and selected water treatment method they are following, and the HRSG supplier shall provide facilities as needed to comply with that standard, e.g. drum internals, blowdown sizing, etc.

NOTE For selection of the water treatment program, the purchaser should consider all aspects of design and operation and confer with water treatment specialists.

6.17.3 When water chemistry, water quality and steam purity requirements are not specified by the purchaser, the supplier shall follow recognized industry standards, best practices or guidelines for water quality and steam purity, appropriate for the specified operating conditions.

NOTE 1 Industry recognized documents may include, however are not limited to:

- a) ASME 2012 Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle Cogeneration Power Plants;
- b) ASME 1998 Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers CRTD-Vol. 34;
- c) IAPWS September 2011 Technical Guidance Document: Phosphate and NaOH treatments for the steam-water circuits of drum boiler of fossil and combined cycle/HRSG power plants;

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- d) IAPWS July 2010 Technical Guidance Document: Volatile treatment for the steam-water circuits of fossil and combined cycle/HRSG power plants;
- e) EPRI 2006 Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs);
- f) Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs);
- g) VGB-Standard, Feed Water, Boiler Water and Steam Quality for Power Plants/Industrial Plants, Third Edition, 2011;
- h) API RP 538 Industrial Fired Boilers for General Refinery and Petrochemical Service;
- i) JIS V8223 Water Conditioning for Boiler Feedwater and Boiler Water;
- j) EN 12952-12 (September 2003), Water-tube boilers and auxiliary installations - Part 12: Requirements for boiler feedwater and boiler water quality;
- k) BS 2486-1997, Recommendations for treatment of water for steam boilers and water heaters.

NOTE 2 Example steam turbine OEM steam purity limits are included in ASME 2012 "Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle Cogeneration Power Plants", however, each OEM steam turbine manufacturer should be consulted prior to finalization of the specifications.

6.17.4 The purchaser and supplier shall align on water chemistry, water, and steam quality prior to engineering design of project.

6.17.5 When condensate is returned to the boiler water, online analyzers shall monitor pH, conductivity, and cation conductivity of the condensate prior to entering the boiler feedwater stream.

NOTE Sodium and TOC analyzers should be considered for on-line condensate monitoring.

- **6.17.6** The purchaser shall state makeup water quality; demineralized or softened water, and boiler feedwater quality; water to boiler drum including condensate. The following parameters, as a minimum, shall be quantified:
 - a) conductivity;
 - b) cation conductivity;
 - c) sodium concentration;
 - d) pH;
 - e) hardness concentration (as CaCO_3);
 - f) silica concentration;
 - g) dissolved oxygen concentration (boiler feedwater only if an integral deaerator is not part of the HRSG design);
 - h) iron concentration;
 - i) copper concentration;

j) oxidation-reduction potential (ORP).

6.17.7 The HRSG supplier shall calculate boiler water purity, percentage blowdown and specified steam purity, based on the selected water treatment and feedwater purity. These calculations shall be provided to owner/purchaser for approval.

6.17.8 Suppliers shall include any provisions to appropriately inject and monitor the agreed water chemistry. These shall include:

- a) chemical injection connections;
- b) chemical injection quills, if required;
- c) material selection;
- d) blowdown valve size and cycling control;
- e) chemical pump sizing (when included in scope);
- f) sample conditioning stations (when included in scope);
- g) sample points (for boiler water sample and steam when included in scope).

6.17.9 The purchaser shall assure availability of deaerated feedwater for start-up of the HRSG and steam blows to clean new steam lines.

6.17.10 Boiler feedwater and boiler water cation conductivity shall be monitored continuously for HRSGs on all volatile treatment (oxidizing) (AVT(O)) and all volatile treatment (reducing) (AVT(R)), low level phosphate treatment (PT), or caustic treatment (CT). Boiler feedwater oxygen or ORP shall be monitored continuously for HRSGs on all AVT(O) and AVT(R).

- **6.17.11** When specified by the purchaser, superheated steam sampling and boiler feedwater sampling connections are within scope of HRSG supplier.

6.17.12 All on-line pH analyzers shall have samples cooled between 23 °C and 27 °C (73 °F and 81 °) or include temperature correction i.e. Nernst equation and solution temperature compensation (STC).

6.17.13 Sample points and online analyzers shall be in accordance with ASME CRTD-81 and ASME PTC 19.11-2008 or a proven equivalent.

6.17.14 The purchaser shall specify upset condition management, i.e. specify boiler feedwater specification, boiler water and steam targets along with action levels when these targets are exceeded.

NOTE 1 Guidance on upset management and specifying action levels are provided in the following references.

- a) ASME 2012 Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle Cogeneration Power Plants”
- b) EPRI 2006 Cycle Chemistry Guidelines for Combined Cycles/Heat Recovery Steam Generators (HRSGs)
- c) Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs). EPRI, Palo Alto, CA.

- d) VGB-Standard, Feed Water, Boiler Water and Steam Quality for Power Plants/Industrial Plants, Third Edition, 2011.

NOTE 2 Other recognized references may also provide similar guidance.

7 Design Requirements – Non-Pressure Parts

7.1 General

- **7.1.1** The purchaser shall specify the structural and mechanical design code.
- 7.1.2** Structural components shall comply with the structural design code and the normative requirements of this standard.
- 7.1.3** The purchaser shall specify the wind and earthquake loads.
- 7.1.4** Wind load from external piping, pipe insulation, platforms, and other attached equipment shall be considered in establishing the net area of wind exposure.
- 7.1.5** Structures and appurtenances shall be designed for all applicable load conditions expected during shipment, erection, and operation including cold weather conditions when the HRSG is not in operation.
- 7.1.6** Load conditions shall include, but are not limited to dead load, wind load, earthquake load, live load, and thermal load.
- 7.1.7** Design metal temperature of structures and appurtenances shall be the calculated metal temperature plus 56 °C (100 °F), based on the maximum flue gas temperature expected for all operating modes with an ambient temperature of 27 °C (80 °F) in still air, unless otherwise specified by the purchaser.
- 7.1.8** The effect of elevated design temperature on yield strength and modulus of elasticity shall be considered in the design.
- 7.1.9** All components of the HRSG system shall be completely drainable. Low point drains shall be provided for all enclosures, free standing stacks, and ducts.

7.2 Structural Steel

- 7.2.1** The HRSG shall be supported on a structural steel frame independently carrying the full weight of the tubes and headers with no loads transmitted into the insulation system.
- 7.2.2** The frame shall be designed to permit lateral and vertical expansion of all parts of the HRSG at design temperatures.
- 7.2.3** The casing shall have a design pressure based on the maximum operating pressure plus margin, minimum 10 %. The design pressure shall not be less than the gas turbine trip pressure, with a minimum 5 kPa(ga) (0.725 psig).
- 7.2.4** The HRSG casing shall be a minimum of 6 mm (1/4 in.) thick plate. All casing plate shall be sufficiently stiffened against internal design pressure, damage during transport, erection, and vibration. The casing or stiffening shall not interfere with expansion.

7.2.5 External connections between casing plate shall be fully sealed by welding to prevent ingress of water. Skip or stitch welding shall not be permitted.

7.2.6 Any stiffening element shall be provided with weep holes to prevent accumulation of rainwater.

7.2.7 The outer casing shall be fully seal welded and gas tight.

7.2.8 All openings and connections shall be flanged and gasketed.

- **7.2.9** The structure shall be capable of supporting ladders, and platforms in locations where installed or where specified by the purchaser for future use.
- **7.2.10** Stairs shall be either free standing or attached to HRSG structure as specified by the purchaser.

7.2.11 Structural or support steel shall not hinder any access manways, doors or installed equipment.

7.2.12 Roof design shall prevent the holdup of water e.g. from rain or snow, and shall allow for an unobstructed pathway for runoff of rainwater following one or more of the following measures:

- a) Unobstructed runoff shall be accomplished by arrangement of structural members and drain openings and by sloping the roof, or with a secondary roof for weather protection.
- b) When roof members obstruct the open pathway for runoff, minimum 25 mm X 50 mm (1 in. x 2 in.) slots shall be made in any roofline crossmembers that would obstruct flow of water.
- c) Minimum roof slope shall be 6 mm per 3 m (1/4 in. per 10 ft) or a 25 mm (1 in.) drop from the centerline of the HRSG to the outside edge, whichever is greater.

7.2.13 When pitched roofs are provided for weather protection, eaves and gables should prevent the entry of windblown rain.

7.2.14 Duct structural systems shall support ductwork independent of expansion joints during operation, when idle or with duct sections removed.

7.2.15 Appurtenance shall be freestanding supported and not attached to the HRSG proper.

7.3 Access and Inspection Openings

7.3.1 The HRSG shall be designed with adequate tube spacing, tube bank depth, cavities, access doors and clear spaces between tube sections for inspection and maintenance access. Refer to 6.1.22 through 6.1.25.

7.3.2 The HRSG design shall include features to facilitate future repairs, such as plugging of leaking tubes, and repair of tube-to-header welds.

7.3.3 Bolted access doors with gaskets having a minimum clear opening of 600 mm x 600 mm (24 in. x 24 in.) shall be provided for entrance to all parts of the HRSG system for inspection and maintenance.

7.3.4 Access doors shall be easily accessible from grade or platform with entry and egress clear of obstructions for maintenance activities with threshold located no more than 600 mm (24 in.) above the internal gas path floor and external grade or platform.

7.3.5 Doors thresholds shall be located no more than 600 mm (24 in.) above internal gas path floor and external grade or platform.

7.3.6 There shall be minimum of one door between each tube section.

7.3.7 There shall be a minimum of one handle on the inside and outside of the duct or casing to support safe entry; the exception being inside of the duct downstream of a duct burner.

7.3.8 All HRSG internal spaces shall be accessible, i.e. all gas paths, dead spaces, return bend header boxes, etc.

7.3.9 Doors shall be pressure tight and insulated to maintain casing temperature. Internal construction and insulation details shall prevent casing hot spots.

7.3.10 Access doors shall be equipped with gaskets manufactured from non-asbestos compressed sheet gasket materials or graphite gasket materials rated for continuous operation at the temperature of the application.

7.3.11 Access doors shall be provided with hinges or, for doors greater than 40 kg, (90 lb), a davit; both including handgrips for removal.

NOTE Slide type hinges or davits should be provided for doors that include internal liners.

7.4 Expansion Joints and Pipe Penetration Bellows

7.4.1 Expansion joints shall be used for accommodating duct and casing expansion.

- **7.4.2** Purchaser shall specify the minimum lifetime of the expansion joint. Lifetime shall include commissioning cycles.

NOTE The design life of expansion joints should be a minimum of four years.

7.4.3 Expansion joint at cold end of HRSG may be subject to negative and positive differential pressure and shall be designed in accordance.

7.4.4 Expansion joint shall be designed for dew point corrosion.

7.4.5 Expansion joints shall be fabric type, multi-layer design.

7.4.6 Expansion joints shall be bolted.

7.4.7 Expansion joint shall be designed for expansion in all three directions (torsion, tension, compression, bending) and vibration as per purchaser specification.

7.4.8 Expansion joint internal insulation bolster shall be protected from erosion by internal flue gas lining.

7.4.9 Expansion joints shall have lifting lugs if too heavy to handle without cranes/lifting devices.

7.4.10 Expansion joint supplier shall take into consideration temperature ramp rates as specified by purchaser.

7.4.11 If pre-assembled expansion joint is applied, it shall be designed with proper supporting for erection.

7.4.12 Casing penetrations shall be used for accommodating any difference in expansion or movement between piping and casing.

7.4.13 Purchaser shall specify the minimum lifetime of the casing penetration bellows. Bellows design life of expansion joint shall be 4 years as minimum. Lifetime shall include commissioning cycles.

7.4.14 Casing penetrations design shall be such that conducting of heat to external parts is limited and does not lead to damage or hot spots.

7.4.15 Casing penetrations shall be designed for expansion in all three directions (torsion, tension, compression, bending).

7.4.16 Purchaser shall specify the required type of bellow to be used (stainless or fabric type). If SS bellows are used, these shall be equipped with protective shields during commissioning. If fabric type is applied these shall be multi-layer design.

7.4.17 Purchaser shall specify if permanent protective shielding shall be supplied.

7.4.18 Purchaser shall specify if bellows need to be bolted or welded. If not specified supplier can select own preference considering operating conditions.

7.4.19 When applying bellows in vertical arrangement at low point of HRSG, for drain purpose it shall be foreseen with a drain connection or weep hole.

7.5 Casing, Ductwork, and Insulation

7.5.1 The HRSG shall be cold casing design unless otherwise specified by the purchaser or if the operating conditions and flue gas composition require a different design.

- **7.5.2** The HRSG casing and insulation design system, i.e., cold, warm or hot, shall be specified by the purchaser in consideration of the operating conditions, ambient conditions and the acid dew point temperature of the flue gas.

7.5.3 Should the supplier's evaluation of the casing and insulation design system differ from that specified by the purchaser in 7.5.2, the supplier shall advise the purchaser accordingly.

7.5.4 Casing and ductwork material selection shall be based on the selected casing design type, i.e. cold, warm or hot.

7.5.5 For casing metal temperatures lower than 425 °C (800 °F), casing and ductwork shall be constructed with material in accordance with the structural design code.

EXAMPLE ASTM A36/A36M, ASTM A242/A242M, ASTM A572/A572M, or equivalent materials from the structural design code.

7.5.6 For casing metal temperatures that exceed 425 °C (800 °F), stainless or alloy steels shall be used.

7.5.7 Insulation material shall be bio-soluble alkaline earth silicate fiber (AES), or purchaser approved equivalent material.

7.5.8 The supplier shall design ducting and inlet duct to assure uniform flow distribution at the first heating surface considering the different GT operating conditions.

7.6 Flue Gas Baffles

7.6.1 Flue gas bypass baffles shall be provided, as may be required, to prevent hot gases from bypassing heat transfer surfaces therein reducing HRSG performance or causing excess temperature in downstream tubes or components.

7.6.2 The location of the baffles shall be based on HRSG supplier's proven experience.

7.6.3 Flue gas baffle materials shall, as minimum, be based on the same design criteria as the liner materials in the same location.

7.7 HRSG View Port Design and Location

See Section 8.

7.8 Painting and Coatings

7.8.1 HRSG steel shall be prepared in accordance with either ISO 8501-1 Grade Sa 2 $\frac{1}{2}$ or SSPC SP 6/NACE No.3 and primed with one coat of inorganic zinc primer to a minimum dry film thickness of 75 μ m (0.003 in.). Surfaces shall be painted in accordance with the manufacturer's recommendations on temperature and relative humidity.

7.8.2 Uninsulated flue gas ducts and stacks and air ducting shall be primed with an inorganic zinc primer. Surface preparation and dry film thickness shall be in accordance with the paint manufacturer's recommendations.

7.8.4 Platforms, handrails and toe boards, grating, stairways, fasteners, ladders and attendant light structural supports shall be hot-dipped galvanized. Galvanizing shall comply with ISO 1461, or the applicable sections of ASTM A123/A123M, ASTM A143/A143M, ASTM A153/A153M, ASTM A384/A384M and ASTM A385/A385M or equivalent. Bolts joining galvanized sections shall be galvanized in accordance with ISO 10684 or ASTM A153/A153M, or zinc coated in accordance with ASTM B633/633M or equivalent.

- **7.8.5** When specified by the purchaser, internal corrosion protection coatings shall be applied.

7.8.6 Unless otherwise specified, internal coatings shall be applied in accordance with the manufacturers' recommended practices, including surface preparation and ambient conditions.

- **7.8.7** When finish painting is required, the purchaser shall specify the paint material and color.

NOTE Finish paint color and material may affect the internal insulation thickness.

7.9 Insulation and Liner Systems

7.9.1 Unless otherwise specified or agreed by the purchaser, internal insulation with a metal liner shall be used.

NOTE Monolithic fiber modules without an internal metal liner may be used if allowed by local regulations and with approval by the purchaser.

7.9.2 Insulation thickness shall be calculated to maintain a maximum surface temperature of 60 °C (140 °F) at an ambient temperature of 27 °C (80 °F) in still air with no direct exposure to the sun.

NOTE If site specific conditions require a different thermal design basis, the owner is responsible for defining the differences, since changing the design basis will impact the required insulation thickness.

7.9.3 Personnel protection shall be provided in locations where personnel are exposed to the casing when the maximum surface design temperature is in excess of 60 °C (140 °F).

7.9.4 The heat loss of the casing, as part of the overall net thermal efficiency of the HRSG, shall not exceed 0.5 %.

7.9.5 Insulation systems shall be designed in consideration of thermal expansion of all parts.

7.9.6 The insulation maximum continuous use temperature rating shall be at least 111 °C (200 °F) above the maximum expected operating temperature based on the flue gas temperature in the respective zone of the HRSG system.

NOTE This temperature margin is used to ensure long term reliability of the insulation system.

7.9.7 Fibrous insulation blanket, in layered or in module type construction, shall be a minimum of 128 kg/m³ (8 lb/ft³) density, needled material. The minimum blanket thickness of each layer shall be 25 mm (1 in.).

7.9.8 Insulation blankets shall be designed in multiple layers for insulation thickness greater than 50 mm (2 in.) with staggered seams to minimize the number and severity of localized hot spots in the casing.

7.9.9 Local hotspots due to local construction details, shall be less than 1 % of the HRSG casing area. Under no condition shall the casing hot spot temperature exceed the material temperature limit temperature.

7.9.10 Insulation support system shall be robust to ensure insulation material does not sag in operation. Supplier shall use support systems that have been proven in similar applications.

7.9.11 Unless otherwise specified, where internal liners are used, they shall be made of solid steel plates of appropriate material for the temperature zone.

- **7.9.12** Perforated liner plates shall only be used when permitted by the purchaser.

NOTE Perforated liner plates should not be used upstream of any installed catalyst systems due to the increased risk of plugging the catalyst.

7.9.13 Liners shall overlap in the direction of exhaust gas flow (where physically possible) to prevent lifting of the liner plate and possible damage or loss of the insulation material.

7.9.14 Provisions for liners to expand with temperature shall be included.

7.9.15 The design temperature of the liner shall be determined based on consideration of the GT/HRSG complete range of operating conditions and including a design temperature margin of at least 55 °C (100 °F). Radiation effects shall be included in the determination of the maximum expected liner temperature.

7.9.16 When a duct burner is included in the design, the liner material within a minimum of 2.4 m (8 ft) above, below and downstream of the burner shall be minimum 309 SS material.

7.9.17 Maximum liner plate design temperatures shall be in accordance with Table 6

Table 6--Maximum Design Temperatures for Liner Materials

Material	Maximum Temperature
Carbon steel	450°C (842°F)
409 SS	650°C (1200°F)
410 SS	705°C (1300°F)
304 SS	815°C (1500°F)
309 SS	870°C (1600°F)
310 SS	870°C (1600°F)
NOTE 410 SS is not recommended for welded parts.	

NOTE Additional guidance on material selection may be found in API 560 – tube-support materials.

7.9.18 Internal liner thickness, insulation and liner support pin size and spacing shall be based on the supplier's proven design with minimum requirements as specified in Table 7.

NOTE The internal lining system design comprised of the liner, insulation and liner supports, is critical to the long-term reliability of the equipment. Sagging and or complete failure of the internal lining system could create large areas with high casing temperatures with potential for casing leakage and loss of containment.

Table 7--Minimum Liner and Support Design

Area	Minimum Liner Thickness	Maximum Stud Spacing
High Velocity/Turbulent ^a	3 mm (12 GA)	280 mm (11 in.) center-center
Low Velocity/non-turbulent	1.5 mm (16 GA)	280 mm (11 in.) – center-center around plate perimeter. 560 mm (22 in.) center-center plate mid-span
^a High velocity/turbulent area defined as inlet duct area upstream of a distribution device or first HRSG module where no distribution device is provided.		

7.9.19 Internal liner stud sizing shall be minimum 12 mm (1/2 in.).

7.9.20 All stud material shall be stainless steel consistent with the liner material selection.

7.9.21 Stud material shall be suitable for the maximum expected temperature in the zone in which it is applied.

7.9.22 There shall be no welding of neighboring liner plates.

7.9.23 When fibrous insulation construction is used with the normal operating fuel containing less than 15 mg/kg (15 ppm by mass) sulfur content, the casing shall have an internal corrosion protective coating. The protective coating shall have a maximum continuous use temperature of 175 °C (350 °F) or greater and it shall be applied after the stud anchors are welded to the casing.

NOTE Alternate corrosion protective solutions may be considered by the purchaser.

7.9.24 When the use of monolithic fiber modules without an internal metal liner is permitted by the purchaser, they shall only be used in designated areas of the HRSG in accordance with the following requirements:

- a) A pre-welded stud pattern shall be used to ensure high quality fit up.
- b) Fibrous blocks shall be shop installed to greatest extend possible. Suitable shipping protection shall be provided for the casing panels to minimize damage during shipping. The supplier shall provide any necessary materials and procedures for any minor repairs that need to be done in the field.
- c) After casing panel installation, the fibrous block material shall be sprayed with a suitable rigidizing solution unless otherwise recommended by the insulation supplier. Thorough cleaning of any loose fibers that have fallen during installation shall be performed if a catalyst is located downstream of the installation. The degree of cleaning shall be agreed between purchaser and supplier.
- d) Flue gas velocities shall not exceed the maximum allowed velocity of the monolithic insulation.

7.10 Ladders, Platforms, and Stairways

7.10.1 In addition to the requirements herein stated, ladders, platforms, and stairways shall comply with applicable local occupational health rules and regulations and any purchaser specified requirements.

7.10.2 Platforms shall be provided at the following locations:

- a) all steam drums, including access to manways that are greater than 1 m (3.3 ft) above grade.
- b) main steam and boiler feedwater stop and non-return valves;
- c) safety relief valves;
- d) blowdown and shutoff valves;
- e) vent and drain valves used during commissioning or routine operation;
- f) instrumentation, control valves, and attemperators;
- g) manways;
- h) observation doors;
- i) electrical equipment;
- j) emissions samplings ports;
- k) duct burner valves and instrumentation;
- l) SCR ammonia injection grid manifold.

7.10.3 Platforms shall have a minimum clear width as follows:

- a) operating platforms: 915 mm (36 in.);
- b) maintenance platforms: 915 mm (36 in.);
- c) walkways: 760 mm (30 in);
- d) flue gas analyzers: 915 mm (36 in.) on either side;
- e) face of the analyzer connection to the edge of the platform: 1525 mm (60 in.).

- **7.10.4** The purchaser shall specify instrumentation dimensions ~~(and expected location)~~ in consideration of maintenance access and platform sizing.

7.10.5 Platform decking shall have a minimum thickness of 6 mm (1/4 in) checkered plate or 25 mm x 5 mm (1 in x 3/16 in.) open grating or as specified by the purchaser. Stair treads shall be open grating with a checkered plate nosing.

7.10.6 Dual access shall be provided to each operating platform, except if the individual platform length is less than 6 m (20 ft).

7.10.7 Unless otherwise specified, all platforms that are routinely accessed for operations and maintenance shall have a minimum of one means of access with a stairway, others by ladder. The alternate point of access shall be opposite the main access.

NOTE Alternative access route may be ladder.

7.10.8 An intermediate landing shall be provided if the vertical rise exceeds 6 m (20 ft) for ladders and 4.5 m (15 ft) for stairways.

7.10.9 When post combustion NO_x control equipment is provided within the scope of supply for the HRSG, in addition the requirements herein specified, platforms shall be arranged to not inhibit the removal of catalyst.

7.10.10 Platform, ladder and stairway shall be bolted assemblies and bolted to gussets that are welded primarily to the HRSG structure. HRSG thermal expansion shall be accounted for in the structural design.

7.10.10 Ladders shall be caged from a point 2.3 m (7.5 ft) above grade or any platform. A self-closing safety gate shall be provided for all ladders serving platforms and landings. Ladders shall be arranged for side step-off; step through ladders shall not be used unless specified or agreed by the purchaser.

7.10.11 Stairs shall have a minimum width of 750 mm (2.5 ft), a minimum tread width of 240 mm (9.5 in), and a maximum riser of 200 mm (8 in). The slope of the stairway shall not exceed a 9 (vertical) to 12 (horizontal) ratio.

7.10.12 Headroom over platforms, walkways, and stairways shall be a minimum of 2.1 m (7 ft).

7.10.13 Handrails shall be provided on all platforms, walkways, and stairways in accordance with local codes and regulations.

7.10.14 Handrails, ladders, and platforms shall be arranged so as not to interfere with regular maintenance and measuring taps/ports. Where interference exists, removable sections shall be provided.

7.10.15 The gap between the toe plate and casing or adjacent steel shall not exceed 75 mm (3 in.).

7.11 Stacks

7.11.1 The design and fabrication of HRSG stacks shall be in accordance with ASME STS-1 or equivalent including applicable local codes and the specified structural design code.

7.11.2 Exhaust stacks for horizontal HRSGs shall be free standing from grade. Exhaust stacks for vertical HRSGs shall be mounted on top of the HRSG structure. In all cases stacks shall be self-supporting. Guyed stacks shall not be used.

NOTE Bypass stacks may be free standing from grade or supported by the bypass damper structure.

7.11.3 For stack flue gas temperatures above 425 °C (800 °F), internally insulated (with stainless steel liner) carbon steel or Type 304 stainless steel (or higher) stacks shall be used.

NOTE For stack design flue gas temperatures below 425°C (800°F), unlined carbon steel stacks may be used.

7.11.4 External insulation or internal acid resistant coating shall be provided if the expected stack metal temperature falls below the flue gas acid dew point. For determining stack metal temperature, the complete operating range and complete ambient conditions range shall be considered.

7.11.5 Personnel protection shall be provided on surfaces not externally insulated with metal temperatures above 60 °C (140 °F), within reach of operating personnel.

7.11.6 Flue gas sample connections shall be provided in accordance with applicable local environmental regulations. Platforms and caged ladders are required for access to sampling points.

7.11.7 Stacks shall have at least on DN 150 (6 NPS) and four equally spaced DN 80 (3 NPS) emission sample test connections.

7.11.8 Stacks shall have connections for permanent monitoring equipment as specified.

7.11.9 Emission sample ports shall be located a minimum of 0.5 x ID below the top of the stack.

7.11.10 Sample connections shall be stainless steel.

- **7.11.11** Sample ports shall have bolted covers or screwed covers as per specification.

7.11.12 Sample port covers shall have loss preventing chain/wire.

7.11.13 Unless specified by the purchaser, the stack diameter shall be selected based on HRSG supplier standard and experience. Minimum stack height shall be based on local air permit requirements for up and downstream undisturbed flow lengths from the emission sample ports.

7.11.14 The stack shall have sloped bottom with a low point drain, with a minimum drain size of 50 mm (2 in.), complete with block valve.

7.11.15 The bottom of stack shall be accessible for inspection either from a door in the bottom of stack or from an outlet duct.

7.11.16 Stacks shall have as minimum one lifting davit with minimum lifting rated capacity of 205 kg (500 lb), located at the sampling platform.

7.11.19 A minimum corrosion allowance of 1.6 mm (1/16 in.) shall be applied, except in the case when a corrosion protecting coating is used.

- **7.11.17** When specified by the purchaser, a stack damper shall be provided.

7.11.18 When a stack damper is applied, it shall be self-opening on overpressure in the HRSG.

7.11.20 There shall be an access door/manhole above stack damper for inspection purposes.

7.11.21 The stack damper shall have locking devices as a safety protection to allow safe entry above the stack damper.

7.12 Fans and Motors for Fresh Air Firing

- **7.12.1** Fans when specified, shall be constructed in accordance with API 673, or the purchaser's specifications.

7.12.2 The purchaser shall specify if the fresh air firing system shall be designed as a forced or induced draft system.

7.12.5 When changeover operation from GT to fresh air firing mode is required, the purchaser; HRSG supplier and duct burner supplier shall work together to fully define and design for all operating scenarios. The owner shall specify the changeover time requirements (time from turbine trip to burners in operation).

7.12.6 The owner shall specify the HRSG performance requirements during fresh air fired mode of operation.

7.12.7 The purchaser shall advise the supplier of the minimum time required for the fan to accelerate from rest to full speed. This minimum time shall also apply for isolation dampers to travel from fully closed to fully open position.

7.13 Flue Gas Bypass System

7.13.1 General

- **7.13.1.1** A divert damper shall provide for directing the turbine exhaust into a bypass stack and seal the flow from entering the HRSG or, when specified by the purchaser, to allow for controlling the flow of exhaust.

7.13.1.2 Dampers and isolators shall be located upstream of any duct burners.

7.13.1.3 Unless otherwise specified by purchaser, the selection of bypass damper type; single blade or multi louver, shall be based on operation and performance requirements and suppliers' proven experience.

7.13.1.4 The supplier shall provide a detailed justification for the selected design of dampers and isolation systems.

7.13.1.5 Multi-louver flue gas bypass system designs shall be configured with fail-safe interlocks to prevent closure of both dampers, i.e. bypass and the HRSG duct, therein assuring an open pathway for turbine exhaust gas (TEG) to atmosphere.

7.13.1.6 When applying an isolation guillotine, limit switch interlocks shall be provided between a damper and guillotine.

7.13.1.7 When specified to have combined GT operation and HRSG maintenance at same time, two independent fail-safe isolation barriers shall be provided, e.g. damper and guillotine or damper and blanking plate. A minimum of two sealing planes shall be provided to allow safe entry into the HRSG while the gas turbine is operated in simple cycle mode.

NOTE Sealing air can be provided and monitored to confirm seal status.

7.13.1.8 When a diverter system is provided, it shall include, but not be limited to:

- a) all required accessories;
- b) all structural parts, e.g. frame, blade etc.;
- c) actuator;
- d) ductwork;
- e) expansion joints as required;

f) thermal insulation;

g) instrumentation.

- **7.13.1.9** When specified by the purchaser, a seal air system for the diverter system shall be provided.

7.13.1.10 For diverter systems with seal air:

- a) 100 % sealing shall be achieved;
- b) sealing air pressure shall be minimum 50 mm H₂O (2 in. H₂O) above the GT operating pressure;
- c) a safeguarding alarm for low seal air pressure shall be provided.

7.13.1.11 For system without seal air, the leakage rate shall be agreed with purchaser.

7.13.1.12 The diverter shall be designed and constructed to operate correctly under the specified operating conditions during the design lifetime of the HRSG or diverter.

7.13.1.13 The diverter internal flow path shall be designed to not exceed an average of velocity of 40 m/s (130 ft/s).

7.13.1.14 The supplier shall provide details on the expected free flow area and guaranteed maximum pressure drop.

7.13.1.15 The diverter damper pressure drop shall be included in the overall system allowable pressure drop.

7.13.1.16 The diverter damper assembly shall include an automatic control actuator complete with an external position indicator and limit switches for remote position monitoring and control.

7.13.1.17 The diverter system shall be designed for the complete range of expected operating temperature and pressure.

7.13.1.18 Damper components (include supports, hinges, e.g. for blade, actuators etc., shall not be subject to deformation or deterioration due to corrosive, high temperature or velocity conditions and not move under the effects of gravity, dynamic pressure or vibration; except for seals.

7.13.1.19 The diverter damper shaft and blades shall be robust in design providing stiffness for tight sealing and flutter resistance under all operating conditions.

7.13.1.20 The HRSG ducting system design shall include expansion joints to minimize thermal loads and forces on the diverter damper.

7.13.1.21 Lifting lugs shall be provided for handling removable components of the diverter.

7.13.1.22 The diverter frame shall be internally insulated.

7.13.1.23 The design and fabrication of the diverter damper assembly shall be in accordance with the structural design code or consistent with the code or standard applied to the adjacent ducting, whichever is more stringent.

7.13.1.24 Internal components shall be fixed to supporting members so that free thermal expansion is maximized.

7.13.1.25 Seals shall not be welded directly to the frame and be replaceable.

7.13.1.26 There shall be allowances made to accommodate the differential thermal expansion between exposed and unexposed parts of landing bars and seal mounting for the specified range of operating conditions.

7.13.1.27 Blade design shall be suitable for the maximum expected operating conditions. The diverter blade shall be designed and insulated so that distortion/deformation is prevented.

7.13.1.28 All parts directly exposed to hot TEG shall be made of stainless steel grade materials as specified in Table 6.

7.13.1.29 The diverter blade design temperature shall be 50 °C (90 °F) above the maximum operating TEG temperature.

7.13.1.30 The thermal insulation of the damper/bypass system shall be an integrated part of the lining design. The same requirements concerning internal insulation design details, surface temperatures and hot spots as specified for general casing, ductwork and insulation shall apply.

7.13.1.31 In addition to internal insulation design of normal casing, the design shall consider that there are internal moving parts. These shall not be hindered in operation due to internal liner design.

7.13.2 Diverter System Seal Design

7.13.2.1 All seal elements shall be pressure assisted by the exhaust gas when in the closed position.

7.13.2.2 The cavity between the seals shall be buffered by seal air fans to maintain a positive isolation.

Note For small GT applications, tightness of seals may be enough without seal air.

- **7.13.2.4** When specified by the purchaser, an automatic back-up source of seal air shall be included in the system design with the source specified as:

a) two 100 % capacity seal air fans. or,

b) interconnected with the plant compressed air system (utility or instrument air).

7.13.2.5 The pressure taps for the diverter seals shall be on the seal, downstream of any dampers provided, and opposite the seal air inlet connection.

7.13.2.6 Seals shall be furnished in segments not longer than 1 m (3.3 ft) in length, capable of compensating the differential expansion between the seal and its mounting.

7.13.2.7 Seals shall be replaceable at the site.

7.13.2.8 Seals shall be all-metal, non-permeable and flexible to accommodate expansion and movements of the damper and casing.

7.13.2.9 The physical sealing capability of the diverter shall not deteriorate due to high TEG temperature, e.g. 650 °C (1200 °F) or TEG velocity at maximum load conditions with diverter blades in their fully open or closed position.

NOTE Deterioration is only expected through the actions of service wear.

7.13.2.10 The supplier shall specify the degree of gas flow isolation, as a percentage of TEG flow at maximum load, provided by the damper type proposed. >>>RW – Add a line item on the data sheet – Diverter leakage at maximum load (% flow)

7.13.2.11 Seals shall be made of materials that maintain adequate mechanical properties at design conditions for a minimum of five years.

7.13.2.12 Seal materials shall be capable of accommodating distortions in the diverter framework and blade up to 10 mm per meter (1/8 in. per foot) run length.

7.13.2.13 The maximum distortion in the diverter framework shall be consistent with the recognized industry standard for steel construction, i.e. L/360.

7.13.2.14 The diverter seal air system shall be complete with seal air fan, interconnecting ductwork, controls, instruments, valves, etc.

7.13.2.15 The seal air fan(s) shall not to be exposed to the hot exhaust gases.

7.13.2.16 The seal air fan capacity shall be at least twice the calculated seal leakage rate in consideration of possible deterioration of the seals.

7.13.3 Diverter Drive System

- **7.13.3.1** The purchaser shall specify the preferred or required type of diverter drive system:

- a) electric,
- b) pneumatic, or
- c) hydraulic actuator.

7.13.3.2 When a hydraulic actuator is supplied; the diverter shall have one hydraulic system including two pumps, each of 100 % duty, two independent hydraulic actuator systems with separate hydraulic lines with a common tank.

7.13.3.3 Actuators and drive shaft shall be capable of supplying 200 % of the required damper force/torque considering the most severe operating condition.

7.13.3.4 Manual operation of the diverter shall be possible in the event of a power failure. Interlocks shall be provided to prevent the power drive from starting while the diverter is under manual operation. A disengaging clutch shall be incorporated to facilitate manual operation of the damper.

7.13.3.5 Shaft shall be provided with clearly visible position indicator from grade and manual operation position.

7.13.3.6 The couplings in the transmission shaft(s) shall be all-metal and flexible.

7.13.3.7 The actuator and associated gearboxes shall be mounted external to the duct and accessible for inspection and maintenance while HRSG is in operation.

7.13.3.8 Mounting brackets of limit switches shall be adjustable to allow the closing positions of the damper blade to be accurately set.

7.13.3.9 Limit switches shall be contact free, rigid and capable of sustaining the dynamic forces of the damper blade for all modes of operation.

7.13.3.10 The functionality of the limit switches shall not be affected by thermal expansion.

7.13.3.11 Locking pins shall be provided to hold the diverter in the closed position.

7.13.3.12 Diverter bearings shall be:

- a) free of external lubrication;
- b) not affected by particulates in flue gas or dust;
- c) self-aligning;
- d) replaceable without need to remove bearings house from the frame;
- e) fabricated from non-jamming materials and consist of replaceable pads.

7.13.4 Diverter System Shaft Seals

7.13.4.1 The damper shaft shall extend through the duct wall to external bearings and sealed to prevent gas leakage.

7.13.4.2 The shaft sealing system of the diverter shall:

- a) be designed to accommodate thermal expansion and not deform;
- b) contain fully metallic labyrinth type diaphragms;
- c) contain no fibrous material;
- d) be replaceable without removing the bearing;
- e) not inhibit the self-aligning capabilities of the bearings.

7.13.5 Guillotines, Blanking Plates, and Blind Plates

7.13.5.1 The purchaser shall specify the need for any HRSG isolation and the type of isolation device to apply (guillotine, blanking plate, blind plate).

7.13.5.2 A guillotine and/or blanking plate shall be inserted into the ducting joint downstream diverter damper.

NOTE A blind plate may be applied by unbolting ducting flanges and installing a blind plate.

7.13.5.3 Blanking and blind plates shall only be installed when the GT is not in service.

NOTE Depending on design, it may be possible to install an isolation plate with the GT in operation.

7.13.5.4 The isolating device shall be designed with enough stiffness and strength to withstand 1.5 times the design pressure of the upstream ducting without deformation.

7.13.5.5 The design temperature of the isolating device shall be 50 °C (90 °F) above the highest operating TEG temperature.

7.13.5.6 A guillotine shall be inserted from the top down by means of a drive using a chain and wheel mechanism while assuring proper positioning into a sealing system.

NOTE 1 Automation is recommended on larger HRSGs.

NOTE 2 Some designs may require side mounted, stored plates in different location and the use of cranes.

7.13.5.7 The guillotine shall be secured and stored in an enclosure above the duct while not in use.

7.13.5.8 The guillotine slot shall be designed for the minimum use of purge air to prevent overheating and hot spots while the guillotine is not in use.

7.13.5.9 Positive ventilation/purging with air shall be applied between the diverter and guillotine to prevent hot surface. Guillotine surface shall not exceed the maximum ducting temperature when in use.

7.13.5.10 There shall be an engineered design and safeguarded seal air system preventing leakage of flue gas into the HRSG to provide safe work conditions downstream the guillotine while the GT is in operation.

7.13.5.11 The guillotine damper actuators shall be readily accessible from the HRSG platforms. Drives shall be furnished complete with all mounting bases and connecting linkage.

7.14 Post-Combustion NO_x Control

- **7.14.1** When specified by the purchaser, a selective catalytic reduction (SCR) post combustion NO_x control system shall be provided. The purchaser shall specify the emission control requirements.
- **7.14.2** When specified by the purchaser, provisions for the future installation of a post combustion NO_x control system shall be provided.

7.14.3 The SCR reactor shall include test elements in the catalyst modules placed in accessible locations for removal during a shutdown of the HRSG system.

7.14.4 API 536 and purchaser specifications shall be used for the selection and design of the SCR post combustion NO_x control system with due consideration given to the specific process and mechanical requirements for application in an HRSG system.

7.13.5 The HRSG system flue gas side pressure drop, and exhaust temperature calculations shall include consideration of the impact of any planned or specified future provision of post combustion NO_x control system components, e.g. catalyst beds in the clean and fouled conditions.

7.14.6 The design of the SCR shall not inhibit the start-up time of the HRSG.

7.14.7 The design of the HRSG shall consider the following minimum requirement for maintenance and future replacement of SCR catalyst:

- a) Gas path internal components that require replacement during the lifetime of the HRSG shall be sized to fit through the manholes or special designed access provision, e.g. a removable piece of duct.
- b) HRSGs shall be equipped with manhole doors and access upstream and downstream of the catalyst reactor. For details of access doors refer to 7.3.

7.15 Post-Combustion CO/VOC Control

- **7.15.1** When specified by the purchaser, a post combustion CO/VOC control system shall be provided. The purchaser shall specify the emission control requirements.
- **7.15.2** Purchaser shall specify if provision is required for future installation of post combustion CO/VOC control system.

7.15.3 The HRSG system flue gas side pressure drop and exhaust temperature calculations shall include consideration of the impact of any planned or specified future provision of post combustion CO/VOC control system components, e.g. catalyst beds in the clean and fouled conditions.

7.15.4 The CO/VOC reactor shall include test elements in the catalyst modules placed in accessible locations for removal during a shutdown of the HRSG system.

7.15.5 The design of the CO/VOC control catalyst shall not hinder the operation of the HRSG.

7.15.6 The design of the HRSG shall consider the following minimum requirement for maintenance and future replacement of CO/VOC catalyst:

- a) Gas path internal component that require replacement during the lifetime of the HRSG shall be sized to fit through the manholes or special designed access provision, e.g. a removable piece of duct.
- b) HRSG shall be equipped with manhole doors and access upstream and downstream catalyst. For details of access doors refer to 7.3.

7.16 Sootblowers

- **7.16.1** When specified by the purchaser, sootblowers shall be included in the scope of supply.

NOTE When sootblowers are not specified and the supplier considers that they are required for the service, the purchaser should be advised accordingly.

7.16.2 The impact of sootblower operation on HRSG operation and performance over the life cycle for the HRSG shall be considered in design by the supplier.

7.16.3 Sootblower installation and location shall use technology proven in HRSG application including consideration of the fuel being used.

7.16.4 The maximum unsupported length of sootblower lances shall not be more than 3 m (10 ft)

7.16.5 Unless otherwise specified, the steam sources shall be from the HRSG.

7.16.6 Sootblowing equipment shall include all necessary piping, valves, drains, drives, control connections, platform etc., to provide full functionality.

7.16.7 Steam lines to sootblowers shall be sloped to a trapped low-point drain.

7.15.8 Forced draft seal air shall be supplied to the sootblower casing connection/stuffing box to prevent leakage of flue gas from the HRSG.

7.16.9 A dedicated fan shall be used for seal air.

7.15.10 Tube bank depth (number of tube rows) shall be limited so that sootblowing will be effectively clean all tubes.

7.15.11 The tube pitch and sootblower row spacing shall be designed to allow full cleaning of the tubes, for the selected sootblower design.

7.16.12 The sootblower material shall be selected suitable to the flue gas temperature without consideration of the cooling effect of the steam.

7.17 Tube Mechanical/Vibration Supports

7.17.1 Tube vibration analysis shall be provided by the HRSG supplier for all operating cases. Analysis shall be performed for vortex shedding, turbulent buffeting, acoustic resonance, and fluid elastic instability.

7.17.2 Supplier shall provide baffles and intermediate tube supports to mitigate the flow induced vibration issues.

7.17.3 Material selection for vibration support materials shall be in accordance with Table 8.

Table 8--Maximum Design Temperatures for Tube-support Materials

Material	Maximum Temperature
Carbon steel	425°C (800 °F)
409 SS	650°C (1200°F)
410 SS	705°C (1300°F)
304 SS	815°C (1500°F)
309 SS	870°C (1600°F)
310 SS	870°C (1600°F)
NOTE Type 410 SS is not recommended for welded parts.	

NOTE For additional guidance on material selections for tube-support materials, refer to API 560.

7.17.4 Vibration support material for supports directly downstream and in-line with burner flame shall be a minimum of Type 309 SS.

8 Design Requirements – Supplemental Fuel Firing

8.1 Duct Burner System

NOTE The specification requirements in this section are suitable for most natural and refinery fuel gasses. However, there may be specific design challenges with non-typical fuels, such as high hydrogen.

8.1.1 Supplemental fuel firing systems shall include all parts required to provide a fully functional duct burner system.

EXAMPLE Fuel train, interconnecting piping, burners, baffles, ignitors, flame scanners, cooling air blowers, burner management system (BMS), and view ports.

8.1.2 Site specific ambient conditions shall be included in the burner system design.

8.1.3 The HRSG supplier and burner vendor shall agree on the TEG velocity distribution requirement at the burner-plane inlet.

8.1.4 The duct burner shall be designed for all specified fuels.

NOTE Low calorific fuel may require special design considerations, including the need for supplemental fuel and/or augmenting air.

8.1.5 The supplier shall provide scale model testing or CFD analysis demonstrating compliance with TEG velocity distribution requirements into the duct burner and temperature distribution to downstream heating surface.

8.1.6 The burner vendor shall determine any need for augmenting air based on fuel composition, flue gas conditions at location of burner and burner performance/emission requirements.

8.1.7 Any supplemental fuel firing system shall be designed to achieve the required burner performance and enhance start-up, normal operation and shutdown, with any of the specified fuels.

8.1.8 Burners shall be of a proven design with stable flame, without flame impingement on walls or tubes for the specified operating range.

8.1.9 Flame stability shall be proven during commissioning over the complete operating range of the burner.

8.1.10 The burner vendor shall determine the calculated flame length for the specified operating cases in consideration of the fuel firing and air demand requirements.

8.1.11 A minimum of 1.2 m (4 ft) shall be added to the calculated flame length to determine the duct length between burner and first heating surface.

NOTE When consideration of the emission and temperature distribution requirements indicate the need for a greater distance between the duct burner and first downstream heating surface, the burner vendor should advise the HRSG supplier accordingly.

8.1.12 An isosurface of 2467 mg/m³ (2000 ppm by volume) (dry) CO shall be used to define the flame envelope.

8.1.13 Flue gas temperature measurements shall be provided downstream of the burner and upstream of the first heating surface in accordance with the following requirements:

- a) thermocouples located on one side of the duct for a duct width less than 3.6 m (12 ft);
- b) thermocouples located on both sides of the duct for a duct width greater than 3.6 m (12 ft);
- c) minimum thermocouple length is 800 mm (32 in.);
- d) thermocouples to be shielded against direct flame radiation and inserted with a guide tube or thermowell;
- e) temperature measurement points not subjected to flame impingement;
- f) one measurement point for each 2.4 m (8 ft) of tube length equally distributed over the height of the duct (horizontal gas path) or length (vertical gas path);
- g) the minimum distance of the plane of measurement away from the front of the heating surface is 600 mm (24 in.).

8.1.14 There shall be an emergency isolation fuel valve on the main fuel supply line located approximately 30 m (100 ft) away from the HRSG.

NOTE This emergency isolation valve would typically be outside of the HRSG supplier's scope of supply and is intended to be in addition to the fuel isolation valves included in fuel gas train and burner management system for the duct burner system.

8.2 Duct Burners

8.2.1 When no margin is specified in 4.1, a fired duty margin of 10 % shall be used.

- **8.2.2** The purchaser shall specify if burner elements in the duct burner shall operate as a single group or multiple burner elements in operation.

Example All burner elements on/off as one group or each burner element on/off individually.

8.2.3 Burner elements shall be designed for the complete operating range of gas turbine exhaust flow conditions, i.e. flow and temperature, including a maximum TEG temperature margin of 50 °C (90 °F).

8.2.4 The design of the duct burner elements, including igniter, shall include the effect of any flame back-radiation to the burner.

8.2.5 The number of duct burner elements shall be determined based on specified total heat requirement and heat release per element.

8.2.6 Duct burner elements arrangement shall provide uniform temperature and emissions downstream the duct burner.

8.2.7 The design of the duct burner elements shall include measures to avoid fuel coking.

NOTE Measures may include:

- a. Eliminating or minimizing dead ends of duct runner in the gas path.
- b. Applying insulation at dead ends of duct runners in the gas path

c. Prevent fuel inside the duct burner element reaching coking temperature (fuel dependent).

8.2.8 The maximum temperature of fuel inside the duct burner element shall not exceed 400 °C (750 °F).

- **8.2.9** The purchaser shall specify the need for cleaning of duct burner runners; either offline or online cleaning (e.g. steam cleaning).

8.2.10 No bluff body shall be used in design of the duct burner except if required to protect ignition burner.

8.2.11 Burner element fuel pipes shall be minimum Type 304 SS and flame holders/stabilizers minimum Type 309 SS or equivalent.

8.2.12 Each burner element shall be equipped with a flame detector. Flame detector shall detect ignition flame and main flame.

NOTE Additional flame detection may be required based on risk analysis or purchaser requirements.

8.2.13 Ability of the flame detection system to detect and discriminate between burners shall be proven during commissioning for the complete load range.

8.3 Ignition Unit

8.3.1 Each burner element shall be equipped with a permanently installed ignition unit, including associated equipment such as power, transformer, spark igniter, air connections (if required).

8.3.2 No continuous pilots shall be applied, unless required by applicable regulations or if specified by purchaser.

8.3.3 Ignition/pilot burner/pilot shall be designed for continuous exposure to TEG and suitable for intermittent operation in a pressurized combustion furnace.

8.3.4 Optical flame detection shall be applied (see main burner)

8.3.5 Ignition/pilot burner/pilot shall be removable while GT is in operation. Guide tube design shall prevent TEG from leaving duct during operation.

8.3.6 Ignition/pilot burner/pilot shall have stable flame suitable for the full TEG operating range.

8.3.7 The minimum capacity of Ignition/pilot burner shall be > 150 kW (500,000 btu/hr).

8.3.8 Ignition/pilot burner type is subject to purchaser approval.

8.3.9 Unless otherwise specified, the supplier shall use a Class 3 igniter.

- **8.3.10** A Class 1 or 2 igniter shall only be used when specified by the purchaser.

8.4 Burner Piping and Fuel Train

8.4.1 Fuel trains shall be designed in accordance with local regulatory and any purchaser specified requirements.

8.4.2 The fuel train shall include at least two tight shut-off valves (TSOs). If local regulations or the purchaser requires an automated vent valve, that shall be added.

NOTE Additional instrumentation may be required depending on the system selected, e.g. a valve proving system.

8.4.3 The fuel train and burner piping shall include an appropriate number and location of vents and drains for effective venting and drainage.

8.4.4 Unless otherwise specified, fuel gas piping shall be designed in accordance with the pressure design code, e.g. ASME B31.1, ASME B31.3 or equivalent.

- **8.4.5** The purchaser shall specify the design pressure and temperature of the fuel piping system upstream of the fuel train.

8.4.6 Material applied for the fuel system shall be suitable for all types of fuel.

NOTE If there is risk of water condensation, with H₂S present in the fuel, materials to prevent wet H₂S corrosion (HIC, SOHIC, SSCC) should be applied in accordance with ANSI/NACE MR0103/ISO 17945 or ANSI/NACE MR0175/ISO 15156.

- **8.4.7** When specified by the purchaser, burner piping shall be included in the supplier's scope of supply including instrumentation and components as identified on the burner fuel piping P&ID. The piping design and layout shall follow recognized good practices for design including appropriate measures for good support and free of vibration that could be transmitted from the HRSG.

8.4.8 Burner piping shall not obstruct manways, observation windows or access to any equipment.

8.4.9 Burner piping shall also not hinder operation of the burner or boiler and shall not pass through the ducting.

8.4.10 Unless otherwise specified by the purchaser, the use of flexible hoses shall be avoided for supply of fuel to duct burner elements.

NOTE Flexible hoses are generally acceptable for use on ignition burners/pilots and the associated combustion air supply and, unless otherwise specified, may be used for these applications.

8.4.11 When flexible hoses are used for duct burners, the design and configuration shall be subject to the purchaser's approval and include the following:

- a) length as short as practical;
- b) design pressure > 1.5 times the burner maximum operating pressure, the minimum being 100 kPa(g) (14.5 psig);
- c) installed downstream of any burner isolation valve, i.e. not exposed to fuel shut-in pressure;
- d) provide easy access to any upstream shut-off valve;
- e) end fittings integral to the tubing with size and rating the same as the mating connections;
- f) be constructed from suitable metal material for the selected for the application.

8.4.12 The burner vendor shall provide an analysis to determine whether multiple fuel trains or control valves are required.

- **8.4.13** The purchaser shall specify multiple trains if required for reasons beyond control of HRSG/burner vendor.
- 8.4.14** The fuel skid components shall be shop assembled and mounted on a rigid steel frame, intended for floor mounting.
- 8.4.15** Steel frame shall be galvanized or have a factory applied protective coating suitable for the local climate.
- 8.4.16** Painting and coating shall as minimum comply with Section 7.8.
- 8.4.17** Unless otherwise specified, all electrical devices and instruments shall be pre-wired to single junction box cabinet on the fuel skid.
- 8.4.18** A pressure regulating valve for each fuel stream shall be supplied on the fuel skid to provide a constant fuel gas supply pressure into the burner fuel train.
- 8.4.19** The pressure regulating control system shall be designed with adequate volume between regulating stages and between downstream valves to prevent pressure surging.
- 8.4.20** A safety pressure relief valve shall be supplied on the fuel skid to protect the burner fuel piping, valves and instrumentation upstream of the final valve in the gas train unless the system is otherwise protected from full fuel line pressure upstream of the fuel skid in the purchaser's piping.
- 8.4.21** The main fuel gas train, as a minimum, shall include the following:
 - a) one manual (lockable) isolation valve;
 - b) one inlet y-type strainer, with a mesh size < 0.25 times smaller than the applied orifice;
 - c) two safety shut-off valves (SSOVs) with open/close limit switches;
 - d) one vent valve with closed position switch;
 - e) one fuel flow control valve, with minimum position switch;
 - f) inlet and outlet pressure gauges (in SI/SAE units) with isolation valves;
 - g) flow meter with associated isolation valves;
 - h) pressure measurement (tapping, associated valves and transmitters);
 - i) temperature measurements (thermowell a primary elements)
 - j) maintenance purge connections with manual isolation valves at the inlet of the fuel train, between SSOVs and at the outlet.

NOTE In case of a second fuel, the same requirements shall apply to the second fuel train.

- 8.4.22** The ignition gas train, as a minimum, shall include the following:
 - a) one manual (lockable) isolation valve;

- b) one inlet y-type strainer, with a mesh size < 0.25 times smaller than the applied orifice;
- c) two TSSOVs with open/close limit switches;
- d) one vent valve with an optional closed position switch;
- e) one fuel flow control valve, with minimum position switch;
- f) inlet and outlet pressure gauges (in SI/SAE units) with isolation valves;
- g) flow meter with associated isolation valves;
- h) pressure measurement (tapping, associated valves and transmitters);
- i) temperature measurements (thermowell and primary elements)
- j) maintenance purge connections with manual isolation valves at the inlet of the fuel train, between SSOVs and at the outlet.

8.4.23 The instrument air train assembly, as a minimum, shall include the following:

- a) one manual (lockable) Isolation valve;
- b) spare tap with manual isolation valve;
- c) air regulator valves;
- d) inlet and outlet pressure gauges (in SI/SAE units) with isolation valves;
- e) flow meter with associated isolation valves;
- f) pressure measurement (tapping, associated valves and transmitters);
- g) temperature measurements (thermowell and primary elements).

8.4.24 Fuel gas flow measurement shall be included in fuel train (not necessary on the skid). The uncertainty of the gas flow meter measurement shall be less than 2% over the complete operating range.

NOTE The purchaser may specify higher accuracy, e.g. for reasons of performance test.

8.4.25 When required the fuel gas vent line to atmosphere shall be located at a safe location. Vents shall not be within 15 m (50 ft) of combustion turbine air intake and at least 3 m (10 ft) above the highest HRSG platform or within 15 m (50 ft) of other equipment.

8.4.26 Vents shall exhaust upwards, with provision to prevent rain ingress, e.g. goose-neck piping.

NOTE Drainage on vents may use a weep hole up to 12.5 mm (0.5 in.) is allowed.

8.4.27 Distance between SSOVs for a double block arrangement shall be minimized.

8.4.28 The automatic SSOVs and vent valves shall be a failsafe design. The spring return actuator on the valve shall be sized to position the valve in the safe state within two seconds for valve < 150 mm (6 in.) and within four seconds for valves ≥ 150 mm (6 in.). when de-energized.

8.4.29 SSOVs for fuel gas shall have a seat design that offers Class V or better.

8.4.30 Proof of valve position switches (open and closed) are required.

8.4.31 Control valve shall provide a minimum turndown of 10:1 on the gas flow unless restricted by extreme fuel compositions, combinations of fuel etc.

- **8.4.32** The purchaser shall specify if a turndown of more than 10:1 is required.

NOTE: There may be a need for additional equipment and or bypass over main control valve to allow for larger range.

8.4.33 Automatic vent valves that act as vent in a double block and bleed set up, i.e. between two TSO valves in series, shall comply with the following.

- a) It shall meet the same leakage and position switch/transmitter requirements of the TSO valves.
- b) It shall be equipped with an upstream block valve and pressure gauge between the block valve and vent TSO valve.
- c) The manual vent block valve shall be car-sealed open (CSO) during normal operation.

- **8.4.34** When on-line TSO valve testing is required, the purchaser shall specify the valve arrangement and how such testing is to be performed.

NOTE Possible options may include parallel TSO valves with one valve car-sealed closed leaving the other in service, taking duct burners out of service, etc.

8.5 Duct Burner Observation Ports

8.5.1 The HRSG supplier shall provide air cooled observation windows to monitor the duct burner elements, pilots, flames and first row of downstream tubes.

8.5.2 The observation windows shall provide proper view, for online inspection, off flames, walls, etc. in line with the following minimum requirements:

- a) overall coverage of 50 % of the burner in case of matrix/runner type burner;
- b) minimum 25 % of each individual duct burner (runner);
- c) 100 % view at (all) burner throats of register type burners;
- d) view at igniter flames;

NOTE A peephole may be used to proof pilot flame.

- e) cross sectional view at the flame front to evaluate absence of flame impingement;
- f) view of 50 % of downstream heating surface.

8.5.3 There shall be a minimum of one platform with an observation window on the side of the HRSG opposite the pilot to allow for troubleshooting of pilots.

8.5.4 Observation windows shall be constructed with fused silicate glass and protective pivoting metal plate.

8.5.5 Glass, view port and frames shall be supplied with air purging/cooling.

8.5.6 A dedicated air fan for purge air and igniter cooling/combustion air shall be provided.

NOTE Alternatively, instrument air/plant air may be used if specified by purchaser.

8.5.7 The purge/cooling air fan shall be capable of supplying 125 % of the nominal required air for all consumers.

8.5.8 Purge air shall be designed to provide safe temperatures over the complete operating range of the GT and duct burner.

8.5.9 Observation doors and ports shall be easily accessible from platforms for effective viewing while standing and without obstruction for viewing, use of thermographic equipment or door opening.

8.6 Fresh Air Firing

NOTE This standard provides requirement for a HRSG with and without supplemental firing. Many of the same requirements also apply to HRSGs suitable for fresh air firing (FAF), and as a minimum, should be followed together with additional good engineering practice and purchaser requirements with respect to the impact of FAF.

When fresh air firing is required, the purchaser shall specify in detail the requirement for the fresh air firing system, mode of change over, rate of change etc.

NOTE Annex C provides additional considerations for fresh air firing.

8.7 Flow Modeling

8.7.1 A computational flow model (CFD) study and/or scale model study shall be performed on any HRSG using supplemental firing or catalyst system.

8.7.2 CFD and/or scale model study shall be based on expected operating data at the specified operating loads and include all details that impact the flow/temperature distribution into the HRSG. This study includes the GT exhaust velocity profile (in x, y, z directions), temperature, and other details.

8.7.3 When a HRSG is designed for FAF operation, the CFD study shall include simulation of the FAF operating cases.

8.7.4 The supplier shall be responsible to select the operating cases of interest that impact the design. As a minimum, maximum firing, design case and any other specified operating case shall be studied and reported.

8.7.5 Suppliers shall ensure proper flow and temperature distribution to ensure reliable operation over the lifetime of the HRSG such that it:

- a) complies with suppliers' internal standards;
- b) complies with burner and catalyst manufacturer requirements, e.g. distribution at inlet of burner or catalyst;

c) complies with any additional requirements by purchaser.

8.7.6 When CFD/scale model studies indicate the need for flow correction devices/distribution grids they shall be included in the HRSG system design to ensure proper flow distribution to the burner, internal flue gas treatment injection points and/or catalyst systems.

8.7.7 Burner flame length calculations and temperature distribution shall be based on expected flow and temperature distribution at the inlet of the burner plane from the CFD study.

9 Fabrication and Shop Assembly

9.1 General

9.1.1 HRSG modules, all auxiliary equipment, ladders, stairs, and platforms shall be shop assembled to the maximum extent possible consistent with the available shipping, receiving, and handling facilities specified by the purchaser.

9.1.2 Machined faces shall be coated with an easily removable rust preventive. Openings in pressure parts shall be covered to prevent entrance of foreign materials.

9.1.3 All surfaces to be welded shall be free from scale, oil, grease, dirt, and other harmful agents. Welding operations shall be protected from wind, rain and other weather conditions that can affect weld quality.

9.1.4 All HRSG system steel structures shall be designed and fabricated in accordance with the specified structural design code and structural welding code.

9.1.5 Pressure components shall be designed and fabricated in accordance with the applicable provisions of the specified pressure design code.

9.1.6 Post-weld heat treatment, where applicable, shall be performed in accordance with the specified pressure design code.

9.2.7 Welders shall be qualified in accordance with the specified design code.

9.1.8 Welding consumables shall be ordered with specific material test reports at least for the chemical composition and shall be ordered from a minimum number of heats for one project. The chemical composition shall show all significant elements, incl. [Ni] and [Mn] to determine a safe upper limit for the PWHT-temperature. The lower limit for the AC1-temperature as guaranteed by the manufacturer of the welding consumable shall be complied with.

NOTE As an alternative to the lower limit for the AC1-temperature guaranteed by the manufacture, the lower limit may be estimated from the specific chemical composition of the welding consumable when approved by the purchaser.

9.1.9 Welding consumables shall be stored and classified by size, type, and material in a specific room having controlled environmental conditions.

9.1.10 Pre-heat of consumables is mandatory.

9.2 Structural-Steel Fabrication

9.2.1 Seam welds between plates shall be continuous welds.

9.2.2 Fillet welds shall be of uniform size with full throat and legs.

9.2.3 Both sides (internal and external) of exterior seams between plates and structural members shall have a continuous full penetration weld.

9.2.4 Welding filler materials shall be in accordance with the specified structural design code and shall have a chemical composition matching that of the base materials being joined.

9.2.5 Impact test requirements and Charpy values shall be specified by the purchaser for all welds with design metal temperatures below - 30 °C (- 22 °F) and for submerged arc welds at design metal temperatures below - 18 °C (0 °F).

9.2.6 Circular and slotted bolt holes in columns and base plates shall be drilled or punched. Or automated flame cut achieving same quality. Base plates shall be shop-welded.

9.2.7 The minimum thickness of gusset plates shall be 6 mm (1/4 in.).

9.2.8 Shop connections shall be bolted or welded. Bolted field joints are preferred. Where field bolting is impractical, erection clips or other suitable positioning devices shall be furnished for field-welded connections.

9.2.9 The minimum size of bolts shall be 16 mm (5/8 in.) in diameter, except where the flange width prohibits use of such size bolts. In no case shall bolts be less than 12 mm (1/2 in.) in diameter.

9.2.10 Drain holes in structural members shall be a minimum of 25 mm (1 in.) in diameter unless structural design cannot accommodate it. Checkered plate flooring shall be furnished with one, 12 mm (1/2 in.) diameter drain hole for every 1.4 m² (15 ft²) of floor plate area.

9.2.11 Suitable lifting lugs shall be provided for the erection of all sections where the section mass exceeds 1820 kg (4000 lb). The lifting load used shall be 1.5 times the section mass to allow for impact.

9.2.12 All structural steel and sub-assemblies shall be clearly marked with letters or numbers at least 50 mm (2 in.) high for field identification.

9.2.13 All loose items such as rods, turnbuckles, clevises, bolts, nuts and washers shall be shipped in bags, kegs or crates. Bags, kegs or crates shall be tagged with the size, diameter and length of contents so that tags for each item are individually identifiable.

9.2.14 A minimum 5 % surplus number of bolts, washers and nuts (size and material) used in the erection of the system shall be furnished.

9.3 Control Skids

9.3.1 General

9.3.1.1 Any control skid shall be shop assembled with all components, piping, instrumentation, electrical components and tubing to the maximum extent that is reasonable.

9.3.2 Skid Base

9.3.2.1 Skid base material shall be either stainless or coated carbon steel to limit corrosion. Water treatment skids shall be stainless.

NOTE: Carbon steel bases should be completely seal welded prior to coating to prevent "rust weeping".

9.3.2.2 All structural skid bases shall have a minimum of four lifting lugs to allow safe handling and lifting of the skid assembly.

9.3.2.3 A minimum of two ground connections for grounding of the skid shall be provided; preferably at opposite corners of the skid base.

9.3.2.4 Any burrs on structural components shall be ground off and flush with the structural surface.

9.3.2.5 All crosscut edges of structural material shall be ground to a 3 mm ($\frac{1}{8}$ in.) radius to remove the sharp edge.

9.3.3 Piping

9.3.3.1 Unless otherwise specified, piping shall be constructed in accordance with the pressure design code.

EXAMPLE ASME B31.1 (where applicable), ASME B31.3 or equivalent.

9.3.3.2 All interface to purchaser utilities shall terminate at skids edge with a raised face weld neck flange (RFWN) in accordance with the pressure design code, e.g. ASME B16.5.

9.3.3.3 Threaded connected shall not be used.

NOTE Threaded may be used for instrument connections.

9.3.3.4 Welded valves shall be installed in accordance with manufacture's recommendations by either disassembling the valves prior to installation or cooling the valves during installation.

9.3.3.5 Pipe supports shall be rigid and of a design that allows easy maintenance.

NOTE: It is recommended that the support hardware be selected to maximize contact with the pipe to prevent excessive wear on the piping.

NOTE Pipe supports that are welded to the process pipe should be of same material type as the pipe itself.

9.3.3.6 Machined surfaces such as flange faces shall not be placed in direct contact with steel or concrete materials during the manufacturing process. Proper protection such as wood, plastic or cardboard shall be placed between the machined surface and the potentially damaging material.

9.3.4 Instrumentation

9.3.4.1 Where possible instrumentation shall be oriented on the skid to allow easy access and maintenance.

9.3.4.2 All instruments shall have a stainless steel tag with its corresponding identification number on it attached using stainless steel wire. Markings shall be stamped or etched.

9.3.5 Electrical

9.3.5.1 All instruments and electrical components shall be wired to a minimum of one junction box enclosure, located at the edge of the skid assembly.

NOTE All skid wiring should terminate on the same side of terminals leaving the other side vacant for field wiring to be terminated on the opposite side.

9.3.5.2 Analog and discrete instrument signals shall have separate conduit and be separated within the electrical enclosure or in two separate enclosures.

9.3.5.3 Conduit shall be of rigid type.

9.3.5.4 A low point "drip loop" shall be provided between the instrument and the connection to the rigid conduit network to prevent water from entering at the fittings.

9.3.5.5 Length of flexible conduit shall be within specified code requirements and limited in length.

9.3.5.6 Conduit shall be sized large enough to allow the installation of future wiring as follows:

- a) Analog conduit: Two additional shielded twisted pair cables for analog signals (4-20 mA, 0-5 VDC, etc.).
- b) Discrete conduit: Six additional wires for discrete (120 VAC, 220 VAC, 480 VAC, etc.) signals of same size as initially installed.

9.4 Duct and Casing

9.4.1 Any internal coating on the casing shall be applied in factory as much as possible. Clear instructions shall be provided for applying coating in field.

9.4.2 Internal insulation and lining shall be pre-installed to the maximum extend. Clear instruction and detailed drawings shall be supplied to enable field installation.

9.5 Pressure Part Modules

9.5.1 Steam drum and internals shall be completely fabricated and assembled in the shop.

NOTE Certain internals may need to be removed in the field before chemical cleaning and/or steam blow.

9.5.2 Shell sections shall each be completely welded longitudinally and corrected for out-of-roundness and peaking of the weld seam prior to assembly and not re-rolled or formed following any final non-destructive examination of the longitudinal seams.

9.5.3 The layout of shell, head plates and transitions shall be as follows:

- a) The longitudinal shell seams are not intersected by other welds, e.g. Category D joints or fillet welds attaching reinforcement pads, saddle wrapper plates to the pressure boundary, etc.
- b) Longitudinal shell and transition joints shall be staggered by at least 60 °.

9.5.4 Nozzles or manways shall be located such that their necks, reinforcement pads or attachment welds are not located on any of the weld seams.

9.5.5 Flatness of gasket contacts surfaces shall be in line with code and details shall allow proper sealing.

10 Inspection, Examination, and Testing

10.1 General

10.1.1 The purchaser, with reasonable notice, shall have unrestricted right to inspect and observe work during all stages of fabrication to ensure such equipment, materials and workmanship are in accordance with the purchase order.

- **10.1.2** When specified by the purchaser, pre-inspection meetings between the purchaser and the fabricator shall be held before the start of fabrication.

10.1.3 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.

10.1.4 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 discontinuities are found.

10.1.5 The supplier/vendor shall ensure that all documents as listed in the purchaser's inspection and test plan are available during final inspection.

10.1.6 The supplier shall make every effort to store the goods subject to inspection (examination and testing) indoors or under cover and in such a way that inspection can be performed easily and quickly.

10.1.7 Welding procedures, procedure qualification records and welding-consumable specifications for all pressure-retaining welds shall be in accordance with the pressure design code and the vendor shall provide these to the purchaser.

10.2 Quality Plan

10.2.1 The supplier and any vendor shall have a quality assurance procedure in line with, or in accordance with the principles of ISO 9001.

10.2.2 The quality plan shall relate to the specific contract, and shall detail activities, procedures, and product realization processes in order to meet the contract scope of work. The ITP from the sub-vendors can be attached to the quality plan, although these are separate documents.

10.2.3 The quality plan shall identify all the statutory national and local requirements, as well as addressing the contract and project requirements.

10.2.4 The quality plan shall follow general guidelines, as laid down in ISO 10005, or equivalent.

10.3 Quality Assurance and Inspection and Test Plan

10.3.1 The supplier shall submit their quality assurance and comprehensive ITP incorporating their own requirements and that of fabricators, vendors etc. for purchaser's review and approval.

10.3.2 The ITP shall include the type and extent of purchaser involvement in terms of hold and witness points and documents for review and approval.

NOTE: The quality assurance and ITP should, as a minimum, include a chronological list of inspection activities with each including the specific tests to be performed, acceptance criteria and reference to applicable project control documents, codes, standard and specific clauses thereof.

10.3.3 All inspections, examinations and tests shall be carried out in accordance with the approved ITP.

NOTE In general, the ITPs should include the following with the minimum being those items identified as “required”:

- a) title, description, and scope;
- b) reference to the contract and purchase order;
- c) list of activities to be performed and deliverables (required);
- d) safety critical elements (SCE) references noted (if applicable);
- e) person responsible for the activity/deliverable;
- f) person responsible for verifying the activity/deliverable;
- g) frequency or schedule for verifying the activity/deliverable;
- h) resulting documentation required for verifying the activity/deliverable;
- i) acceptance criteria for verifying the activity/deliverable;
- j) identified hold point (required);
- k) inspection hold points (required);
 - 1) purchaser involvement;
 - 2) quality involvement;
 - 3) third party, regulatory or certification authority involvement.

10.3.4 As a minimum, shop inspection and testing shall include tests as shown in Table 9.

10.3.5 The purchaser shall specify the extent of inspection level for radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing, visual, hardness, and ferrite check.

10.3.6 There shall be no cracks or linear indications in welding.

- **10.3.7** When specified by the purchaser, PMI of specific components shall be performed.

10.3.8 Welder’s qualification documentation shall be made available during any inspection procedures.

10.3.9 Nozzle reinforcement pads shall be pneumatically tested between 100 kPa(ga) (15 psig) and 170 kPa(ga) (25 psig).

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Table 9--Minimum Testing

Test	Description	Applicability and Frequency
NDE	Non-destructive examination (NDE) of material and welds shall comply with the relevant specifications listed in the purchaser's requisition. NDE tests include: visual, ferrite, hardness, RT, UT, MP, PMI, etc.	Refer to purchaser's requisition
Dimensional checks	Supplier and/or purchaser shall check that main and overall dimensions of equipment are in accordance with the dimensions specified on the general arrangement drawings.	Complete check for skid, loose supplied equipment, templates. Random check for loose supplied prefabricated pipes
	Location and position of battery limit connection shall be checked.	Complete check
	Location and position of the anchor holes shall be checked.	Complete check
Hydrotest	Hydrotesting shall in accordance with the requirements of relevant project specifications, codes and standards. Hydrotesting for vessels and piping system shall be minimum of 60 minutes. Equipment surfaces shall not be painted until all inspection is completed. Fuel train exempted as mentioned before.	For all pressure retaining parts
Performance test	Performance tests shall conform to the relevant code or standard applicable to the equipment.	Complete check
Continuity checks	Continuity checks of all electrical and instrument cabling from device to junction box	Complete check
Functional test	All instrumentation and electrical equipment functions shall be verified, including simulation of all alarms, shutdowns and remote signals using water or instrument quality air as a substitute for the process liquid/gas to prove the integrity of the control equipment/instrumentation.	Complete check
Lifting test	When applicable, with contractual spreader bar.	

10.3.10 The acceptance requirements shall comply with this standard, the purchaser's requisition, and with relevant codes and standards.

10.4 Shop Testing and Inspection

10.4.1 General

10.4.1.1 The machinery package, especially the skid mounted equipment, shall be tested at the supplier's shop as an integral unit, to minimize commissioning problems during installation and on site startup.

10.4.1.2 The supplier shall submit the factory acceptance test (FAT) procedures in advance for purchaser approval.

NOTE The purchaser reserves the right to send a team of different disciplines to witness and approve the FAT before the skid is released for shipment.

10.4.1.3 Any outstanding requirements shall be clearly identified on a punch list for completion after final assembly at site.

- **10.4.1.4** When specified on datasheet, all equipment shall be subject to a weight control procedure as follows:

- a) final weighing prior to transport from the fabrication facility;
- b) final weighing witnessed by the purchaser's inspector;
- c) provide a weight certificate detailing weight and center of gravity for each individual package;
- d) the weight and center of gravity clearly marked on each individual package.

10.4.1.5 For factory testing unless otherwise specified, all closures, instruments and other testing equipment required shall be provided by the supplier at no cost.

10.4.1.6 All test equipment shall be checked and have valid calibration certification.

10.4.1.7 A purchaser's witnessing of shop test results shall not constitute a waiver of the supplier's obligation to provide equipment which meets all specified operating conditions.

10.4.1.8 Any defects found by the purchaser's designated inspector shall be rectified in the inspector's presence. Where this is not possible or practical, checklists shall be prepared and signed by the designated inspector stating all outstanding items. Copies of these lists shall be sent to the purchaser for their subsequent verification of defect resolution.

10.4.1.9 The equipment shall not be tested or leave the factory before all discovered defects have been rectified.

- a) The recorded results of all inspection and tests performed shall be submitted.
- b) Mill and shop inspection shall not relieve the Supplier from their contractual responsibility for replacing any defective material and for repairing any defective workmanship that may be discovered in the field.

10.4.1.10 When equipment or modules are pressure tested in the installed position in the fabrication shop, the supplier shall ensure that all parts of the assembly, including the supporting structure and base, can withstand the load resulting from the pressure test.

10.4.1.11 When blocking of spring hangers is required, the hangers shall be reset to the design position after testing.

10.4.1.12 The earthing bosses and all bonding shall be tested for electrical continuity.

10.4.2 Testing of Instruments

10.4.2.1 All instruments shall be tested and verified in an instrument shop prior to installation on the package/skid equipment.

10.4.2.2. The verification shall include a comparison of instruments specifications (as supplied) with the instrument data sheets.

10.4.2.3 All instruments shall be tested with a known input signal using a simulator.

10.4.2.4 Instrument pre-calibration sheets shall be fully completed and signed by the supplier's QA/QC inspector for all instruments and ancillary equipment.

10.4.2.5 The purchaser reserves the rights to request full calibration based on the results.

10.4.2.6 The tests carried out by the supplier prior to the factory test shall include the following:

- a) Verifying all input and output signals for continuity throughout the system within package/skid limit, from incoming/outgoing junction boxes to/from the individual instrument within system.
- b) Shutdown logic field testing.
- c) Perform leak test on pneumatic (instrument) tubing.

10.4.3 Testing Electrical Works

10.4.3.1. Testing of electrical works shall include the following test as a minimum:

- a) insulation testing;
- b) conductivity and earth (ground) resistance tests;
- c) wiring and terminal checks;
- d) functional tests;
- e) phasing tests.

10.5 HRSG Specific Inspection Requirements – Pressure Parts

10.5.1 The supplier shall submit inspection certificates in accordance with ISO 10474 Type 3.1.B and/or EN 10204 or equivalent for tubing, piping and all pressure vessels materials.

10.5.2 The supplier shall submit pressure and capacity test certificates for the safety valves and the pressure parts themselves.

10.5.3 The above certificates shall satisfy the applicable code requirements and be available at site prior to the initial operation of the HRSG.

10.5.4 Bare tubes shall be inspected prior to finning.

10.5.5 The bonding of continuous welding between fin and tube shall be tested and inspected to be above 90 %.

10.5.6 The diverter and guillotine shall be tested for leakage rates/tightness. The testing shall be with pressurized air/nitrogen but if the size of the diverter is too large to enable pressurized air testing, a dimensional verification and tightness calculation shall be done. The calculations shall be subject to purchaser approval.

10.5.7 Sealing air systems of the diverter and guillotine shall be tested for functionality, e.g. stroke test, before shipment.

10.6 Non-Destructive Testing

10.6.1 All non-destructive testing (NDT) shall be performed in accordance with the supplier/vendor written approved (by purchaser) procedure and comply with the pressure design code.

10.6.2 Acceptance/rejection criteria as defined by the pressure design code and this standard and/or vendor written approved (by purchaser) procedure shall be applicable.

10.6.3 All NDT on parts which are to be post weld heat-treated, shall be made after post weld heat treatment.

10.6.4 All pressure and non-pressure welds shall be visually inspected by the supplier/vendor and documented.

10.7 Field Tests

10.7.1 All pressure parts shall be hydrostatically tested after welding at the site in accordance with the pressure design code.

10.7.2 All field welds for pressure parts shall be visually inspected, and NDT shall be applied on a percentage as agreed in the purchaser requirements.

10.7.3 In case of failure of the NDT test the supplier/vendor shall rectify and perform 100 % NDT on the rectified parts.

10.7.4 Failure criteria and consequences in accordance with the pressure design code shall be applicable.

10.8 Instrumentation, Control, and Protective System Testing

10.8.1 Fuel train instrumentation and valves and the BMS shall be tested during FAT in factory.

NOTE Additional field testing may be required as specified.

10.8.2 Valves shall be functional tested during commissioning, e.g. strokes tests, response times etc.

10.8.3 Stack damper automatic opening shall be tested in the factory and after installation.

10.8.4 Diverter shall be tested in the factory and functional stroke tested in the field.

10.8.5 Control loops, safety loops, signals shall be tested in the field. Instrumentation readings shall be checked for accurate values.

10.9 Hydrostatic Testing

10.9.1 General

10.9.1.1 Hydrostatic testing shall comply with local regulations, the pressure design code, this standard and any additional purchaser specifications.

10.9.1.2 As a minimum, all heating surface modules and pressure vessels shall be hydrostatically tested in the shop.

10.9.1.3 Fuel and pilot gas train, where applicable, shall be pressure tested as specified by the purchaser.

10.9.1.4 Pressure parts shall be pressure tested in the field after completion of construction.

10.9.1.5 The supplier shall isolate or remove the instruments and ancillary equipment prior to hydrostatic testing.

10.9.1.6 The supplier shall show all high point vents and low point drains in the isometric drawings and shall be included in the scope of supply.

10.9.1.7 Should any additional vents and drains be required based on the supplier's testing program, they shall be included in the supplier's scope of supply, including the supply of required material.

10.9.1.8 Before hydrostatic testing, the test fluid and vessel/piping material shall be allowed to equalize to approximately the same temperature. In case metal temperature and/or test fluid, at any time during the test is below 8 °C (46 °F), the minimum allowable metal temperature shall be determined.

10.9.1.9 Gaskets (if applicable) required for service shall be used during hydrostatic testing.

10.9.1.10 Draining, flushing, and drying of the equipment/piping shall follow immediately after the hydrostatic testing. If equipment is dried by blowing, drains or vents shall be opened in order to avoid pressuring the equipment.

10.9.2 Water Quality for Hydrostatic Testing

10.9.2.1 Potable water (or better quality) shall be used for hydrostatic testing on carbon steel or low-alloy steel.

10.9.2.2 Water for hydrostatic testing, apart from the requirements as to chloride content, shall be free from sediment, i.e. un-dissolved solids of any description.

10.9.2.3 Whatever the source of the hydrotest water, it shall be filtered through a 10 µm (1250 MESH) filter when filling the system.

10.9.2.4 The water used for hydrostatic testing of austenitic steel, ferritic stainless steel, and high Ni alloys shall be free of any concentration of chlorides either present originally or resulting from evaporation.

10.9.2.5 The chloride content for hydrostatic test water shall be checked at time of testing and point of placement.

10.9.2.6 All austenitic stainless steel shall be clean prior to final assembly and hydrostatic testing.

10.9.2.7 The equipment and/or piping shall be tested with condensate; boiler feedwater or demineralized water.

10.9.2.8 In locations where water of the required quality is not available (initially or permanently), temporary facilities shall be used, e.g. mobile packaged demineralization units, to prepare the test water.

NOTE Alternatively, austenitic stainless steel, ferritic SS, high Ni alloy steel may be tested with potable water with a verified chloride content not exceeding 50 mg/kg (50 ppm by mass), provided that it is either drained and mechanically dried immediately after testing or flushed with demineralized water immediately after testing.

10.9.2.9. The system shall be drained and dried after hydrotest and flushing. No heating shall be applied for drying in the case of austenitic steel tubes.

10.9.2.10 The use of biocide to minimize the risk of microbiologically influenced corrosion (MIC) shall be considered if the water will remain in the system for an extended period.

10.9.2.11 Austenitic stainless steel piping sections and components, e.g. valves and expansion joints, that do not allow full draining or mechanical drying and that do not require field hydrotesting, shall be isolated from the system. If these components still require testing, they shall be tested separately from the system, using condensate, boiler feedwater or demineralized water.

10.9.2.12 Removing water or drying by blowing with hot air or gas shall not be performed unless the testing or flushing has been done with condensate; boiler feedwater or demineralized water.

10.9.2.13 Steam-traced or electrically traced systems shall be tested or at least properly flushed with condensate or demineralized water prior to the functional testing of the tracing.

10.9.3 After Completion of Tests

10.9.3.1 After controlled depressurization, all remaining vent and low point drain valves shall be opened and the system thoroughly drained.

10.9.3.2 Temporary blinds and other equipment installed for testing shall be removed on completion of the test.

10.9.3.3 Test pressure gauges shall be removed.

10.9.3.4 Any temporary vent and drain facilities installed for testing shall be removed and the tie-in points plugged in accordance with pressure stipulations for that section of pipework.

10.9.3.5 Gaskets at flanged joints, which have been broken for testing, shall be renewed, unless otherwise agreed with the purchaser.

10.10 Acceptance Testing and Site Performance Testing

10.10.1 Guarantee testing shall be after start-up and commissioning.

10.10.2 After start-up and commissioning, the purchaser shall inform the supplier about carrying out guarantee tests.

10.10.3 The HRSG performance test shall be in accordance with the purchaser's requirements.

10.10.4 The supplier shall submit an acceptance test plan and required interfaces with third parties for approval by purchaser.

10.10.5 The HRSG test procedure shall be based on ASME PTC 4.4, or a purchaser approved equivalent.

10.10.6 If performance testing is not in the HRSG supplier's scope, the supplier shall provide a test procedure containing guidance on testing from the perspective of the HRSG. Those responsible for the performance test shall use the supplier provided information to develop a detailed test procedure, subject to approval by all parties as described in ASME PTC 4.4.

NOTE It may not include details on GT or signals outside scope of HRSG supplier.

- **10.10.7** The purchaser shall specify if a performance test is included or excluded from the HRSG supplier's scope of supply.

10.10.8 Emission testing shall be in accordance with the purchaser's and local regulatory requirements.

NOTE If possible, the emission testing should be combined with HRSG performance test.

11 Instrumentation, Controls, and Protective Systems

11.1 General

11.1.1 The supplier shall develop and supply P&IDs and functional descriptions for control, measurement, and instrumented protective functions (IPF) for operation and protection of the HRSG.

- **11.1.2** The control and safeguarding system shall as a minimum be compliant with NFPA 85 and all local or national regulatory authority specified by the purchaser.

NOTE The purchaser may specify exceptions to NFPA 85.

11.1.3 When the purchaser chooses to specify exceptions to the control and safeguarding system requirements of NFPA 85, an engineering study shall be performed that includes alternative control and safeguarding measures. In such cases, the designer shall be responsible for demonstrating and documenting the validity of the proposed design.

- **11.1.4** The purchaser shall specify any requirements in addition to those specified in NFPA 85 and this standard.

11.1.5 Whether or not the instrumentation is supplied with the HRSG installation, all necessary instrument process connections shall be provided by the HRSG supplier.

11.1.6 The connections furnished unless otherwise required or specified shall be DN 40 (1 1/2 NPS) forged-steel couplings Class 3000 SW welded to the outside casing plate. If the refractory lining exceeds 75 mm (3 in.) in thickness, the opening shall be lined with austenitic stainless steel pipe (schedule 80). A hex-head forged-steel threaded plug shall be furnished with each coupling.

NOTE Flanged connections may also be used.

11.1.7 Where designated as appropriate by a hazard and operability study (HAZOP) review, the purchaser shall designate the appropriate safety integrity levels (SIL) for the safety instrumented systems associated with all the instrumentation, control and protective systems for the HRSG.

11.1.8 A HAZOP review shall determine the redundancy of critical control components.

11.1.9 The supplier shall provide process data required to size and specify all primary element P&ID instrumentation.

11.2 Instrumentation

11.2.1 The following connections and instruments (if in scope) shall be supplied, as a minimum, or as required by the applicable code. The measurement shall be applied for each pressure level if multiple pressure levels are applied:

11.2.1.1 Flue Gas Temperature Measurement:

- a) upstream of auxiliary burner (if fitted),
- b) downstream of auxiliary burner (if fitted),
- c) inlet to first heating surface,
- d) outlet of each evaporator section,
- e) upstream of diverter,
- f) inlet of the exhaust stack,
- g) upstream of emissions catalyst bed,
- h) between banks with different services, e.g. economizer, evaporator, superheater.

NOTE One or more connections should be provided at the above points dependent upon duct size. All cavities should have a provision to measure temperature.

11.2.1.2 Flue Gas Pressure Measurement:

- a) turbine exhaust, static pressure,
- b) upstream and downstream of duct burners (if fitted), including differential measurement,
- c) upstream and downstream of exhaust silencers including differential measurement,
- d) upstream and downstream of the ammonia injection grid and catalyst, including differential measurement.

11.2.1.3 Water/steam Temperature Measurement:

- a) feedwater preheater and economizer coil inlet,

- b) feedwater preheater and economizer coil outlet,
- c) desuperheater inlets and outlets (steam side),
- d) spray water temperature,
- e) steam superheater outlet,
- f) reheat coil inlet and outlet,
- g) tube skin thermocouples on the first row of tubes after auxiliary burners.

NOTE Details to be agreed between purchaser and supplier.

11.2.1.4 Pressure (water/steam coils):

- a) feedwater preheater and economizer coil inlet,
- b) feedwater preheater and economizer coil outlet,
- c) steam drum pressure,
- d) steam superheater outlet,
- e) reheater inlet & outlet,
- f) blowdown tank pressure.

11.2.1.5 Flow (water/steam coils):

- a) feedwater preheater and economizer,
- b) desuperheater water (spray water flow),
- c) superheated steam line,
- d) reheater flow.

11.2.1.6 Level Measurement:

- a) Steam drum level measurements for protective function; minimum three measurements (voting logic 2oo3),

NOTE The number of nozzles depends on the type of measurement applied and may be two nozzle connections per measurement.

- b) Steam drum level measurements for control function; minimum of two measurements,

NOTE: Protective function drum level measurement may serve as second level measurement (for control).

- c) Steam drum remote level indicator; minimum one measurement,
- d) Blowdown tank level measurements; minimum of two measurements,

- e) When applying differential pressure type level transmitters, provide proper freeze protection when the range of ambient includes temperatures at or below the freezing point of water.
- f) Level transmitter to cover the full range from low level trip to high level alarm (and or trip),
- g) Additional pressure and flow measurement in case of a forced circulation evaporator.

NOTE To be agreed between purchaser and supplier.

11.2.1.7 Analyzing Equipment:

- a) Water and steam sample points and analyzing instruments to be supplied as required to support the selected water chemistry program.

NOTE Analyzing equipment may not be in the scope of the HRSG supplier.

11.2.1.8 Other:

- a) one set off open/close limit switch per diverter (for flue gas bypass),
- b) two set off open/close limit switches per damper.

11.3 Alarm and Trips

11.3.1 The HRSG supplier shall design suitable alarm and trips setting to allow safe and reliable operation of the HRSG. The HRSG supplier and purchaser shall agree on the alarm and trip requirements.

11.3.2 The minimum requirements for alarms and trips shall include the following:

11.3.2.1 Water/steam Side:

- a) economizer inlet temperature low alarm,
- b) steam drum pressure high alarm,
- c) steam drum level low alarm,
- d) steam drum level low trip,
- e) drum level low trip shall initiate:
 - 1) a trip of the duct burner fuel supply,
 - 2) a trip GT or diverter.

NOTE Trip of the duct burner and trip of the GT does not need to be at the same drum level. An additional action level (trip duct burner) between low alarm and drum level low GT trip will allow to maintain steam production and or power generator for longer time, e.g. drum level low alarm, drum level low-low alarm (trip duct burner), drum level low-low-low (trip GT)

- f) steam drum level high-high alarm,

NOTE The steam drum may have a high-level trip depending on the design of the system. See Annex C for additional information.

- g) attemperator outlet steam temperature high alarm,
- h) attemperator outlet steam temperature low (minimum superheat from T-sat) alarm,
- i) high steam temperature at the outlet of the superheater,
- j) any high steam temperature trip to protect the downstream equipment as defined by the purchaser,

NOTE If steam conditions can lead to a material temperature exceeding its design value, it is highly recommended to include a high temperature alarm."

- k) high steam pressure at the steam drum and outlet of the HRSG,
- l) blowdown tank level low alarm,
- m) blowdown tank level high alarm.

NOTE 1 A steaming economizer alarm may be applicable depending on the design.

NOTE 2 A low superheater outlet steam temperature alarm may be applicable.

11.3.2.2 Flue Gas Side:

- a) flue gas pressure high alarm,
- b) duct burner outlet temperature high alarm,

NOTE A duct burner outlet temperature deviation high alarm may be applicable as well, depending on burner design and size of HRSG.

- c) duct burner high outlet temperature trip.

11.3.2.3 Duct Burner:

- a) fuel pressure or flow high (overfire protection) alarm,
- b) fuel pressure or flow high (overfire protection) trip,
- c) fuel pressure or flow low (stability) alarm,
- d) fuel pressure or flow low (stability) trip.

11.3.3 Where a supplemental firing system is applied, it shall be equipped with a BMS that automatically trips the main fuel(s) of all or individual burners in the case of a flame failure.

11.3.4 Flame detectors shall not be equipped with maintenance override switches that can override the trip action.

NOTE Maintenance override switches that switch the detector output to 'flame-out' status may be applied.

11.3.5 The BMS shall be equipped with remote and local manual trip switches that initiates shutting off fuel flow by closing all fuel gas (ignition/pilot and main) SSOV's to the duct burner.

NOTE Such a trip is normally required to handle an emergency not covered by the HRSG safeguarding system.

11.3.6. All other HRSG trips shall be achieved through a controlled shutdown procedure.

11.4 Control

11.4.1 General

11.4.1.1 The supplier shall include the following instrumentation components in their scope of supply:

- a) control valve positioners and local position indicators;
- b) limit switches on all SSOVs (open and closed);
- c) line size manual isolation valves for all control valves.

11.4.1.2 The supplier shall include instrumentation to support the required controls. The level of instrument redundancy shall be agreed between purchaser and supplier.

11.4.1.3 The supplier shall bring to the attention of purchaser any instrumentation or controls not mentioned that are required for reliable and safe operation of the HRSG.

11.4.2 Automated Control Systems

11.4.2.1 The HRSG shall, as minimum, include the following automated control systems.

a) Drum Level Control:

- 1) three-element control for normal water level control including BFW control valve,
- 2) BFW control valve manual bypass,
- 3) BFW control valve redundancy when specified by the purchaser,
- 4) steam flow measurement,
- 5) BFW flow measurement,
- 6) steam drum level measurement.

b) Final Steam Temperature Control:

- 1) steam temperature control including spray water control valve,
- 2) spray water control valve manual bypass,

- 3) spray water control valve redundancy when specified by the purchaser.

NOTE Use of a piston type (multi nozzle) design may limit the redundancy possibilities. Use of a piston type design if proposed, should only be used when agreed by the purchaser.

c) Continuous Blowdown:

- 1) degree of automation as specified by the purchaser,
- 2) CBD control valve,
- 3) a flow meter or minimum flow switch as specified by the purchaser,
- 4) control setpoint parameter as specified by the purchaser i.e. conductivity or steam production.

NOTE Control may be based on manual control valve setting by operator.

d) Steam Pressure / Ramp Rate Control:

- 1) steam pressure control including startup vent control valve when specified by the purchaser,
- 2) steam bypass valve when specified by the purchaser.

e) Supplemental Firing Control:

- 1) fuel flow control with control valve.

NOTE Depending on the system and design requirements more control valves may be applicable, e.g. for reasons of turndown.

f) Intermittent Blowdown Control:

- 1) degree of automation as specified by the purchaser;
- 2) control setpoint parameter as specified by the purchaser i.e. high-level discharge control or water quality.

11.4.3 Other Control Systems

11.4.3.1 The HRSG shall include the following control systems when specified by the purchaser.

- a) Economiser Bypass (if needed for anti-steaming):
 - 1) bypass control valve.
- b) Economiser Inlet Temperature Control (to prevent acid dew point issues):
 - 1) application specific automatic control as agreed between purchaser and supplier.
- c) Economiser Outlet Temperature Control Bypass (to provide differential temperature control with an integral deaerator):
 - 1) application specific control as agreed between purchaser and supplier.
- d) Superheater Dripleg Drain Valves:

- 1) application specific control as agreed between purchaser and supplier.
- e) Flue Gas Bypass Control:
 - 1) application specific control as agreed between purchaser and supplier.
- f) Stack damper control
 - 1) application specific level of automation control as agreed between purchaser and supplier,
 - 2) limit switches for open position as a startup permissive.
- g) SCR Control in Accordance with API 536 (with an SCR included in scope):
 - 1) application specific level of automation control as agreed between purchaser and supplier.

11.5 Burner Management System

11.5.1 The BMS shall be separate from other control systems.

11.5.2 The logic system code for the BMS shall be fail safe.

11.5.3 The logic system code for BMS shall be thoroughly tested and locked down, with password access needed for any changes.

11.5.4 When the BMS is operated remotely from the main control room, provisions shall be made to allow for a shutdown locally at the burner/fuel skid.

11.5.5 Burner status information shall be provided locally with status lights or a human-machine interface.

11.5.6 All critical (GT or duct burner) shutdown sensing elements shall have redundancy based on the specified SIL rating.

11.5.7 A minimum of one flame detector shall be applied per duct burner element.

11.5.8 For burner management, separate measurement and transmitters shall be used for control and protective functions.

11.5.9 For fuel flow measurement, the same flow device can be used for control and protective functions, however transmitters shall be separate.

11.5.11 Redundant data highways shall be provided between the BMS and main plant control room.

11.5.12 Hardwired safety signals shall be provided, by purchaser, between the main and remote-control room systems and the BMS.

- **11.5.13** The purchaser shall specify area classification for the BMS as hazardous or non-hazardous.
- 11.5.14** SSOV shall be of an actuated, fail-safe design on loss of control medium.
- 11.5.15** SSOVs shall remain closed until manually reset following any interlock shutdown.

11.5.16 SSOVs shall be fire safe in accordance with API 607 or API 6FA.

11.5.17 Closure time of SSOVs shall be less than two seconds.

11.5.18 SSOVs shall be quarter turn ball valve.

11.5.19 Depending on the size of the SSOV, ball valves may not be suitable in which case the supplier shall propose a different valve type.

11.5.20 SSOVs shall as minimum be designed to the purchaser specified design pressure of the fuel supply.

11.5.21 Safety pressure relief valves shall be used to prevent over pressure of the safety shutoff valve.

12 Storage, Handling, Identification, and Shipping

12.1 General

- **12.1.1** The extendt of skidding, boxing, crating, or coating for export shipment shall be specified by the purchaser.
- **12.1.2** The purchaser shall specify all long-term storage requirements. The supplier shall inform the purchaser of any specific product requirements and procedures.

12.1.3 The supplier shall be responsible for loading and anchoring equipment to prevent damage during shipment if shipment is included in scope.

12.2 Identification

12.2.1 All equipment, boxes, crates and packages shall be marked with its item and purchase order number plus suitable warnings about lifting limitations such as center of gravity, lifting points and weight.

12.2.2 Tagging/labeling of loose, packaged or crated equipment or components that does not have a permanent nameplate shall be identified with a metal tag with indelible marking, e.g. stamped or etched with tag number on the P&ID.

12.2.3 Nameplates for the burner shall be located on the burner skid, BMS panel or HRSG casing. Nameplate location shall be shown on the supplier drawings.

12.2.4 Heat treated components shall be marked clearly to prohibit further welding or burning or arc strikes.

12.2.5 The words "DO NOT WELD" shall be stenciled/painted (in at least two places 180° apart) on equipment that has been postweld heat-treated.

12.2.6 The supplier shall identify, on the drawings, the maximum number of shop-lined sections that can be stacked and orientation of sections for shipping and storage purposes.

12.2.7 Any temporary components for shipment, transport or erection, shall be clearly identified on the equipment and the field-assembly drawings to ensure removal before commissioning of the equipment.

12.2.8 A stainless steel (Type 304) nameplate, welded to a bracket projecting beyond any insulation shall be furnished by the supplier.

12.3 Packaging

12.3.1 Fit-up and trial assembly of equipment mounted piping and instrumentation shall be completed in the supplier's shop prior to shipment.

12.3.2 The equipment shall be thoroughly cleaned of all foreign matter, all liquids used for cleaning or testing shall be drained out, flushed (and drain again) and the equipment/piping dried before shipment.

12.3.3 The supplier shall be fully responsible for properly protecting all shop installed insulation to avoid damage during storage and shipment.

12.3.1 The supplier shall supply proper weather protection during shipment, storage and erection.

12.3.4 All equipment openings shall be suitably protected to prevent damage and the possible entry of water and other foreign material.

12.3.5 Pipe flanges shall be covered with plastic or plywood or metal covers and held in place using tie wraps or bolts through the stud holes.

12.3.6 Butt weld openings that are beveled shall be suitably covered to protect the bevel from damage.

12.3.7 All threaded connections shall be protected by plugs and/or covers.

12.3.8 Machined surfaces shall be protected with heavy grease or other rust preventative coating that shall last for at least 24 months.

12.3.9 Skid assemblies, skid parts, crates and other ship-loose items shall be completely protected for shipping such as wrapped with shrink wrap material, tarping, plastic wrap material or wood crated.

12.3.10 Individual sections and items identified as being susceptible to vibration or jarring during shipment shall be braced with wood or steel. The installed brace shall be spray painted with yellow paint and marked with black text saying, "Remove after shipment".

12.3.11 Conduit that requires disconnection for shipment shall have its wire pulled entirely inside junction box and the end capped with a molded plastic cap properly sized for the connection.

12.3.12 Loose instruments, electrical panels, or other components shall be crated and protected from mechanical damage during shipment, storage and handling. Whenever possible, instrumentation shall be packaged in original manufacturer's boxes inside the crates.

12.3.13 All electrical/instrumentation panels shall have desiccant placed inside to prevent accumulation of moisture. Desiccant shall be fully contained in bags to prevent dispersion and easily removable.

12.3.14 Valves shall be shipped with packing installed unless specified different. Packing shall have a provision to minimize corrosion of valve components.

12.3.15 Auxiliary instruments and trim components shall be shipped boxed for installation in the field so that damage to these parts will be avoided during shipment.

12.3.16 Spare parts shall be packed separately from the system for which they are spare and properly labelled as “spare parts”.

12.3.17 Include a copy of all applicable safety data sheet (SDS) information such as that for desiccant, catalyst etc. with shipment.

12.4 Storage

12.4.1 Suppliers shall provide a preservation procedure after delivery at site for the supplied goods.

12.4.2 The supplier shall include in its scope all necessary accessories and devices for appropriate preservation of equipment and components during shipment and storage.

13 Field Construction and Erection

13.1 The purchaser shall specify any site-specific requirements and scope for field installation and erection by the erection contractor. See Annex F, Table F.2.

13.2 Installation procedures shall be provided by the supplier considering the appropriate use of temporary bracing and alignment fittings to maintain proper fit-up of all field joints and equipment levelling.

13.3 The installation procedure shall include quality control measures, including acceptance criteria, to ensure proper installation.

13.4 The supplier shall provide comprehensive documentation for field installation and erection. The documents shall include, but not be limited to the following:

- a) scope of supply list
- b) packing list
- c) component list
- d) erection drawings
- e) erection tolerances
- f) erection sequences
- g) foundation loads and calculation
- h) weights and lifting instructions
- i) handling and storage instruction
- j) hydrostatic test procedure
- k) piping layout
- l) list of spool pieces
- m) shipping list

n) tags and markings for erection

13.5 Lifting shall be performed in accordance with the supplier's lifting plan and procedures including any pre-installed refractory/insulation systems installed prior to individual or assembled component lifting.

13.6 Lifting shall be performed in a manner to maintain structural integrity and design characteristics.

13.7 The supplier shall design lifting devices and lifting details in accordance with ASME BTH-1 and ASME B30.20.

13.8 HRSG equipment shall be provided with properly designed lifting lugs, when necessary, to safely lift the equipment for delivery and erection.

13.9 The lifting lugs shall be properly inspected and tested. As a minimum, PT shall be applied on lifting lugs.

NOTE There may be small equipment that can be handled by hand or small lifting devices without need for lifting lugs.

13.10 When lifting lugs are used for erection only, the supplier shall clearly indicate this on drawings or equipment.

13.11 Methods for lifting equipment as well as crane and hoist selection are responsibility of the erection contractor. The erection contractor shall consider site conditions, including weather forecast when planning and executing lifting.

- **13.12** The purchaser shall provide information to the supplier or erection contractor should they need to specify any weight and crane limitation.

13.13 The supplier shall provide temporary supports as required for erection of their scope.

13.14 The supplier shall clearly indicate any temporary supports/equipment that is required to be returned to the supplier.

NOTE The purchaser/erection contractor should store such components in an accessible area for the supplier to collect.

13.15 Any temporary supports/equipment shall be properly color coded.

13.16 The HRSG supplier shall provide a schedule/procedure for application of temporary supports sequence of application and removal.

13.17 The supplier shall provide bolting and torquing requirements.

13.18 It shall be the responsibility of the erection contractor to ensure that the HRSG is erected in accordance with the specifications and drawings furnished by the supplier and in accordance with the applicable sections of this standard.

13.19 Care shall be taken to avoid insulation damage due to weather.

13.20 Protection shall include covers to avoid rain impingement and shall allow drainage, proper fit, and tightening of doors and header boxes.

13.21 Field joints shall be assembled and sealed in accordance with the supplier's requirements.

13.22 Construction joints of the casing resulting from modular construction shall have continuous insulation cover to the full thickness of the adjacent insulation, in compliance with the overall liner/insulation design requirements.

14 Commissioning

14.1 The supplier shall provide commissioning procedures for the HRSG and all associated equipment that is within their specified scope of supply.

14.2 The supplier shall provide guidance to the purchaser on commissioning auxiliaries outside the scope of supply of the supplier if it is expected to impact the operation or performance of the HRSG.

14.3 After completion of mechanical erection, there shall be pre-start-up functionality tests of the control, instrumentation and protective functions. Unless otherwise specified these tests shall be carried out by purchaser and supplier shall provide supervision.

14.5 The supplier shall provide procedures and assistance for commissioning and startup activities. These activities, as a minimum, shall include:

- a) boil out of heating surface/pressure parts;
- b) chemical cleaning of heating surface/pressure parts;
- c) flushing;
- d) steam blow.

14.6 The supplier shall provide field guidance to the purchaser on correct methodology of startup, operation, shutdown, emergency procedure, cleaning and maintenance.

Bibliography

General Bibliography

- [1] API Standard 530, *Calculation of Heater-tube Thickness in Petroleum Refineries*
- [2] API Standard 560, *Fired Heaters for General Refinery Service*
- [3] ANSI/ISA 5.1, *Instrumentation Symbols and Identification*
- [4] ANSI/NACE MR0103/ISO 17945, *Petroleum, petrochemical and natural gas industries -- Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*
- [5] ANSI/NACE MR0175/ISO 15156 *Inquiries and Answers, Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*
- [6] ANSI S12.56 – 1999/ ISO 3746-1995 (R2004), *Acoustics - Determination Of Sound Power Levels Of Noise Sources Using Sound Pressure - Survey Method Using An Enveloping Measurement Surface Over A Reflecting Plane*
- [7] ASME B16.34, *Valves-Flanged, Threaded, and Welding End*
- [8] ASME B16.5, *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*
- [9] ASME B31.1, *Power Piping*
- [10] ASME B31.3, *Process Piping*
- [11] ASME SA 515/SA 515M, *Carbon Steel, for Intermediate and Higher-Temperature Service*
- [12] ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*
- [13] ASTM A217/A217M, *Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service*
- [14] ASTM A242/A242M, *Standard Specification for High-Strength Low-Alloy Structural Steel*
- [15] ASTM A312/312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*
- [16] ASTM A572/572M, *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*
- [17] ASTM D1066-11, *Standard Practice for Sampling Steam*
- [18] ASTM D3370, *Standard Practices for Sampling Water from Flowing Process Streams*
- [19] EN 12952-3, *Water-tube boilers and auxiliary installations - Part 3: Design and calculation for pressure parts of the boiler*

- [20] EN 12952-4, *Water-tube boilers and auxiliary installations - Part 4: In-service boiler life expectancy calculations*
- [21] EN 13480, *Metallic industrial piping (all parts)*
- [22] ISO 3746:2010, *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane*
- [23] ISO 13704, *Petroleum, petrochemical and natural gas industries — Calculation of heater-tube thickness in petroleum refineries*
- [24] ISO 15649, *Petroleum and natural gas Industries – piping*

General Information for Water Chemistry, Water Quality, Steam Sampling, and Steam Purity:

- [25] API Recommended Practice 538, *Industrial Fired Boilers for General Refinery and Petrochemical Service*
- [26] ASME Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle and Cogeneration Power Plants, Table 9b. Feed Water for HRSGs Using Softened Water, ISBN: 9780791859988 (?)
- [27] ASME 2012 Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle Cogeneration Power Plants, ISBN: 978-07918-5998-8.
- [28] ASME 1998 Consensus on Operating Practices for the Control of Feed water and Boiler Water Chemistry in Modern Industrial Boilers CRTD-Vol. 34, ISBN: 0-7918-1204-9.
- [29] IAPWS September 2011 Technical Guidance Document: Phosphate and NaOH treatments for the steam-water circuits of drum boiler of fossil and combined cycle/HRSG power plants.
- [30] IAPWS July 2010 Technical Guidance Document: Volatile treatment for the steam-water circuits of fossil and combined cycle/HRSG power plants.
- [31] EPRI 2006 Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs).
- [32] Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs). EPRI, Palo Alto, CA: 2013.3002001381.
- [33] VGB-Standard, Feed Water, Boiler Water and Steam Quality for Power Plants/Industrial Plants, Third Edition, 2011, ISBN: 978-3-86875-381-3
- [34] JIS V8223 Water Conditioning for boiler feed water and boiler water.
- [35] EN 12952-12, (September 2003) *Water-tube boilers and auxiliary installations - Part 12: Requirements for boiler feedwater and boiler water quality*
- [36] BS 2486-1997 *Recommendations for treatment of water for steam boilers and water heaters*
- [37] VGB-S-006-00 Standard Sampling and Physio cycle Chemical Monitoring of Water and Steam Cycles

General Information on HRSG Upset Management and Action Levels:

- [38] ASME 2012 Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle Cogeneration Power Plants”, ISBN: 978-07918-5998-8.
- [39] EPRI 2006 Cycle Chemistry Guidelines for Combined Cycles/Heat Recovery Steam Generators (HRSGs)
- [40] Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs). EPRI, Palo Alto, CA: 2013.3002001381.
- [41] VGB-Standard, Feed Water, Boiler Water and Steam Quality for Power Plants/Industrial Plants, Third Edition, 2011, ISBN: 978-3-86875-381-3.

Annex A **(informative)**

HRSG Overview

A.1 HRSG – General Description and Equipment Components

A.1.1 General

A Heat Recovery Steam Generator is a system of heating surface(s) that uses waste heat to generate steam. Steam generated could be in single or multiple pressure systems in accordance with the required design.

A.1.2 Pressure Parts Description

Typically, the heating surfaces included in an HRSG are designated as economizer, evaporator and superheater. These three components could be found in single or multiple stages according with the HRSG design requirement. An economizer is designed to heat the water phase, the evaporator is designed to change fluid phase, and the superheater is designed to heat the steam phase. In addition to heating surface, there are other components such as the steam drum, downcomers, risers, links etc. that are important hydraulic components of the HRSG, even though they do not exchange heat.

A.1.2.1 Economizer

Following the path of the boiler feed water flow to convert water into steam, the first section will be the economizer. The economizer is used to heat water from an initial temperature to close to saturation temperature for the operating pressure at the steam drum. The temperature difference between saturation temperature at a given pressure and water temperature entering the drum is called the temperature “approach”. The lower the temperature approach, the closer the water temperature is to the boiling point, i.e. saturation temperature. However, an economizer is not designed to generate steam, therefore the approach temperature should not be zero. A zero-approach temperature represents a thermal limitation for the economizer heat absorption. An economizer is designed to not generate steam, therefore, the fluid temperature at the economizer outlet be 100% subcooled liquid. The heating surface in the economizer has a counterflow arrangement between combustion gases coming from gas turbine and the boiler feed water flow.

A.1.2.2 Steam Drum

Steam drum(s) are positioned in the exterior parts of the HRSG; outside of the gas path. Boiler feed water enters the steam drum and circulates through the evaporator sections where steam, in a two-phase flow (mixture of water and steam) is generated. When the two-phase flow mixture returns to the steam drum by passing through drum internals, where water is separated from steam, with the dry steam directed to the superheater. Some of the steam bubbles generated in the evaporator will release their energy to further heat the subcooled water from the economizer and convert it to saturated liquid in the steam drum.

Steam drum size is selected based on required steam space, space for internals, pressure, steaming capacity, retention time and distances between levels.

A.1.2.3 Downcomer

A downcomer is a section of piping that carries saturated water from the bottom of the steam drum to the lower part of the evaporator. Downcomers are located outside of HRSG in order to avoid steam bubbles formation inside the piping. Depending on the design, a HRSG could have single or multiple downcomers

A.1.2.4 Evaporator

The evaporator tubes absorb heat from the hot flue gas and produce a two phase, water/steam mixture. The mixture circulates back through risers into the steam drum where steam is separated and directed to the superheater. The evaporator is in a cross-flow heating arrangement between combustion gases from the gas turbine (and duct burner where applicable) and water at saturated temperature flowing through the evaporator tubes. The temperature difference between the combustion gases leaving the evaporator and saturation temperature at operating pressure of the evaporator is called the “pinch” point. The pinch point is an important consideration in determining the thermal limitation for heat absorption in the evaporator.

A.1.2.5 Riser

A riser is a section of piping in the upper part of the evaporator that carries a two-phase water/steam mixture to the inlet of the primary separators of the steam drum. Depending on the design, a HRSG could have single or multiple risers.

A.1.2.6 Steam Drum Internals

Inside the steam drum, depending on the HRSG design, there will be single or multiple steam separation stages. Steam separators are designed to separate water from steam in order to send “dry saturated steam” to the process or to the superheater stage of the HRSG.

Steam leaving drum has some degree of moisture i.e. it is not completely dry. The efficiency of a steam separator varies with steam drum operating pressure. Since separation process is based upon changes on fluid directions and fluid density difference, the lower the operating pressure the higher the separation efficiency. ABMA provides values for the minimum efficiency that separators must comply according to operating pressure.

A.1.2.7 Superheater

A superheater is a coil section designed to increase the temperature of saturated steam from the steam drum up to the required temperature (degrees of superheat).

Depending on the difference between final required temperature and saturated temperature, superheaters can be designed in single or multiple stages.

Some designs may include a superheater called “reheater”, terminology comes from steam that has been superheated before then sent to the steam turbine for expansion and then requires reheat to boost the steam temperature in order to pass through a lower pressure steam turbine. Note that the term is also used for steam coming from other sources (process) and it is required to increase temperature for some other lower pressure process.

In order to control steam temperature to the end user, normally an attemperator is used. The function of the attemperator (also known as desuperheater) is to decrease the temperature of the superheated steam until the level requested. The most common type of attemperator is of water injection in the direction of the steam flow. If the superheater is a single stage design, then an attemperator is located at the outlet piping. If superheater has multiple stages, normally desuperheater is located interstage.

A.1.3 Non-pressure Parts Description

Non-pressure parts comprise the components that form the casing, inlet duct, stack, diverter damper (if applicable) and structural steel. In other words, components that have no relationship with steam or water operating pressure.

A.1.3.1 Casing

Most HRSGs use a cold casing design in which the main components of the casing can be described as follows:

- Internal liner: Formed by a metal sheet designed to protect the insulation from damage. Material selection for the metal liner is determined by gas temperature at each module of the HRSG.
- Insulation: Located between internal liner and external casing. Its main function is for personnel protection and to reduce heat loss across external casing i.e. to increase thermal efficiency. Insulation thickness is calculated considering material conductivity, ambient temperature, wind speed, gas temperature, desired heat loss and external casing temperature. As gas temperature decreases along HRSG, so does the required insulation thickness.
- External Casing: It represents the external face or cover of the HRSG. Since insulation is internal to the external casing, the casing material is carbon steel. The external casing thickness is normally 6 mm (¼ in.), however sometimes the casing thickness is increased in order to reduce noise radiation through casing (mainly on inlet duct).

Some HRSGs may require the use of a warm casing design. In which design insulation may (also) be on the external casing. In which case additional sheeting is required to protect the insulation against weather conditions.

A.1.3.2 Inlet Duct

The inlet duct is the transition duct between the outlet flange of the gas turbine and the first heating coil in the HRSG. Basically, it is a casing that has no pressure parts components in its interior.

A.1.3.3 Stack

The stack directs exhaust gas to atmosphere. When it is designed, the speed of gases must be considered, as well as the pressure drop (draft loss) and location for measuring pollution emissions. Stack design considerations include gas velocity, pressure drop (draft loss) and the proper location for emission measurements and platforms. Typically, an HRSG stack is fabricated using carbon steel, it is self-supported, and uninsulated.

A.1.3.4 Structural Steel

The steel structure is used for the following purposes:

- provides support to the pressure parts of the module;
- provide structural support for steam drums;
- supports the exterior casing to create an hermetic gas confinement for the HRSG;
- resists the loads due to internal pressure;

— resists external loads such as wind and earthquake.

The structure consists of main frames that surrounds the HRSG and it is formed by a ceiling beam, joined by field welding and/or bolted connections.

A.2 HRSG Design Considerations—Single and Multiple Pressures

The simplest HRSG arrangement consists of an evaporator module alone. It would receive subcooled boiler feed water, absorb heat from combustion gases and generate saturated steam. All steam generators, also referred to as boilers, require the use of an evaporator module.

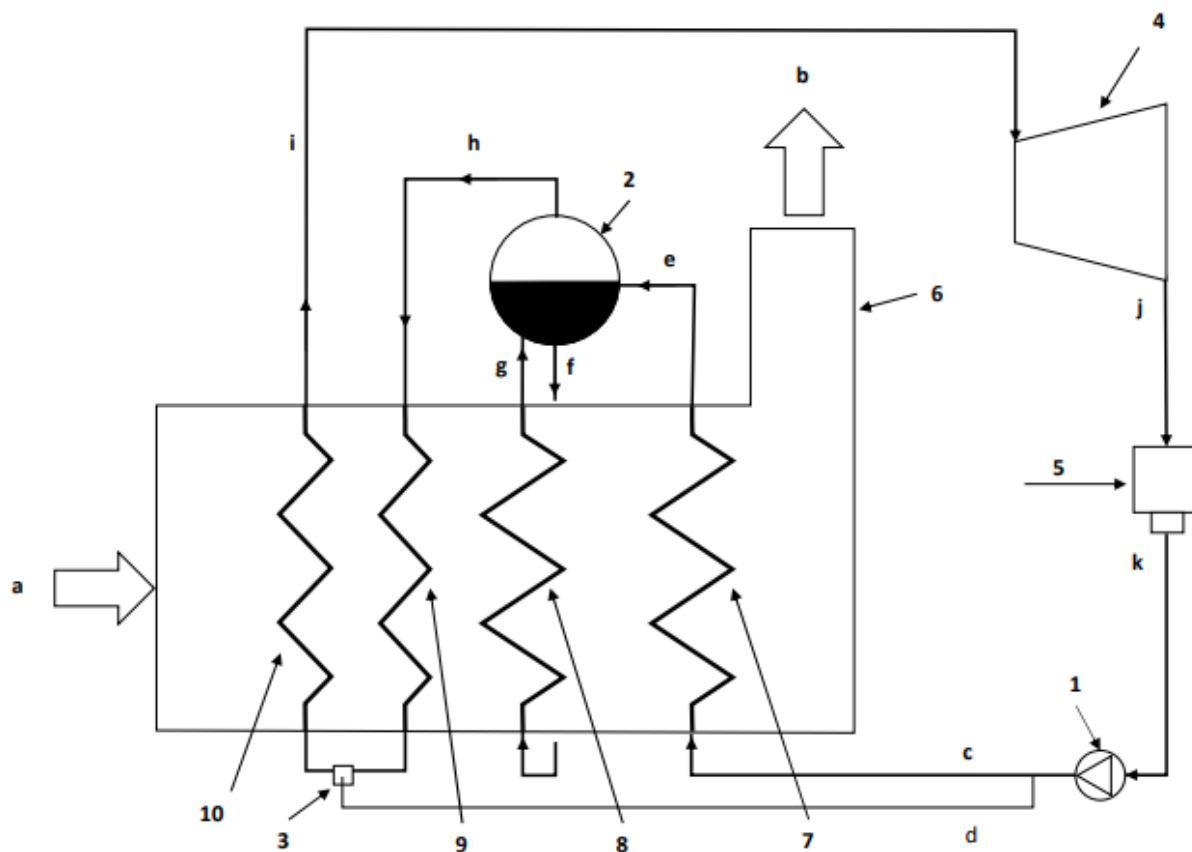
When a higher thermal efficiency is desired, an economizer is added to the configuration. Boiler feed water passes through the economizer module to preheat the water before passing through the evaporator module. The outlet process condition is saturated steam.

When superheated steam for the process or an increase in thermal efficiency is required, then a superheater is added to the configuration. The HRSG could be configured with an evaporator and superheater modules or economizer, evaporator and superheater modules.

An HRSG could be configured as a single or multiple pressure design: it depends on the process consumer requirements. A multiple pressure HRSG is designed as multiple steam generators, with each operating at different pressures contained inside the same casing. All the operating systems are independent of each other.

Refer to Figure A.1 and Figure A.2 for example schematic of a single and dual pressure HRSG systems respectively.

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



Key

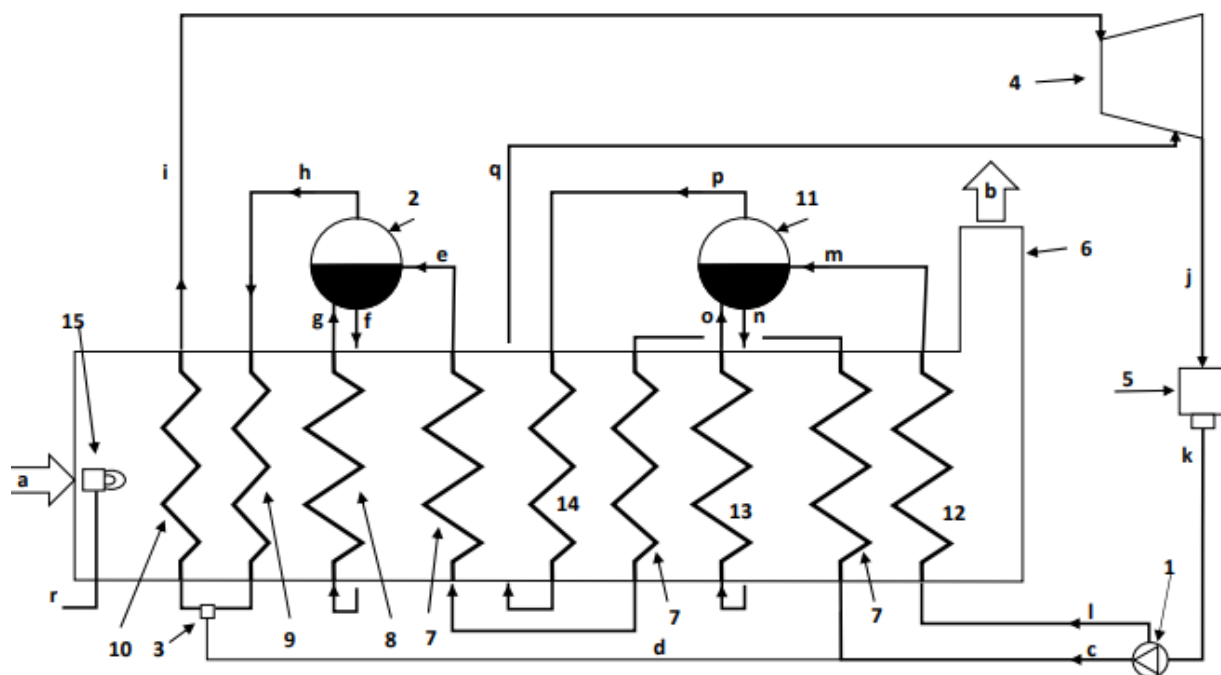
- | | |
|-----------------------------------|--|
| 1 boiler feedwater pump | 6 stack |
| 2 steam drum | 7 economizer |
| 3 attemperator | 8 evaporator |
| 4 steam turbine (or process user) | 9 superheater (1 st stage) |
| 5 condenser | 10 superheater (2 nd stage) |

Notes

- | | |
|---|---|
| a hot flue gas | g water/steam from evaporator (riser) |
| b cold flue gas | h saturated steam |
| c boiler feedwater | i superheated steam (to process or turbine) |
| d attemperator spray water | j used steam (steam turbine discharge/process steam return) |
| e boiler water (economizer outlet) | k condensate |
| f saturated water to evaporator (downcomer) | |

Figure A.1--Single Pressure HRSG

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



Key

- | | |
|--|--|
| 1 boiler feedwater pump | 9 HP steam superheater (1 st stage) |
| 2 HP steam drum | 10 HP superheater (2 nd stage) |
| 3 attemperator | 11 LP steam drum |
| 4 steam turbine (process user) | 12 LP economizer |
| 5 condenser | 13 LP evaporator |
| 6 stack | 14 LP superheater |
| 7 HP economizer (example three sections) | 15 duct burner |
| 8 HP evaporator | |

Notes

- | | |
|--|--|
| a hot flue gas | j used steam (steam turbine discharge or process steam return) |
| b cold flue gas | k condensate |
| c HP boiler feedwater | l LP boiler feedwater |
| d attemperator spray water | m LP boiler water (LP economizer outlet) |
| e HP boiler water (economizer outlet) | n LP saturated water to evaporator (downcomer) |
| f HP saturated water to evaporator (downcomer) | o LP water/steam from evaporator (riser) |
| g HP water/steam from evaporator (riser) | p LP saturated steam |
| h HP saturated steam | q LP superheated steam (to process or turbine) |
| i HP superheated steam (to process or turbine) | r fuel for supplemental firing |

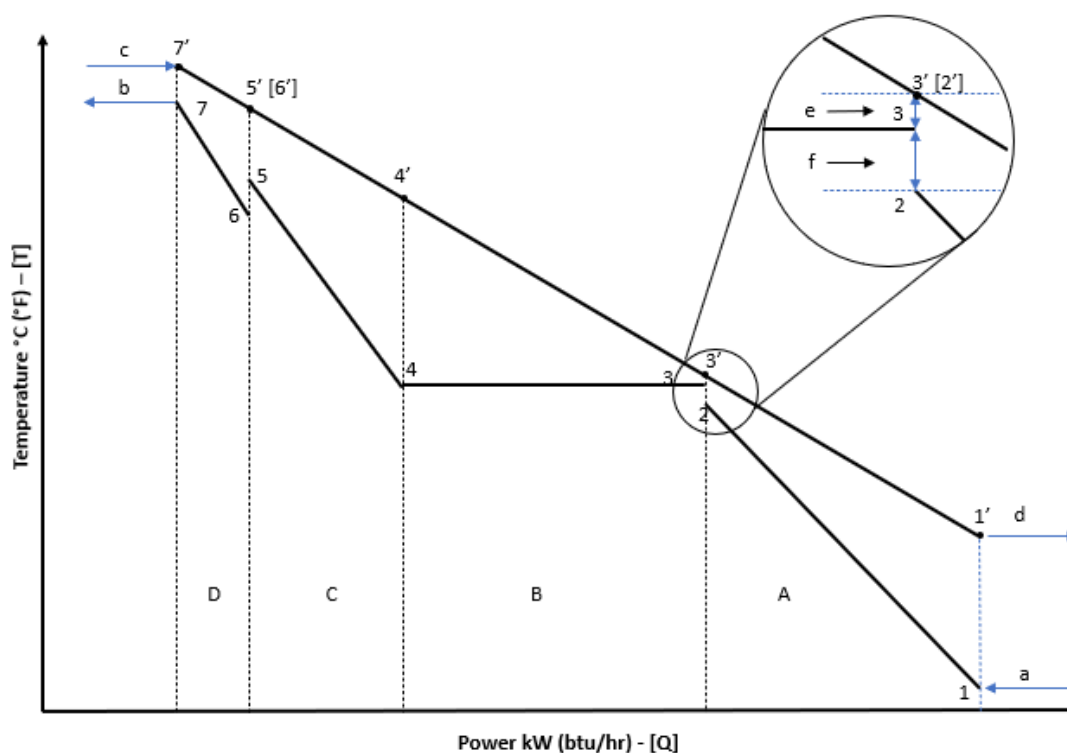
Figure A.2--Dual Pressure HRSG

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

As illustrated in Figure A.2, a dual pressure HRSG is basically two steam generators inside the same casing.

As the number of working pressures increases, thermal efficiency does. Once a steam generator has reached their thermal limitation for steam generation (pinch on evaporators, approach on economizers) then in order to absorb more heat it is necessary to add another steam generator operating at different pressure and continue adding steam generator until it is thermally and economically feasible. Refer to Figure A.3 for an illustration of thermal limitations in an HRSG; also referred to as a TQ diagram.

NOTE HRSG overall heating surfaces are arranged in counterflow with respect to combustion gases, when a multiple pressure HRSG is designed, modules of different operating pressures are arranged intercalary in order to maximize heat absorption.



Key

Water/steam side

- 1 economizer inlet water temperature
- 2 economizer outlet water temperature
- 3 evaporator inlet water temperature
- 4 evaporator outlet water temperature
- 5 superheater (1st stage) outlet steam temperature
- 6 attemperator outlet steam temperature
- 7 superheater (2nd stage) outlet steam temperature

Flue gas side

- 1' economizer outlet flue gas temperature (stack temperature)
- 2' economizer inlet flue gas temperature [= 3']
- 3' evaporator outlet flue gas temperature
- 4' superheater (1st stage) outlet flue gas temperature (evaporator inlet)
- 5' superheater (2nd stage) outlet flue gas temperature [= 6']
- 6' superheater (1st stage) inlet flue gas temperature
- 7' superheater (2nd stage) inlet flue gas temperature [= HRSG inlet flue gas temperature]

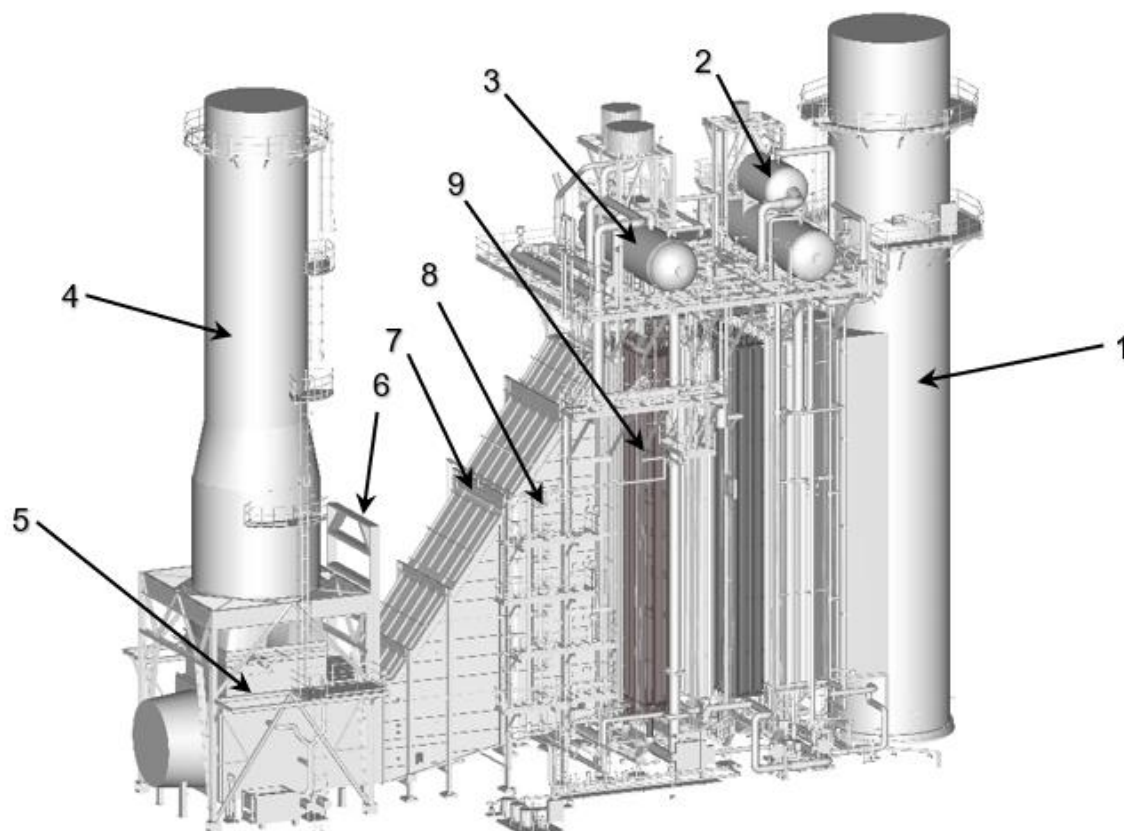
Notes

- | | | | |
|---|--------------------------|---|-------------------------------------|
| a | boiler feedwater to HRSG | A | economizer |
| b | steam from HRSG | B | evaporator |
| c | flue gas to HRSG | C | superheater (1 st stage) |
| d | flue gas to stack | D | superheater (2 nd stage) |
| e | pinch point | | |
| f | approach point | | |

Figure A.3--Thermal Limitations in an HRSG

Refer to Figure A.4 for a typical HRSG general arrangement.

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



Key

1	stack	5	diverter	9	heating surfaces
2	deaerator	6	guillotine		
3	drum	7	inlet duct		
4	bypass stack	8	burners		

Figure A.4--Typical HRSG General Arrangement

Annex B (informative)

Equipment Datasheets

The following datasheets are provided to assist the designer, supplier, and purchaser in specifying the data necessary for the design of a heat recovery steam generator (HRSG) and related equipment for general refinery service.

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

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

SI Units:

HRSG Surface Datasheet -- 4 sheets

HRSG Headers Datasheet -- 2 sheets

HRSG Casing & Insulation Datasheet -- 1 sheet

HRSG Drums Datasheet --1 sheet

HRSG Fuel Datasheet -- 1 sheet

HRSG GT & Burner Exhaust Datasheet -- 1 sheet

HRSG Performance Datasheet -- 3 sheets

HRSG General Remarks Datasheet -- 1 sheet

USC Units:

HRSG Surface Datasheet -- 4 sheets

HRSG Headers Datasheet -- 2 sheets

HRSG Casing & Insulation Datasheet -- 1 sheet

HRSG Drums Datasheet --1 sheet

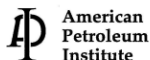
HRSG Fuel Datasheet -- 1 sheet

HRSG GT & Burner Exhaust Datasheet -- 1 sheet

HRSG Performance Datasheet -- 3 sheets

HRSG General Remarks Datasheet -- 1 sheet

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG SURFACE DATASHEET (SI UNITS)

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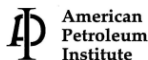
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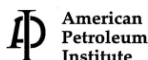
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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.									
2 <input type="checkbox"/> Component # 11									
3 Name ⁽¹⁾ :					Pressure Design Code:				
4 Design Pressure, kPa(ga):			Design Temp., °C:		Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered				
5 Tube O.D., mm:			Tube Min. Wall, mm:		Tube Finned Length, mm:			Tube Material:	
6 No. Tubes wide / row, #:			No. of Flow Circuits, #:		Transverse Spacing (ST), mm:				
7 No. of Rows Deep, #:			Long. Spacing (SL), mm:		No. of Bare Rows, #:			No. of Finned Rows, #:	
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/m:			Fin Height, mm:			
9 Fin Segment (if applied), mm:			Fin Thickness, mm:			Fin Material:			
10 Heating Surface, m ² :			Component Full of Water, m ³ :			Normal Operation Water, m ³ :			
11 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:						
12 <input type="checkbox"/> Component # 12									
13 Name ⁽¹⁾ :					Pressure Design Code:				
14 Design Pressure, kPa(ga):			Design Temp., °C:		Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered				
15 Tube O.D., mm:			Tube Min. Wall, mm:		Tube Finned Length, mm:			Tube Material:	
16 No. Tubes wide / row, #:			No. of Flow Circuits, #:		Transverse Spacing (ST), mm:				
17 No. of Rows Deep, #:			Long. Spacing (SL), mm:		No. of Bare Rows, #:			No. of Finned Rows, #:	
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/m:			Fin Height, mm:			
19 Fin Segment (if applied), mm:			Fin Thickness, mm:			Fin Material:			
20 Heating Surface, m ² :			Component Full of Water, m ³ :			Normal Operation Water, m ³ :			
21 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:						
22 <input type="checkbox"/> Component # 13									
23 Name ⁽¹⁾ :					Pressure Design Code:				
24 Design Pressure, kPa(ga):			Design Temp., °C:		Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered				
25 Tube O.D., mm:			Tube Min. Wall, mm:		Tube Finned Length, mm:			Tube Material:	
26 No. Tubes wide / row, #:			No. of Flow Circuits, #:		Transverse Spacing (ST), mm:				
27 No. of Rows Deep, #:			Long. Spacing (SL), mm:		No. of Bare Rows, #:			No. of Finned Rows, #:	
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/m:			Fin Height, mm:			
29 Fin Segment (if applied), mm:			Fin Thickness, mm:			Fin Material:			
30 Heating Surface, m ² :			Component Full of Water, m ³ :			Normal Operation Water, m ³ :			
31 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:						
32 <input type="checkbox"/> Component # 14									
33 Name ⁽¹⁾ :					Pressure Design Code:				
34 Design Pressure, kPa(ga):			Design Temp., °C:		Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered				
35 Tube O.D., mm:			Tube Min. Wall, mm:		Tube Finned Length, mm:			Tube Material:	
36 No. Tubes wide / row, #:			No. of Flow Circuits, #:		Transverse Spacing (ST), mm:				
37 No. of Rows Deep, #:			Long. Spacing (SL), mm:		No. of Bare Rows, #:			No. of Finned Rows, #:	
38 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/m:			Fin Height, mm:			
39 Fin Segment (if applied), mm:			Fin Thickness, mm:			Fin Material:			
40 Heating Surface, m ² :			Component Full of Water, m ³ :			Normal Operation Water, m ³ :			
41 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:						
42 <input type="checkbox"/> Component # 15									
43 Name ⁽¹⁾ :					Pressure Design Code:				
44 Design Pressure, kPa(ga):			Design Temp., °C:		Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered				
45 Tube O.D., mm:			Tube Min. Wall, mm:		Tube Finned Length, mm:			Tube Material:	
46 No. Tubes wide / row, #:			No. of Flow Circuits, #:		Transverse Spacing (ST), mm:				
47 No. of Rows Deep, #:			Long. Spacing (SL), mm:		No. of Bare Rows, #:			No. of Finned Rows, #:	
48 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/m:			Fin Height, mm:			
49 Fin Segment (if applied), mm:			Fin Thickness, mm:			Fin Material:			
50 Heating Surface, m ² :			Component Full of Water, m ³ :			Normal Operation Water, m ³ :			
51 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:						
52 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number is needed. e.g. superheater 1.									
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



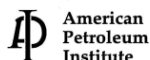
API STANDARD 534 HRSG SURFACE DATASHEET (SI UNITS)

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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.											
2 <input type="checkbox"/> Component # 16											
3 Name ⁽¹⁾ :											
4 Design Pressure, kPa(ga): Design Temp., °C: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
5 Tube O.D., mm: Tube Min. Wall, mm: Tube Finned Length, mm: Tube Material:											
6 No. Tubes wide / row, #: No. of Flow Circuits, #: Transverse Spacing (ST), mm:											
7 No. of Rows Deep, #: Long. Spacing (SL), mm: No. of Bare Rows, #: No. of Finned Rows, #:											
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/m: Fin Height, mm:											
9 Fin Segment (if applied), mm: Fin Thickness, mm: Fin Material:											
10 Heating Surface, m ² : Component Full of Water, m ³ : Normal Operation Water, m ³ :											
11 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal Module Number:											
12 <input type="checkbox"/> Component # 17											
13 Name ⁽¹⁾ :											
14 Design Pressure, kPa(ga): Design Temp., °C: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
15 Tube O.D., mm: Tube Min. Wall, mm: Tube Finned Length, mm: Tube Material:											
16 No. Tubes wide / row, #: No. of Flow Circuits, #: Transverse Spacing (ST), mm:											
17 No. of Rows Deep, #: Long. Spacing (SL), mm: No. of Bare Rows, #: No. of Finned Rows, #:											
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/m: Fin Height, mm:											
19 Fin Segment (if applied), mm: Fin Thickness, mm: Fin Material:											
20 Heating Surface, m ² : Component Full of Water, m ³ : Normal Operation Water, m ³ :											
21 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal module number:											
22 <input type="checkbox"/> Component # 18											
23 Name ⁽¹⁾ :											
24 Design Pressure, kPa(ga): Design Temp., °C: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
25 Tube O.D., mm: Tube Min. Wall, mm: Tube Finned Length, mm: Tube Material:											
26 No. Tubes wide / row, #: No. of Flow Circuits, #: Transverse Spacing (ST), mm:											
27 No. of Rows Deep, #: Long. Spacing (SL), mm: No. of Bare Rows, #: No. of Finned Rows, #:											
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/m: Fin Height, mm:											
29 Fin Segment (if applied), mm: Fin Thickness, mm: Fin Material:											
30 Heating Surface, m ² : Component Full of Water, m ³ : Normal Operation Water, m ³ :											
31 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal module number:											
32 BOILER FEED WATER ANALYSIS											
33 pH @ 25 °C											
34 CC μS/cm											
35 Na mg/kg											
36 Si mg/kg as SiO ₂											
37 O ₂ mg/kg											
38 Fe mg/kg											
39 Cu mg/kg											
40 Chloride mg/kg											
41 Sulfate mg/kg											
42 TOC mg/kg											
43											
44 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number as needed. e.g. superheater 1.											
45											
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



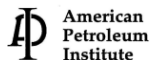
API STANDARD 534 HRSG HEADERS DATASHEET (SI UNITS)

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1	FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.			
2	<input type="checkbox"/> Headers Component # 1			
3	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
4	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
5	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
6				
7	<input type="checkbox"/> Headers Component # 2			
8	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
9	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
10	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
11				
12	<input type="checkbox"/> Headers Component # 3			
13	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
14	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
15	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
16				
17	<input type="checkbox"/> Headers Component # 4			
18	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
19	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
20	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
21				
22	<input type="checkbox"/> Headers Component # 5			
23	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
24	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
25	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
26				
27	<input type="checkbox"/> Headers Component # 6			
28	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
29	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
30	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
31				
32	<input type="checkbox"/> Headers Component # 7			
33	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
34	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
35	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
36				
37	<input type="checkbox"/> Headers Component # 8			
38	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
39	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
40	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
41				
42	<input type="checkbox"/> Headers Component # 9			
43	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
44	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
45	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
46				
47	<input type="checkbox"/> Headers Component # 10			
48	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
49	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
50	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
51				
52	Remarks:			
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



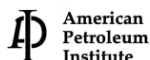
API STANDARD 534 HRSG HEADERS DATASHEET (SI UNITS)

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1	FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.			
2	<input type="checkbox"/> Headers Component # 11			
3	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
4	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
5	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
6				
7	<input type="checkbox"/> Headers Component # 12			
8	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
9	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
10	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
11				
12	<input type="checkbox"/> Headers Component # 13			
13	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
14	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
15	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
16				
17	<input type="checkbox"/> Headers Component # 14			
18	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
19	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
20	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
21				
22	<input type="checkbox"/> Headers Component # 15			
23	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
24	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
25	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
26				
27	<input type="checkbox"/> Headers Component # 16			
28	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
29	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
30	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
31				
32	<input type="checkbox"/> Headers Component # 17			
33	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
34	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
35	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
36				
37	<input type="checkbox"/> Headers Component # 18			
38	Name:	Design Pressure, kPa(ga):	Design Temperature, °C:	Corr Allow, mm:
39	Inlet Header:	OD, D.N.:	Thickness, mm:	Material:
40	Outlet Header:	OD, D.N.:	Thickness, mm:	Material:
41				
42	Remarks:			
43				
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



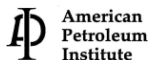
API STANDARD 534 HRSG CASING & INSULATION DATASHEET (SI UNITS)

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1	FILL IN HRSG CASING AND INSULATION DATA. USE MODULES AS REQUIRED PER HRSG DESIGN. MODULES ARRANGED IN GAS FLOW DIRECTION.									
2										
3	Casing & Insulation									
4	Design Parameters:	Ambient Temperature, °C:		Wind Speed, m/s:		Cold Face Temperature, °C:				
5										
6		Inlet Duct	Inlet Duct	HRSG	HRSG	HRSG	HRSG	HRSG	HRSG	HRSG Last
7		Section 1	Section 2	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module
8	Components Comprised in									
9	Module									
10	Hot Flue Gas Temp. °C									
11	Casing Emmissivity									
12										
13	LINER									
14	Liner Thickness mm									
15	Liner Material									
16										
17	INSULATION									
18	Thickness Insulation mm									
19	Insulation Material									
20	Insulation Density kg/m³									
21										
22	CASING									
23	Material									
24	Thickness mm									
25										
26	PAINTING									
27	Exterior Surface Prep.									
28	Exterior Coating									
29										
30	Remarks:									
31										
32										
33										
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG DRUMS DATASHEET (SI UNITS)

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1	<input type="checkbox"/> HP Drum			
2	Design Pressure, kPa(ga):	Design Temperature, °C:	Volume, m³:	Material:
3	Drum Inside Dia., mm:	Drum Thickness, mm:	Head Type:	
4	Drum Length:	Seam to Seam (excluding heads), mm:	Total Length (including heads), mm:	
5	Manholes:	Qty., #:	Size, mm:	Type:
6	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
7	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , mm:	HHWL (Drum Center±), mm:	HWL (Drum Center±) (mm):
8		LLLWL (Drum Center±) ⁽¹⁾ , mm:	LLWL (Drum Center±), mm:	LWL (Drum Center±) (mm):
9		NWL (Drum Center±), mm:		
10	At HRSG Design Point	Retention Time (NWL to LLWL trip), min.:		
11	Drum Weight:	Empty, kg:	Normal Operation, kg:	
12				
13				
14	<input type="checkbox"/> IP Drum			
15	Design Pressure, kPa(ga):	Design Temperature, °C:	Volume, m³:	Material:
16	Drum Inside Dia., mm:	Drum Thickness, mm:	Head Type:	
17	Drum Length:	Seam to Seam Excluding heads, mm:	Total Length (including heads), mm:	
18	Manholes:	Qty., #:	Size, mm:	Type:
19	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
20	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , mm:	HHWL (Drum Center±), mm:	HWL (Drum Center±) (mm):
21		LLLWL (Drum Center±) ⁽¹⁾ , mm:	LLWL (Drum Center±), mm:	LWL (Drum Center±) (mm):
22		NWL (Drum Center±), mm:		
23	At HRSG Design Point	Retention Time (NWL to LLWL trip), min.:		
24	Drum Weight:	Empty, kg:	Normal Operation, kg:	
25				
26				
27	<input type="checkbox"/> LP Drum			
28	Design Pressure, kPa(ga):	Design Temperature, °C:	Volume, m³:	Material:
29	Drum Inside Dia., mm:	Drum Thickness, mm:	Head Type:	
30	Drum Length:	Seam to Seam Excluding heads, mm:	Total Length (including heads), mm:	
31	Manholes:	Qty., #:	Size, mm:	Type:
32	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
33	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , mm:	HHWL (Drum Center±), mm:	HWL (Drum Center±) (mm):
34		LLLWL (Drum Center±) ⁽¹⁾ , mm:	LLWL (Drum Center±), mm:	LWL (Drum Center±) (mm):
35		NWL (Drum Center±), mm:		
36	At HRSG Design Point	Retention Time (NWL to LLWL trip), min.:		
37	Drum Weight:	Empty, kg:	Normal Operation, kg:	
38				
39				
40	Remarks: ⁽¹⁾ If applied			
41				
42				
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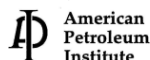
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API STANDARD 534 HRSG PERFORMANCE DATASHEET (SI UNITS)

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1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

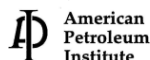
4 Manufacturer _____ Case Number (fill in operating cases as needed): _____

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet Pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG PERFORMANCE DATASHEET (SI UNITS)

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1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

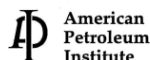
4 Manufacturer Case Number (fill in operating cases as needed):

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet Pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet Pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG PERFORMANCE DATASHEET (SI UNITS)

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1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. COMPONENTS ARRANGED IN GAS FLOW DIRECTION PER HRSG DESIGN.

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

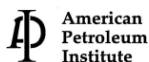
4 Manufacturer _____ Case Number (fill in operating cases as needed): _____

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet Pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	kg/s									
Pressure Drop	Pa									
Inlet Temperature	°C									
Outlet Temperature	°C									
Temperature Difference	°C									
Specific Heat	kJ/kg K									
Heat Rejected	kW									
Heat Loss by Casing	%									
Fouling Factor	m ² ·K/W									
Supplemental Fuel, LHV	kJ/kg									
Suppl. Fuel Firing Duty	MW									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	kg/s									
Inlet Pressure	kPa(ga)									
Outlet Pressure	kPa(ga)									
Pressure Drop	Pa									
Outlet Temperature	°C									
Inlet Temperature	°C									
Temperature Difference	°C									
Heat Absorbed	MW									
Fouling Factor	m ² ·K/W									
Blowdown Water	%									

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



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1	INFORMATION TO BE COMPLETED: <input type="radio"/> BY PURCHASER <input type="checkbox"/> BY MANUFACTURER <input checked="" type="checkbox"/> BY PURCHASER OR MANUFACTURER
2	GENERAL REMARKS
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



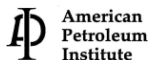
API STANDARD 534 HRSG SURFACE DATASHEET (USC UNITS)

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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.									
2 <input type="checkbox"/> Component # 1									
3 Name ⁽¹⁾ :					Pressure Design Code:				
4 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
5 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
6 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
7 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
9 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
10 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
11 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
12 <input type="checkbox"/> Component # 2									
13 Name ⁽¹⁾ :					Pressure Design Code:				
14 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
15 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
16 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
17 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
19 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
20 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
21 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
22 <input type="checkbox"/> Component # 3									
23 Name ⁽¹⁾ :					Pressure Design Code:				
24 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
25 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
26 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
27 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
29 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
30 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
31 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
32 <input type="checkbox"/> Component # 4									
33 Name ⁽¹⁾ :					Pressure Design Code:				
34 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
35 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
36 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
37 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
38 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
39 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
40 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
41 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
42 <input type="checkbox"/> Component # 5									
43 Name ⁽¹⁾ :					Pressure Design Code:				
44 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
45 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
46 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
47 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
48 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
49 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
50 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
51 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
52 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number as needed. e.g. superheater 1.									
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



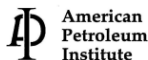
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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.									
2 <input type="checkbox"/> Component # 6									
3 Name ⁽¹⁾ :					Pressure Design Code:				
4 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
5 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
6 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
7 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
9 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
10 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
11 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
12 <input type="checkbox"/> Component # 7									
13 Name ⁽¹⁾ :					Pressure Design Code:				
14 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
15 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
16 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
17 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
19 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
20 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
21 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
22 <input type="checkbox"/> Component # 8									
23 Name ⁽¹⁾ :					Pressure Design Code:				
24 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
25 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
26 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
27 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
29 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
30 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
31 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
32 <input type="checkbox"/> Component # 9									
33 Name ⁽¹⁾ :					Pressure Design Code:				
34 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
35 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
36 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
37 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
38 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
39 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
40 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
41 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
42 <input type="checkbox"/> Component # 10									
43 Name ⁽¹⁾ :					Pressure Design Code:				
44 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered			
45 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:			Tube Material:
46 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
47 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:			No. of Finned Rows, #:
48 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
49 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
50 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
51 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4						Longitudinal Module Number:			
52 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number as needed. e.g. superheater 1.									
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56									
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



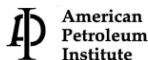
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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.									
2 <input type="checkbox"/> Component # 11									
3 Name ⁽¹⁾ :					Pressure Design Code:				
4 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement:		<input type="checkbox"/> in-line <input type="checkbox"/> staggered	
5 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:		Tube Material:	
6 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
7 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:		No. of Finned Rows, #:	
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
9 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
10 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
11 Number of Modules Width (transversal):			<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:			
12 <input type="checkbox"/> Component # 12									
13 Name ⁽¹⁾ :					Pressure Design Code:				
14 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement:		<input type="checkbox"/> in-line <input type="checkbox"/> staggered	
15 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:		Tube Material:	
16 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
17 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:		No. of Finned Rows, #:	
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
19 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
20 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
21 Number of Modules Width (transversal):			<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:			
22 <input type="checkbox"/> Component # 13									
23 Name ⁽¹⁾ :					Pressure Design Code:				
24 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement:		<input type="checkbox"/> in-line <input type="checkbox"/> staggered	
25 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:		Tube Material:	
26 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
27 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:		No. of Finned Rows, #:	
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
29 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
30 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
31 Number of Modules Width (transversal):			<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:			
32 <input type="checkbox"/> Component # 14									
33 Name ⁽¹⁾ :					Pressure Design Code:				
34 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement:		<input type="checkbox"/> in-line <input type="checkbox"/> staggered	
35 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:		Tube Material:	
36 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
37 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:		No. of Finned Rows, #:	
38 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
39 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
40 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
41 Number of Modules Width (transversal):			<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:			
42 <input type="checkbox"/> Component # 15									
43 Name ⁽¹⁾ :					Pressure Design Code:				
44 Design Pressure, psig:			Design Temp., °F:			Tubes Arrangement:		<input type="checkbox"/> in-line <input type="checkbox"/> staggered	
45 Tube O.D., in.:			Tube Min. Wall, in.:			Tube Finned Length, in.:		Tube Material:	
46 No. Tubes Wide / Row, #:			No. of Flow Circuits, #:			Transverse Spacing (ST), in.:			
47 No. of Rows Deep, #:			Long. Spacing (SL), in.:			No. of Bare Rows, #:		No. of Finned Rows, #:	
48 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented			Fin Density, fin/in.:			Fin Height, in.:			
49 Fin Segment (if applied), in.:			Fin Thickness, in.:			Fin Material:			
50 Heating Surface, ft ² :			Component Full of Water, ft ³ :			Normal Operation Water, ft ³ :			
51 Number of Modules Width (transversal):			<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4			Longitudinal Module Number:			
52 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number is needed. e.g. superheater 1.									
53									
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



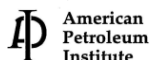
API STANDARD 534 HRSG SURFACE DATASHEET (USC UNITS)

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1 FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.											
2 <input type="checkbox"/> Component # 16											
3 Name ⁽¹⁾ :											
4 Design Pressure, psig: Design Temp., °F: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
5 Tube O.D., in.: Tube Min. Wall, in.: Tube Finned Length, in.: Tube Material:											
6 No. Tubes Wide / Row, #: No. of Flow Circuits, #: Transverse Spacing (ST), in.:											
7 No. of Rows Deep, #: Long. Spacing (SL), in.: No. of Bare Rows, #: No. of Finned Rows, #:											
8 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/in.: Fin Height, in.:											
9 Fin Segment (if applied), in.: Fin Thickness, in.: Fin Material:											
10 Heating Surface, ft ² : Component Full of Water, ft ³ : Normal Operation Water, ft ³ :											
11 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal Module Number:											
12 <input type="checkbox"/> Component # 17											
13 Name ⁽¹⁾ :											
14 Design Pressure, psig: Design Temp., °F: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
15 Tube O.D., in.: Tube Min. Wall, in.: Tube Finned Length, in.: Tube Material:											
16 No. Tubes Wide / Row, #: No. of Flow Circuits, #: Transverse Spacing (ST), in.:											
17 No. of Rows Deep, #: Long. Spacing (SL), in.: No. of Bare Rows, #: No. of Finned Rows, #:											
18 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/in.: Fin Height, in.:											
19 Fin Segment (if applied), in.: Fin Thickness, in.: Fin Material:											
20 Heating Surface, ft ² : Component Full of Water, ft ³ : Normal Operation Water, ft ³ :											
21 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal Module Number:											
22 <input type="checkbox"/> Component # 18											
23 Name ⁽¹⁾ :											
24 Design Pressure, psig: Design Temp., °F: Tubes Arrangement: <input type="checkbox"/> in-line <input type="checkbox"/> staggered											
25 Tube O.D., in.: Tube Min. Wall, in.: Tube Finned Length, in.: Tube Material:											
26 No. Tubes Wide / Row, #: No. of Flow Circuits, #: Transverse Spacing (ST), in.:											
27 No. of Rows Deep, #: Long. Spacing (SL), in.: No. of Bare Rows, #: No. of Finned Rows, #:											
28 Fin Type: <input type="checkbox"/> solid <input type="checkbox"/> segmented Fin Density, fin/in.: Fin Height, in.:											
29 Fin Segment (if applied), in.: Fin Thickness, in.: Fin Material:											
30 Heating Surface, ft ² : Component Full of Water, ft ³ : Normal Operation Water, ft ³ :											
31 Number of Modules Width (transversal): <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 Longitudinal Module Number:											
32 BOILER FEED WATER ANALYSIS						32 STEAM PURITY REQUIRED					
33 pH @ 25 °C						33					
34 CC µmho/cm						34 CC µmho/cm					
35 Na ppm						35 Na ppm					
36 Si ppm as SiO ₂						36 Si ppm as SiO ₂					
37 O ₂ ppm						37 Chloride ppm					
38 Fe ppm						38 Sulfate ppm					
39 Cu ppm						39 TOC ppm					
40 Chloride ppm											
41 Sulfate ppm											
42 TOC ppm											
43											
44 Remarks: ⁽¹⁾ Superheater, reheater, evaporator or economizer following by sequence number as needed. e.g. superheater 1.											
45											
46											
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48											
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



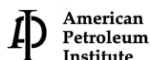
API STANDARD 534 HRSG HEADERS DATASHEET (USC Units)

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1	FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.			
2	<input type="checkbox"/> Headers Component # 1			
3	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
4	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
5	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
6				
7	<input type="checkbox"/> Headers Component # 2			
8	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
9	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
10	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
11				
12	<input type="checkbox"/> Headers Component # 3			
13	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
14	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
15	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
16				
17	<input type="checkbox"/> Headers Component # 4			
18	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
19	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
20	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
21				
22	<input type="checkbox"/> Headers Component # 5			
23	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
24	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
25	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
26				
27	<input type="checkbox"/> Headers Component # 6			
28	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
29	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
30	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
31				
32	<input type="checkbox"/> Headers Component # 7			
33	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
34	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
35	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
36				
37	<input type="checkbox"/> Headers Component # 8			
38	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
39	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
40	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
41				
42	<input type="checkbox"/> Headers Component # 9			
43	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
44	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
45	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
46				
47	<input type="checkbox"/> Headers Component # 10			
48	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
49	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
50	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
51				
52	Remarks:			
53				
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



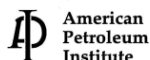
API STANDARD 534
HRSG HEADERS DATASHEET (USC UNITS)

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1	FILL IN HRSG GEOMETRY. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.			
2	<input type="checkbox"/> Headers Component # 11			
3	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
4	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
5	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
6				
7	<input type="checkbox"/> Headers Component # 12			
8	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
9	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
10	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
11				
12	<input type="checkbox"/> Headers Component # 13			
13	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
14	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
15	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
16				
17	<input type="checkbox"/> Headers Component # 14			
18	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
19	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
20	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
21				
22	<input type="checkbox"/> Headers Component # 15			
23	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
24	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
25	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
26				
27	<input type="checkbox"/> Headers Component # 16			
28	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
29	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
30	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
31				
32	<input type="checkbox"/> Headers Component # 17			
33	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
34	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
35	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
36				
37	<input type="checkbox"/> Headers Component # 18			
38	Name:	Design Pressure, psig :	Design Temperature, °F :	Corr Allow, in. :
39	Inlet Header:	OD, (nom.) :	Thickness, in. :	Material:
40	Outlet Header:	OD, (nom.) :	Thickness, in. :	Material:
41				
42	Remarks:			
43				
44				
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



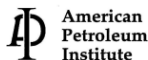
API STANDARD 534 HRSG CASING & INSULATION DATASHEET (USC UNITS)

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1	FILL IN HRSG CASING AND INSULATION DATA. USE MODULES AS REQUIRED PER HRSG DESIGN. MODULES ARRANGED IN GAS FLOW DIRECTION.									
2										
3	Casing & Insulation									
4	Design Parameters:	Ambient Temperature, °F:		Wind Speed, fps:		Cold Face Temperature, °F:				
5										
6		Inlet Duct	Inlet Duct	HRSG	HRSG	HRSG	HRSG	HRSG	HRSG	HRSG Last
7		Section 1	Section 2	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module
8	Components Comprised in									
9	Module									
10	Hot Flue Gas Temp. °F									
11	Casing Emmissivity									
12										
13	LINER									
14	Liner Thickness in.									
15	Liner Material									
16										
17	INSULATION									
18	Thickness Insulation in.									
19	Insulation Material									
20	Insulation Density lb/ft³									
21										
22	CASING									
23	Material									
24	Thickness in.									
25										
26	PAINTING									
27	Exterior Surface Prep.									
28	Exterior Coating									
29										
30	Remarks:									
31										
32										
33										
34										
35										
36										
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Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG DRUMS DATASHEET (USC UNITS)

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1	<input type="checkbox"/> HP Drum			
2	Design Pressure, psig :	Design Temperature, °F :	Volume, ft³ :	Material:
3	Drum Inside Dia., in. :	Drum Thickness, in. :	Head Type:	
4	Drum Length:	Seam to Seam (excluding heads), ft-in. :	Total Length (including heads), ft-in. :	
5	Manholes:	Qty., # :	Size, in. :	Type:
6	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
7	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , in. :	HHWL (Drum Center±), in. :	HWL (Drum Center±) in. :
8		LLLWL (Drum Center±) ⁽¹⁾ , in. :	LLWL (Drum Center±), in. :	LWL (Drum Center±) in. :
9		NWL (Drum Center±), in. :		
10	At HRSG Design Point	Retention Time (NWL to LLWL trip), min. :		
11	Drum Weight:	Empty, lb :	Normal Operation, lb :	
12				
13				
14	<input type="checkbox"/> IP Drum			
15	Design Pressure, psig :	Design Temperature, °F :	Volume, ft³ :	Material:
16	Drum Inside Dia., in. :	Drum Thickness, in. :	Head Type:	
17	Drum Length:	Seam to Seam Excluding Heads, ft-in. :	Total Length (including heads), ft-in. :	
18	Manholes:	Qty., # :	Size, in. :	Type:
19	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
20	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , in. :	HHWL (Drum Center±), in. :	HWL (Drum Center±) in. :
21		LLLWL (Drum Center±) ⁽¹⁾ , in. :	LLWL (Drum Center±), in. :	LWL (Drum Center±) in. :
22		NWL (Drum Center±), in. :		
23	At HRSG Design Point	Retention Time (NWL to LLWL trip), min. :		
24	Drum Weight:	Empty, lb :	Normal Operation, lb :	
25				
26				
27	<input type="checkbox"/> LP Drum			
28	Design Pressure, psig :	Design Temperature, °F :	Volume, ft³ :	Material:
29	Drum Inside Dia., in. :	Drum Thickness, in. :	Head Type:	
30	Drum Length:	Seam to Seam Excluding heads, ft-in. :	Total Length (including heads), ft-in. :	
31	Manholes:	Qty., # :	Size, in. :	Type:
32	Separators:	Primary Sep. Type:	Secondary Sep. Type:	Sep. Total Efficiency (%):
33	Drum Setting Level:	HHWL (Drum Center±) ⁽¹⁾ , in. :	HHWL (Drum Center±), in. :	HWL (Drum Center±) in. :
34		LLLWL (Drum Center±) ⁽¹⁾ , in. :	LLWL (Drum Center±), in. :	LWL (Drum Center±) in. :
35		NWL (Drum Center±), in. :		
36	At HRSG Design Point	Retention Time (NWL to LLWL trip), min. :		
37	Drum Weight:	Empty, lb :	Normal Operation, lb :	
38				
39				
40	Remarks: ⁽¹⁾ If applied			
41				
42				
43				
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API STANDARD 534 HRSG PERFORMANCE DATASHEET (USC UNITS)

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1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. USE COMPONENTS AS REQUIRED PER HRSG DESIGN. COMPONENTS ARRANGED IN GAS FLOW DIRECTION.

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

4 Manufacturer _____ Case Number (fill in operating cases as needed): _____

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow lb/h										
Pressure Drop in. H ₂ O										
Inlet Temperature °F										
Outlet Temperature °F										
Temperature Difference °F										
Specific Heat Btu/lb °F										
Heat Rejected Btu/h										
Heat Loss by Casing %										
Fouling Factor hr.ft ² .°F/Btu										
Supplemental Fuel, LHV Btu/lb										
Suppl. Fuel Firing Duty MMBtu/hr										
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow lb/h										
Inlet Pressure psig										
Outlet Pressure psig										
Pressure Drop in. H ₂ O										
Outlet Temperature °F										
Inlet Temperature °F										
Temperature Difference °F										
Heat Absorbed MMBtu/hr										
Fouling Factor hr.ft ² .°F/Btu										
Blowdown Water %										

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow lb/h										
Pressure Drop in. H ₂ O										
Inlet Temperature °F										
Outlet Temperature °F										
Temperature Difference °F										
Specific Heat Btu/lb °F										
Heat Rejected Btu/h										
Heat Loss by Casing %										
Fouling Factor hr.ft ² .°F/Btu										
Supplemental Fuel, LHV Btu/lb										
Suppl. Fuel Firing Duty MMBtu/hr										
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow lb/h										
Inlet Pressure psig										
Outlet Pressure psig										
Pressure Drop in. H ₂ O										
Outlet Temperature °F										
Inlet Temperature °F										
Temperature Difference °F										
Heat Absorbed MMBtu/hr										
Fouling Factor hr.ft ² .°F/Btu										
Blowdown Water %										

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534
HRSG PERFORMANCE DATASHEET (USC UNITS)

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1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. COMPONENTS ARRANGED IN GAS FLOW DIRECTION PER HRSG DESIGN..

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

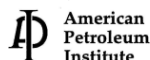
4 Manufacturer _____ Case Number (fill in operating cases as needed): _____

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	lb/h									
Pressure Drop	in. H ₂ O									
Inlet Temperature	°F									
Outlet Temperature	°F									
Temperature Difference	°F									
Specific Heat	Btu/lb °F									
Heat Rejected	Btu/h									
Heat Loss by Casing	%									
Fouling Factor	hr.ft ² .°F/Btu									
Supplemental Fuel, LHV	Btu/lb									
Suppl. Fuel Firing Duty	MMBtu/hr									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	lb/h									
Inlet Pressure	psig									
Outlet Pressure	psig									
Pressure Drop	in. H ₂ O									
Outlet Temperature	°F									
Inlet Temperature	°F									
Temperature Difference	°F									
Heat Absorbed	MMBtu/hr									
Fouling Factor	hr.ft ² .°F/Btu									
Blowdown Water	%									

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow	lb/h									
Pressure Drop	in. H ₂ O									
Inlet Temperature	°F									
Outlet Temperature	°F									
Temperature Difference	°F									
Specific Heat	Btu/lb °F									
Heat Rejected	Btu/h									
Heat Loss by Casing	%									
Fouling Factor	hr.ft ² .°F/Btu									
Supplemental Fuel, LHV	Btu/lb									
Suppl. Fuel Firing Duty	MMBtu/hr									
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow	lb/h									
Inlet Pressure	psig									
Outlet Pressure	psig									
Pressure Drop	in. H ₂ O									
Outlet Temperature	°F									
Inlet Temperature	°F									
Temperature Difference	°F									
Heat Absorbed	MMBtu/hr									
Fouling Factor	hr.ft ² .°F/Btu									
Blowdown Water	%									

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534 HRSG PERFORMANCE DATASHEET (USC UNITS)

REVISIONS	NUMBER	0	1	2	3	4
	DATE					
	ORIGINATOR					
	REVIEWED					
	APPROVED					

JOB NUMBER	PAGE	3	OF	3
PURCHASER				
LOCATION				
UNIT				
ITEM NUMBER				
SERVICE				
REQ NUMBER				

1 FILL IN HRSG PERFORMANCE PER EACH COMPONENT. COMPONENTS ARRANGED IN GAS FLOW DIRECTION PER HRSG DESIGN.

2 DESIGN, MANUFACTURE & TESTING SHALL CONFORM TO SPECIFICATION: ☐ API 534 ☐ Other

3 INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER ☒ BY PURCHASER OR MANUFACTURER

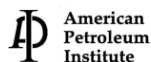
4 Manufacturer _____ Case Number (fill in operating cases as needed): _____

5 **PERFORMANCE DATA**

Component	#	1	2	3	4	5	6	7	8	9
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow lb/h										
Pressure Drop in. H ₂ O										
Inlet Temperature °F										
Outlet Temperature °F										
Temperature Difference °F										
Specific Heat Btu/lb °F										
Heat Rejected Btu/h										
Heat Loss by Casing %										
Fouling Factor hr.ft ² .°F/Btu										
Supplemental Fuel, LHV Btu/lb										
Suppl. Fuel Firing Duty MMBtu/hr										
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow lb/h										
Inlet Pressure psig										
Outlet Pressure psig										
Pressure Drop in. H ₂ O										
Outlet Temperature °F										
Inlet Temperature °F										
Temperature Difference °F										
Heat Absorbed MMBtu/hr										
Fouling Factor hr.ft ² .°F/Btu										
Blowdown Water %										

Component	#	10	11	12	13	14	15	16	17	18
Name:										
<input type="checkbox"/> GAS SIDE										
Gas Flow lb/h										
Pressure Drop in. H ₂ O										
Inlet Temperature °F										
Outlet Temperature °F										
Temperature Difference °F										
Specific Heat Btu/lb °F										
Heat Rejected Btu/h										
Heat Loss by Casing %										
Fouling Factor hr.ft ² .°F/Btu										
Supplemental Fuel, LHV Btu/lb										
Suppl. Fuel Firing Duty MMBtu/hr										
Flow arrangement										
<input type="checkbox"/> FLUID SIDE										
Fluid Flow lb/h										
Inlet Pressure psig										
Outlet Pressure psig										
Pressure Drop in. H ₂ O										
Outlet Temperature °F										
Inlet Temperature °F										
Temperature Difference °F										
Heat Absorbed MMBtu/hr										
Fouling Factor hr.ft ² .°F/Btu										
Blowdown Water %										

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications



API STANDARD 534
HRSG GENERAL REMARKS DATASHEET (USC UNITS)

REVISIONS	NUMBER	0	1	2	3	4
	DATE					
	ORIGINATOR					
	REVIEWED					
	APPROVED					

JOB NUMBER	PAGE	1	OF	1
PURCHASER				
LOCATION				
UNIT				
ITEM NUMBER				
SERVICE				
REQ NUMBER				

1	INFORMATION TO BE COMPLETED: <input type="radio"/> BY PURCHASER <input type="checkbox"/> BY MANUFACTURER <input checked="" type="checkbox"/> BY PURCHASER OR MANUFACTURER
2	GENERAL REMARKS
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Annex C (informative)

Design and Operational Considerations

NOTE The following provides design considerations and information supporting content to the normative sections of this standard. The applied numbering in this Annex and heading align with the normative sections.

C.1 Scope

Several designs of HRSGs exist:

- horizontal gas path with vertically arranged heating surface tubes;
- vertical gas path with horizontally arranged heating surface tubes;
- system with natural or forced circulation;
- system with or without steam drum;
- HRSG placed downstream combustion turbines or downstream other heat sources.

This standard specifies minimum requirements and provides guidance for the design, materials, fabrication, inspection, testing, preparation for shipment and erection of HRSGs downstream of combustion turbines in oil and gas application.

The requirements fit very well with horizontal gas path natural circulation HRSGs and, to a large extent, with vertical gas path natural circulation HRSGs. Vertical gas path HRSGs and forced circulation system may require additional requirement and or deviations to the existing requirement. Once Through Steam Generators (OTSG) as applied downstream gas turbines are not specifically covered in this standard. It is recognized that the design of an OTSG is significantly different from a drum type horizontal natural circulation or vertical natural circulation type HRSG, in particular, the evaporator system (no circulation, no steam drum), while at the same time there are also many similarities, e.g. heating surface, non-pressure parts. As such, this standard may be used in combination with additional requirement for OTSGs as well.

When using this standard, suppliers should be clear on deviations to the requirements of this standard, while purchasers should be aware of specific designs that may not fully fit in the described details.

C.2 Normative References

This standard cannot cover all the specifications and codes that may be required for local legislation. Where required the standard will provide specific references, and it may also indicate possible alternatives.

C.3 Terms, Definitions, and Abbreviations

Note that some definitions or acronyms may be specific for the HRSG industry and deviate from used abbreviations in e.g. fired heaters.

C.4 Proposals and Documentation

C.4.1 Performance Testing and Guarantees

A performance test should be performed to demonstrate compliance with the agreed performance guarantees.

Guarantee testing should be in accordance with ASME PTC 4.4. Typical performance guarantees include:

- steam temperature
- steam flow
- energy output
- efficiency
- emissions

The purchaser may allow a tolerance or uncertainty to the measured test results or may specify zero-tolerance. A zero tolerance generally result in the HRSG supplier making more accurate test measurements as this will reduce their risk on performance shortcoming.

Measurements are influence by instrument uncertainty and method of measurement. It may be agreed to execute performance test with plant instrument, dedicated test instruments or a mix. An uncertainty analysis will help determine the impact of individual instrument uncertainty variables.

The expected and guaranteed performance is based on boundary conditions outside the control of the HRSG supplier. Corrections will be applied for boundary conditions deviating from the specified boundary conditions.

Important boundary conditions for the HRSG are:

- gas turbine exhaust mass flow
- gas turbine exhaust composition
- gas turbine exhaust temperature.
- duct burner heat input
- boiler feed water inlet temperature (for all pressure levels)
- steam/water outlet pressure (for all pressure levels).

It is important to note that steam pressure is often mistaken as being a guarantee. From a mechanical standpoint, the supplier has to prove that the HRSG can withstand the design pressure and temperatures, but this is not related to the HRSG performance guarantees. The pressure is a result of the steam consuming system and as such an important boundary condition. Correction can be done with correction curves or computer modeling.

ASME PTC 4.4. provides procedures for testing and evaluation.

Depending on the scope of the project, a purchaser may decide to apply an overall performance guarantee in the case of a “turnkey project”, e.g. when a complete combined heat and power (CHP) or combined cycle (CC) package is sourced. The performance of the whole may be accepted as such without further measuring the individual components, e.g. GT, HRSG or steam turbine. This method is also called a “No Harm, No foul clause”. It is regularly applied by main contractors to save testing time and money.

C.5 Design Requirements - General

C.5.1 Noise

Noise requirements and limits can vary significantly depending on plant location, federal, state and local regulations.

The owner needs to be fully aware of and define the noise requirements for each major piece of equipment in the plant. The owner or their engineering contractor should prepare noise specifications based upon a plant noise model that divides the plant into several discrete sources.

Applicable noise requirements may be near field and or far field noise requirement. Long term exposure and peak exposure may play a role in the determination of the requirements.

Even if there are no clear local regulations the owner needs to consider the general health impact of noise emission.

C.5.2 Noise Control Design Options

The HRSG supplier is responsible for determining the appropriate noise mitigation design required to meet contractual guarantees. Some typical noise mitigation methods are:

- heavier HRSG casing plate to reduce both near and far field noise levels;
- stack or outlet duct silencing baffles to reduce far field noise levels;
- perforated liner plate and/or acoustic insulation;
- acoustic walls or shrouds when increased casing weight is not sufficient.

The owner may also elect to place the HRSG inside a building. This will minimize the HRSG contribution (except for the stack exit) to the far field noise at the plant boundary. Near field noise mitigation may still be required depending on contract requirements. Locating an HRSG inside a building does not relieve the HRSG supplier from meeting the contractual noise guarantees.

Exhaust flow perpendicular to tubes in HRSG coil bundles generates aero-acoustic tones due to vortex shedding that can excite acoustic modes of the surrounding duct. The resonant aero-acoustic sound can create an intense acoustic resonance. If acoustic resonance of enough power exists, the resonance can be damaging to tubes and can create an audible tone that is disturbing to plant personnel.

C.5.3 Computation Fluid Dynamics and Scale Modeling

CFD modeling and physical air flow models (scale models) can provide useful insight in the behavior of the flue gas flow and to some extent the behavior of duct burners and/or SCR systems.

Scale modeling will only provide possibility to review flow distribution while CFD can also provide combustion calculations, concentration calculations and heat transfer.

CFD is more commonly applied, however that does not rule out the possibilities of using scale modeling. For both methods, the purchaser should provide information related to the project specific gas turbine being used. Typical or supplier in-house information for a specific GT model may not include the impacts associated with project specific changes and may lead to erroneous results.

C.6 Design Requirements – Pressure Parts

C.6.1 Attemperator Design

Attemperators or desuperheaters exist in a wide range of designs. The selection of the attemperator has a big impact on the functionality and reliability of the steam temperature control. Depending on application and operating range either; interstage, final stage or both are used. However, the preferred location is interstage, i.e. in between two superheater sections. The HRSG supplier needs to provide sufficient operating details to the attemperator vendor in order to provide a proper design.

Attemperators in HRSGs generally make use of spray water for temperature control. For specific purposes heat exchanger type de-superheaters/attemperators may be used. If so, this needs to be clearly communicated.

Certain piston type attemperators may lead to over pressurizing of the upstream piping between non-return-valve and attemperator. In such a case, overpressure protection needs to be installed.

Steam quality (conductivity) may be impacted by the selected source of spray water.

C.6.2 Deaerator

In order to control oxygen concentrations in the boiler feed water a deaerator is used. A deaerator is generally a vessel in which oxygen is released from the water using thermal or mechanical energy. There is wide variety of design available in the market.

An incorrectly designed deaerator may lead to high oxygen concentrations in the boiler feed water, which will lead to an oxygen related corrosion mechanism. Functionality of the deaerator may also be impacted by water and steam distribution and or damaged internals.

Certain design of HRSGs may use the LP drum as boiler feed water source for a second or third pressure level. For such a design, it may be possible to also include a deaerator function to the LP drum. Such a requirement should be properly specified. This document does not provide any additional guidance on design of deaerators.

C.6.3 Water Chemistry

For selection of a water treatment program, the purchaser should carefully consider all aspects of design and operation and confer with water treatment specialist (internal or external)

When the boiler feedwater is softened, water quality and steam purity specifications should be in accordance with ASME Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle and Cogeneration Power Plants, Table 9b. Feed Water for HRSGs Using Softened Water.

The following HRSG design and operating conditions should be considered when selecting feed water and boiler water chemistry controls:

- cycling operation or base loaded;
- shutdown considerations;
- condenser design and operations, presence of auxiliary steam that maintains vacuum when offline;
- complexity of the HRSG, i.e. multiple steam drums, reheat, etc.;
- steam pressure level;
- deaerator integral to LP evaporator or stand alone;
- superheat and reheat sections;
- cascading blowdown from high pressure steam drum to medium or low-pressure steam drum;
- fast ramping;
- presence of duct burners;
- propensity towards flow accelerated corrosion (FAC);
- propensity towards phosphate hideout;
- metallurgy - all ferrous or mixed metallurgy system;
- attemperator water source.

Boiler feedwater and boiler water cation conductivity should be monitored continuously for HRSGs on all volatile treatment (oxidizing) (AVT(O)) and all volatile treatment (reducing) (AVT(R)), low level phosphate treatment (PT), or caustic treatment (CT). Boiler feedwater oxygen or oxygen reduction potential (ORP)

For CT programs, sodium content of steam should be monitored continuously. For other treatment programs, continuous monitoring of sodium content in steam is recommended however is not as critical.

C.7 Design Requirements—Non-pressure Parts

C.7.1 Operation and Design of Diverter Dampers/guillotine

Flue gas dampers in HRSGs are applied for two purposes:

- diverting the flue gas from HRSG to atmosphere (flue gas bypass stack), or
- closing the stack to conserve heat.

Dampers are not used for draft control like in fired heaters (API 560).

Due to the large volume flow from the gas turbine, the diverter damper and stack damper are generally much larger than the dampers used in fired heaters. It should be noted that in an HRSG, dampers are operated in a positive pressure environment and diverters are operated in a high velocity flue gas and as such, are subject to high mechanical forces.

Several designs are available with the selection depending on required functionality. Design may be single flap, multi louvre or bi-plane. Although the general advice is not to use diverters for control of heat input to the HRSG, it may be applied. If applying such an approach these operating conditions shall be properly included in the design of the HRSG. It does not only impact the selection of the actuator but also the design of the heating surfaces.

Actuator for diverter may be motor, pneumatic or hydraulic powered. The selection should consider all operating conditions of the diverter and the related forces, as well as the closing and opening time requirements.

C.8 Design Requirements--Supplemental Firing

C.8.1 Fresh Air Firing Considerations

Designing an HRSG for both TEG and FAF requires a lot of additional design consideration and additional equipment. FAF provides additional flexibility to the system, but also introduces additional risk. The impact of FAF should be carefully considered. FAF may impact the overall reliability and or maintenance.

If fresh air firing is applied, all related operating cases shall be included in the design of the HRSG. This includes design firing rates, and all turn down cases. It shall be noted that the behavior of the HRSG on FAF is different than TEG mode.

Also, the dynamic operation of switch over from TEG mode to FAF mode (and vice versa) should be considered.

The control and safeguarding systems need to be suitable for both TEG and FAF mode. All possible safety scenarios should be properly studied.

In case of fresh air firing and immediate switchover continuous pilots (of certain minimum duty) may be required to comply with purge credits. This shall be considered in case of designs with FAF.

Some supplemental firing systems required auxiliary air to the supplemental firing burners. This is not considered FAF.

C.8.2 Special Considerations for Various Fuels

The quality of fuel should be assured, through proper operation and conditioning of the fuel. Coking of fuel is highly impacted by olefins, condensate and the presence of unsaturated hydrocarbons. A coalescing filter in the fuel system can help mitigate coking.

Refinery fuel gas and hydrogen fuels may require separate firing elements and fuel handling systems, due to their unique firing characteristics.

Low supply pressure fuels provide additional challenges to the design of the fuel train and burners.

Fuels containing sulfur compounds, e.g. mercaptans, H₂S, etc., create significant corrosion problems in the fuel handling systems. Special considerations need to be taken to reduce these adverse corrosion effects. Sulfur containing fuel may also impact emission and post-combustion NO_x control catalyst selection.

Entrained liquids in the fuel gas should be avoided/prevented. Properly designed knock-out drums, coalescing filters and heat tracing help to reduce the risk of liquid entrainment.

The location of the knock-out drum should be as close as possible to fuel skid and it may be necessary to apply heat tracing on fuel lines. The use of stainless steel fuel lines is recommended since it will reduce the risk of corrosion on the fuel lines and corrosion products fouling valves (control a TSO) and fouling of duct burner elements.

Material selection for all fuel handling and transmission components should be evaluated for compatibility with the supplemental fuel.

Fuel bound nitrogen will impact NO_x emission. The impact on NO_x shall be properly reviewed.

When firing multiple fuels, evaluation is needed to determine if mixing the fuels is appropriate or if separate fuel valve trains and firing elements are needed.

C.9 Fabrication and Shop Assembly

No supplemental information provided.

C.10 Drains and Operation of Drains

Many damages have been reported in the industry due to insufficient draining capacity of superheater sections or incorrecction (automated) operation of such drains.

It should be noted that large amounts of condensate will collect in the superheater sections during a shut-down. Note that condensate will not only form during prolonged shutdown due to natural cooling down, but also during short stops due to the GT purge in the following restart.

If the condensate is not properly drained preferential flow may establish in the SH sections. Certain tubes may be cooled by flowing steam while others are stagnant due to presence of condensate blocking flow.

Drains should be sufficient in number and size and properly placed so that it can quickly release this condensate during a start of the HRSG to prevent this problem.

C.11 Inspection, Examination, and Testing

C.11.1 Inspection Witness Points

It is recommended that the purchaser witnesses the following tests. When witnessing is not possible/practical, test certificates should be submitted for review. These may include, however not limited to:

- pressure vessels: dimensional checks and hydrotest;
- valves: hydrotesting;
- instrumentation: review of reports on material, range, calibration and performance;
- pumps: hydrotesting and performance testing;
- agitator/mixer: performance test;
- membranes: visual and dimension checks, hydrotest;

- tanks: dimensional checks, water fill test check, vacuum box test (where applicable);
- piping: hydrotest;
- electrical: review of inspection reports.

C.11.2 Guidelines for PMI Testing

The following guidelines for PMI testing are provided.

- a) PMI testing should be applied to the following:
 - 1) alloy steel pressure containing casings and components;
 - 2) pressure vessels and piping systems subject to the process fluid or fuel gas (~~see Items 2, 3, 4~~);
 - 3) rotor shafts, and impellers in vital and essential services that are made of low-alloy steel, high alloy martensitic steel, ferritic or austenitic stainless steel, or nickel alloys.
- b) PMI of the Type 316 components limited to 10 % of the pipe, valves and fittings.
- c) When the primary seal flush is not Type 316, 100 % PMI should be performed on all components in the system.
- d) 100 % PMI of Type 316L materials.
- e) Inspection reports should be documenting the PMI examination for component, e.g. for piping, with line number and pipe specification including the spool or fabrication drawing, showing the locations of PMI tests by the shop/field fabricator or field fabricator.
- f) The PMI program output should include the compilation of auditable material traceability records and included as part of the manufacturing data book.

C.12 Instrumentation

C.12.1 Steam Drum High Level Trip

The steam drum may have a high-level trip depending on the design of the system.

NOTE High water level may lead to carry over of water and or salts to the steam system. Over time this may cause SH and or ST fouling or damage. A high-level trip may be applied. It is noted that such a trip would also lead to loss of steam production. Such a loss of steam production may have significant consequence and may not be acceptable. The purchaser needs to weigh the pros and cons of such a trip for the rest of its system. If other equipment is depending on the steam flow the impact of tripping. the boiler may be too large.

An additional option to reduce the steam drum level is use of intermittent blowdown. This blowdown could be activated on a high-level signal. Other measures may be a forced close of the BFW control valve, BFW isolation valve or trip of the BFW pumps.

C.12.2 NFPA Gas Turbine/Duct Burner Purge Credit

For gas turbine/HRSG units that experience frequent cycling, mechanical stresses to the hot pressure parts can be reduced significantly by allowing fast starts, with no turbine or duct burner ambient air furnace

purges. The NFPA 85 codes lists various arrangements for controls, valves, and sensing elements. Essentially the fuel supply to the gas turbine and the duct burner system incorporates "triple shutdown block valves", with gaseous fuels "double safety vent valves", with safety instrumentation used to verify that fuel has not leaked into the HRSG system. The status of the fuel shutdown valves, and safety instrumentation must be continuously monitored by the burner management system and the plant control system.

Annex D **(informative)**

Maintenance and Serviceability Considerations

D.1 Operating Cycle – Period of Time

The design of the HRSG should be such that shutdown periods are limited. When applied in refineries or chemicals plants the impact of an HRSG shutdown is significant. Often production processes will be disturbed.

Even if gas turbines may shutdown for short inspections, the inspection of an HRSG requires a much longer outage due to the need for equipment cool down and access to the HRSG confined spaces.

The purchaser and supplier should agree on the continuous operation period, however a period of continuous operation for a minimum of 24 months is considered a reasonable period between planned outages. From an equipment design perspective, a longer period is feasible.

Annex E (informative)

Purchaser's Checklist

This checklist (Table E.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 E.1---Checklist for Heat Recovery Steam Generators

Section	Requirement	Action / Selection	
4.2.3 d)	Completed noise data sheet with proposal	Yes	No
4.3.4 a)	Fireside CFD	Yes	No
4.4.1.1	Performance test performed	Yes	No
4.5.1 j)	Noise data sheet with the final records	Yes	No
5.3.1.1	Operating philosophy: cycling or base load		
5.3.1.3	GT ramp rates: specify		
6.1.1	Pressure design code		
6.1.3	Local or national regulation applicable to the supplied equipment		
6.1.15	Corrosion allowance for water / steam headers and piping		
6.2.8	Normative statements in Annex G – Tube Finning	Yes	No
	Annex G with modification	Yes	No
	Alternate specifications or requirements provided	Yes	No
6.4.12	Inspection nozzles: capped or flanged		
6.9.2	Water quality supplied to the deaerator		
6.9.3	Deaerator performance requirements		
6.11.5	Extent of vent and drain automation		
6.12.7	Safety relief valves: flanged or welded connection		
6.12.11	Requirement for relief valve redundancy	Yes	No
6.12.20	Safety relief valve testing on site – purchaser requirement	Yes	No
6.14.12	Shut-off valve bypass for downstream piping warmup	Yes	No
6.14.19	Vents and drains suitable for throttling	Yes	No
6.17.2	Water treatment standard and selected water treatment method.		
6.17.6	Water quality: makeup water, boiler feedwater, water to boiler drum (including condensate)		
6.17.11	Superheated steam sampling and boiler feedwater sampling connections are within scope of supply.	Yes	No
7.1.1	Structural and mechanical design code.		
7.2.9	Structural support in consideration of future ladders and platforms.	Yes	No
7.2.10	Stairs: Free standing or attached to HRSG structure.		

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

Section	Requirement	Action / Selection	
7.4.2	Minimum lifetime of expansion joints.		
7.5.2	Casing and insulation system design: Cold, warm or hot.		
7.8.5	Internal corrosion protection coatings required.	Yes	No
7.8.7	Finish paint material and color		
7.9.12	Perforated liner plates permitted.	Yes	No
7.10.4	Instrumentation dimensions (and expected location) in consideration of maintenance access and platform sizing.		
7.11.11	Stack sample port covers: Bolted or screwed.	Bolted	Screwed
7.11.17	Stack damper required	Yes	No
7.12.1	Fan specification (where applicable): API 673 or purchaser specification,		
7.13.1.1	Flue gas bypass system (divert damper) required.	Yes	No
7.13.1.9	Seal air system for the diverter system required.	Yes	No
7.13.2.4	Automatic back-up source of seal air required.	Yes	No
7.13.3.1	Preferred or required type of diverter drive system: a) electric, b) pneumatic, or c) hydraulic actuator		
7.14.1	Provision of a SCR by supplier with purchaser supplied emission control requirements.	Yes	No
7.14.2	Provision for future installation of NOx control system.	Yes	No
7.15.1	Provision of a CO/VOC control system by supplier with purchaser supplied emission control requirements.	Yes	No
7.15.2	Provision for future installation of CO/VOC control system.	Yes	No
7.16.1	Sootblowers included in the scope of supply	Yes	No
8.2.2	Burner elements in the duct burner to operate as a single group or multiple burner elements in operation.	Single	Multiple
8.2.9	Duct burner runners cleaning; either offline or online cleaning.	Offline	Online
8.3.10	A Class 1 or 2 igniter instead of Class 3	Yes	No
8.4.5	Design pressure and temperature of the fuel piping system upstream of the fuel train.		
8.4.7	Burner piping included in the supplier's scope of supply including instrumentation and components as identified on the burner fuel piping P&ID.	Yes	No
8.4.13	Multiple fuel trains required by the purchaser.	Yes	No
8.4.22 d)	Optional ignition gas train required	Yes	No
8.4.32	Duct burner turndown more than 10:1	Yes	No
8.4.34	TSO on-line testing required.	Yes	No
	Valve arrangement and method of testing		
10.1.2	Pre-inspection meetings before the start of fabrication.	Yes	No
10.3.7	PMI of identified components	Yes	No
10.4.1.4	Weight control procedures	a)	b)
10.10.7	Performance test is included or exclude from the scope of supply	Included	Excluded
11.1.2	Any local or national regulatory authority for the control and safeguarding system; if so, specify.		
11.1.4	Requirements in addition those specified in NFPA 85 and this standard; if so specify		
11.4.2.1 a) 1)	BFW control valve redundancy	Yes	No
11.4.2.1 b) 3)	Spray water control valve redundancy	Yes	No

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

Section	Requirement	Action / Selection	
11.4.2.1 c) 1)	Continuous blowdown degree of automation; specify		
11.4.2.1 c) 4)	Continuous blowdown control setpoint; specify conductivity or steam production.		
11.4.2.1 d) 1)	Steam pressure control including startup vent control valve.	Yes	No
11.4.2.1 d) 2)	Steam bypass valve.	Yes	No
11.4.2.1 f) 1)	Intermediate blowdown control degree of automation; specify		
11.4.2.1 f) 2)	Intermediate blowdown control setpoint; specify high-level discharge control or water quality.		
11.4.3.1 a)	Economizer bypass	Yes	No
11.4.3.1 b)	Economizer inlet temperature control	Yes	No
11.4.3.1 c)	Economizer outlet temperature control bypass	Yes	No
11.4.3.1 d)	Superheater dripleg drain valves	Yes	No
11.4.3.1 e)	Flue gas bypass control	Yes	No
11.4.3.1 f)	Stack damper control	Yes	No
11.4.3.1 g)	SCR control in accordance with API 536	Yes	No
11.5.13	BMS area classification; hazardous or non-hazardous		
12.1.1	Extent of skidding, boxing, crating, or coating for export shipment; specify		
12.1.2	Long-term storage requirements; specify		
13.12	Field erection weight and crane limitations; specify		

Annex F (informative)

Terminal Points and Scope List

F.1 Terminal Points.

Terminal points may differ strongly by project. Details of terminal point to be agreed between purchaser and supplier.

Table F.1---Typical Terminal List

NOTE Not an exhaustive list.

Terminal Point	Description	Required Yes / No	Terminal Type / Rating
Turbine exhaust gas	Starting at gas turbine and not including outlet flange		
Steam	Final steam stop valve		
Boiler feedwater	Main BFW isolation valve upstream of HRSG		
Continuous and intermittent blowdown	Connection to blowdown tank		
Blowdown tank	Connection to sewer		
Fuel gas	Inlet of the block valve upstream of the fuel gas control and IPF skid		
Drains	Connection at the blowdown tank		
Instrument air	Block valve at the common supply line		
Plant air	Block valve at the common supply line		
Nitrogen	Block valve at the common supply line		
Electrical	Terminal box of HV motor		
Electrical	Terminal box of LV motor		
Electrical	Safety switches of MOV		
Electrical	Junction box of ignition control panel		
Electrical	Connection box of lighting fixture		

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

Terminal Point	Description	Required Yes / No	Terminal Type / Rating
Electrical	Connection box of power receptacle		
Electrical	Earth pit		
NOTE 1.			
NOTE 2 .			

F.2 Scope List

Scope list may differ strongly by project. Details of scope list to be agreed between purchaser and supplier.

Table F.2---Scope List

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
I	Pressure Parts				
1	Superheater HP (IP/LP, if applicable)				
2	Evaporator HP (IP/LP, if applicable)				
3	Economizer HP (IP/LP, if applicable)				
4	Attemperator (spray type de-superheater/ attemperator HP)				
5	Steam drum HP (IP/LP, if applicable)				
6	Safety valves with silencer (according to ASME-I requirement)				
7	Start-up vent valve				
8	Chemical dosing				
9	All headers				
10	Pressure safety relief valves				
11	Insulation of steam drum and drum heads				
II	Condensate-/Feed Water System				
1	Deaerator (external)				
2	Deaerator insulation				
3	Feedwater pumps HP (2 x operating) with electrical motor driver				
4	Feedwater pumps HP (1 x stand-by) with electrical motor driver				
5	Feedwater pumps HP with backpressure type steam turbine driver				
6	Feedwater control valve station				
7	Start-up control valve, if required				
8	HRSG filling system (with 2 x 100 % fill. pumps), if required				
9	External deaerator storage tank				
10	Feedwater stop valve				

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			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
III	Flash / Blow-down System)				
1	Pressurized flash tank, if applicable				
2	Atmospheric blowdown tank				
3	Blowdown cooler				
4	Personnel protection for tanks				
IV	Chemical dosing				
1	One oxygen scavenger solution preparation tank				
2	2 x 100 % oxygen scavenger metering pumps				
3	One oxygen scavenger metering tank				
4	3 x 50 % oxygen Scavenger dosing pumps				
5	One phosphate solution preparation tank				
6	2 x 100 % phosphate metering pumps				
7	One phosphate metering tank				
8	3 x 50 % phosphate dosing pumps				
9	One amine solution preparation tank				
10	2 x 100 % amine metering pumps				
11	One amine metering tank				
12	3 x 50 % amine dosing pumps				
13	Oxygen scavenger piping from dosing tank to deaerator storage tank				
14	Phosphate piping from dosing tanks to deaerator storage tank				
15	Amine piping from dosing tank to steam drum				
V	Supplementary Firing Installation				
1	Duct burner				
2	Burner elements for NG (and/or dual fuel gas, if applicable)				
3	Local start/ stop panel (If required)				
4	Burner management system (BMS)				
5	UV flame scanners				
6	Ignition system				
7	Fuel piping and wiring between fuel control skid and burners				
8	Fuel valve and control skid				
9	Fuel pressure reducing station, if required				

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			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
10	Fuel piping to skid				
11	Cooling air fans				
12	CFD modelling (including burner model)				
13	Flow correction device (e.g. perforated plate) upstream the duct burner				
VI	Forced draft (FD) air system (if required)				
1	FD fan				
2	Electrical drive				
3	Inlet silencer				
4	Inlet vane damper				
5	Inlet vane control				
6	Expansion joints				
7	Inlet ducting				
8	Transition duct				
VII	Ducting and Casing				
1	Expansion joint at GT outlet to diverter damper				
2	Ducting from Expansion joint at GT outlet to diverter damper				
3	Ducting from diverter damper inlet to boiler				
4	Ducting and casing of pressure parts				
5	Expansion joints at HRSG inlet				
6	Boiler outlet duct to stack				
7	Deflecting baffles, if required				
8	Internal insulation with stainless steel liner				
9	External insulation, for personal protection				
VIII	Exhaust System				
1	Bypass stack up to HOLD (Note: Project / EPC Action) m (ft) above ground level including internally cladding of stainless steel				
2	Main stack, up to HOLD (Note: Project / EPC Action) m (ft) above ground level				
3	Main stack and bypass stack lightning protection system				
4	Support structure bypass stack				
5	Support structure main stack				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
6	Expansion joint inlet bypass stack				
7	Acid resisting inner liner of the top 9 m (30 ft) of main and bypass stack, if required				
8	Helical strakes or suitable wind spoiler for main stack				
9	Expansion joint inlet main stack				
10	Continuous emission monitoring system (CEMS)				
IX	Flue Gas Damper				
1	Diverter damper				
2	Bypass damper seal air system				
3	Boiler inlet damper				
4	F.A. outlet damper seal air system				
5	Stack damper, if applicable				
6	Actuator				
7	Guillotine damper				
8	Blanking plate				
X	Flue Gas Silencers				
1	Main stack silencer, if required				
2	Bypass stack silencer, if required				
XI	Piping				
1	Internal piping between tube banks HRSG				
2	Piping between makeup pumps terminal point and Deaerator (inside the battery limits)				
3	Piping between deaerator and BFW pumps (inside the battery limits)				
4	FW piping from BFW pumps to FW gate valve (inside the battery limits)				
5	Piping from economizer inlet to FW pumps outlet (inside the battery limits)				
6	Piping for safety valves				
7	Drain/blow down piping to flash/blow down tanks				
8	Main steam piping up to motorized steam valve				
9	FW pump low load return pipes to deaerator				
10	HP steam start up vent lines				
11	Spray water (de-superheater/attenuator) piping				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
12	Piping between boiler and flash tank (if applicable)				
13	Piping between boiler and blowdown tank				
14	Compressed air piping, if required				
	- utility air piping within HRSG area				
	- instrument air piping within HRSG area				
15	Piping lines of N ₂ blanking system for each HRSG				
16	Insulation for the appropriate HRSG piping				
17	Piping supports and hangers				
18	Main steam stop valve				
19	Superheater start-up vent valves				
20	Superheater drain valve				
21	Steam drum vent valve				
22	Piping between tank and sewer				
23	Piping from deaerator to filling pump (if applicable)				
24	Piping of service water system				
25	Piping of fuel gas				
XII	Steel Structure				
1	Steel structure for HRSG				
2	Walkways and platforms				
3	HRSG house				
	- Type: semi enclosure (roof canopy at top of the drum) (Note: Project / EPC Action, TBC by Project)				
4	Rack structure				
5	Deaerator and storage tank structure support				
XIII	Construction				
1	Erection manuals				
2	Erection drawings				
3	Field erection				
4	Field erection labour				
5	Foundation work				
6	Weather protections for sensitive equipment				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
7	Assembly, setting and alignment of equipment				
8	Foundation loads				
9	Civil work				
10	Anchor bolts and base plate				
11	Anchor bolt design				
12	Interconnection bridge between HRSGs				
13	Lifting beam for modules				
XIV	Soot Blowers				
1	Soot-blowers				
2	Control panel				
3	Platforms and stairs				
4	Steam piping up to soot-blowers				
XV	General				
1	Final painting (materials and works at site)				
2	Spare parts for commissioning				
3	Spare parts for 2 years				
4	Transport to site				
5	Instruction / operation manuals				
6	Steam tracing, if required				
7	Training during commissioning				
8	Field erection labour				
9	Commissioning				
10	Commissioning supervisor				
11	Sampling system				
12	First fill of lubricants				
13	Compressed air system				
14	HRSG performance test supervisor				
15	HRSG performance test instruments				
16	Hoist and monorails				
17	Pre-commissioning, commissioning and start-up	I			
18	Lifting beam				
19	Hydro testing at shop and drying (drying procedure shall be confirmed by purchaser)				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
XVI	Instrumentation				
1	Instrument process connections				
2	In-line flow elements				
3	Thermowells				
4	Control valves (foundation field bus positioner)				
5	HP/LP pressure reducing station (1 x100 %)				
6	Electrically operated on / off valves				
7	Pneumatic operated on / off valves				
8	Foundation field bus transmitters				
9	Instrument wiring and tubing				
10	Discrete detectors (pressure switch)				
11	Local indicators				
12	Impulse resp. measurement pipes				
13	Analyzers for steam and water sampling system (online).				
14	Online analysers for flue gas (NOx, SOx, CO and UHC)				
15	Process control system (PCS)				
16	Distributed control system (DCS)				
17	Emergency shut-down system (ESD)				
18	Burner management system (BMS)				
19	Local instrument Panels, if required				
20	Remote control panels				
21	Electrical instrument heat tracing, if required				
22	Local terminal boxes, reape. Junction boxes				
23	IP55 protection for terminal boxes				
24	I&C cables from field instrument up to general junction boxes located in ground level of each HRSG				
25	I&C cable for General Junction box to control room				
26	Cable tray, ladder and accessories in HRSG battery limit				
27	Cable tray, ladder and acc. from General Junction boxes up to control room				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
28	Mechanical instrument Hook up, including instrument process lines				
29	Tag plates				
30	Interlock between steam turbine pump driver control and main DCS.				
XVII	Electrical				
1	Medium voltage switchgear for motor of feedwater pumps				
2	L.V. MCC panel for HRSGs				
3	Local distribution panel for normal & emergency application				
4	D.C. Distribution panel (If any)				
5	M.V. motors for F.W. Pumps				
6	L.V. Motors for L.V. application				
7	Integrated type motor operated valves				
8	Lighting fittings and accessories on HRSG platform and structure				
9	Aircraft warning Light for main and bypass stack				
10	Maintenance sockets (single phase and three phase) within HRSG battery limit				
11	Lightning protection system and secondary grounding materials within HRSG battery limit				
12	Power cable of L.V. electrical equipment for HRSG				
13	Cable tray, ladder and accessories in HRSG battery limit				
14	Cable glands and adapter				
15	Conduit and fittings				
16	Junction box and local control box (push-button station)				
17	Cable accessories (cable shoe, tie, adhesive)				
18	Step down transformer 20/0.4 Kv for L.V. application				
19	Medium voltage switchgear for Motor of Feed water pumps				
20	M.V. cable for M.V. application (M.V. motors and from switchgear to transformer)				
21	Cathodic protection system				

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

			Required	Provide by:	Erected By:
Item	Scope List (per HRSG)	Remark	Yes/No	Supplier (S) Contractor (C)	Supplier (S) Contractor (C)
22	Fire alarm system				
23	Paging and communication system				
24	Primary grounding materials (earthing mesh)				
25	Secondary grounding materials				
26	UPS for BMS and control system application				

Annex G (informative)

Requirements for Application and Testing of High-frequency Resistance Welded Finned Tubes

G.1 Scope

NOTE 1 This Annex contains recommended requirements for dimensions, tolerances and testing of high-frequency electric resistance welded finned tubes for use in boiler, HRSG and other fired heat transfer equipment applications.

NOTE 2 Where the word “tube” is applied, material normally designated as “pipe” is also included.

NOTE 3 Tube and fin materials may be carbon, ferritic alloy or austenitic alloy steel and need not be matching materials.

NOTE 4 When this Annex is specified for normative use by the purchaser, suppliers should identify any exceptions or proposed alternative in their proposal.

G.2 Bare Tube Requirements

G.2.1 Outside Diameter

Deviations of outside diameter to the nominal tube diameter shall not exceed ± 0.5 mm (± 0.02 in.) or the applicable bare tube specification tolerance, whichever is less.

G.2.2 Straightness

Tubes shall be straight with a maximum deviation of 2.5 mm (0.1 in.) for every 3 m (10 ft) of tube length, and maximum 6 mm over the total length.

G.2.3 Tube Outside Surface

G.2.3.1 Outside surface roughness shall not exceed 12.5 μ m (500 μ in.).

G.2.3.2 Tubes for finning shall be free of pits, dents, laminations, gouges or other surface defects exceeding 0.3 mm (0.01 in.)

G.2.3.2 Scale or rust shall not infringe into specified minimum tube wall thickness.

G.3 Requirements for Finning

G.3.1 Fin Thickness

The thickness of the fins after welding to the tube shall be in accordance with tolerances specified in Table G.1

Table G.1--Fin Thickness Tolerance

Specified Fin Thickness		Tolerance	
mm	in.	± mm	± in.
0.81 – 1.00	(0.032 – 0.039)	0.10	0.004
1.01 – 1.60	(0.040 – 0.063)	0.13	0.005
1.61 – 2.00	(0.064 – 0.079)	0.15	0.006

G.3.2 Fin Height

G.3.2.1 Fin height after welding, measured perpendicular to the tube surface, shall be as specified with the following tolerance:

- fin height less than or equal to 20 mm (0.79 in.): ±0.8 mm (0.03 in.)
- fin height larger than 20 mm (0.79 in.): ±1.0 mm (0.04 in.)

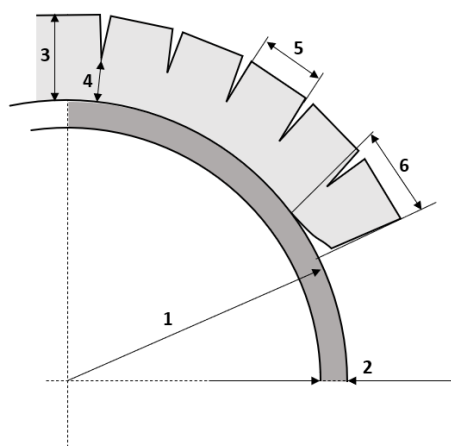


Figure G.1--Fin Details

Key

- 1 tube radius
- 2 tube wall thickness
- 3 fin height
- 4 segment fin root
- 5 segment width
- 6 unwelded end of finning

G.3.3 Fin Density

The number of fins per unit length of tube shall be as specified, ± 2 percent, measured over at least 300 mm (12 in.) of welded fins. See Figure G.2.

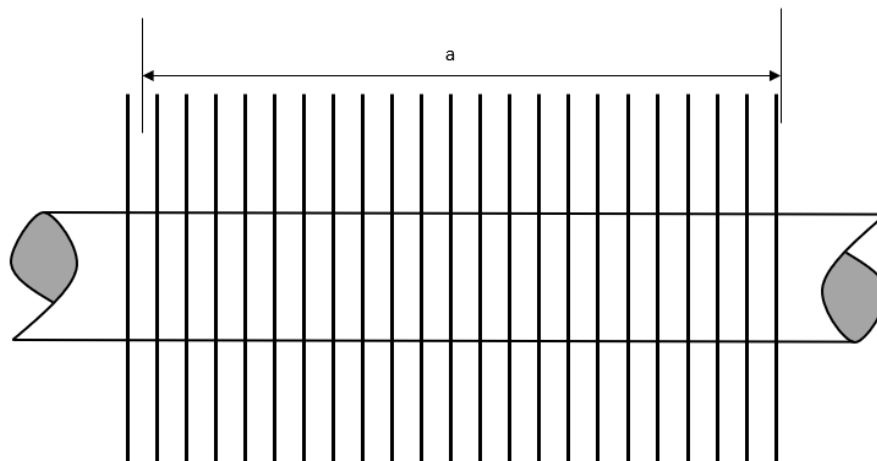


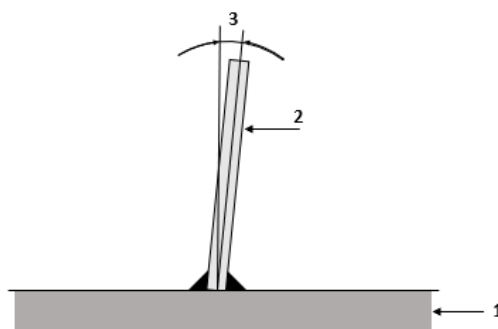
Figure G.2--Fin Density

Notes

a measured number of fins over minimum 300 mm (12 in.)

G.3.4 Fin Inclination

The fin shall be welded 90 degrees to the tube surface. Inclination of the fin shall not exceed 5 degrees from the vertical for fin heights ≤ 20 mm (0.79 in) and 10 degrees from the vertical for fin heights > 20 mm (0.79 in.). See Figure G.3.



Key

- 1 tube wall
- 2 fin
- 3 inclination

Figure G.3--Fin Inclination

G.3.5 Fin Corrugation

The total width of corrugation, excluding any weld expulsion, shall not exceed three times the specified fin thickness. See Figure G.4

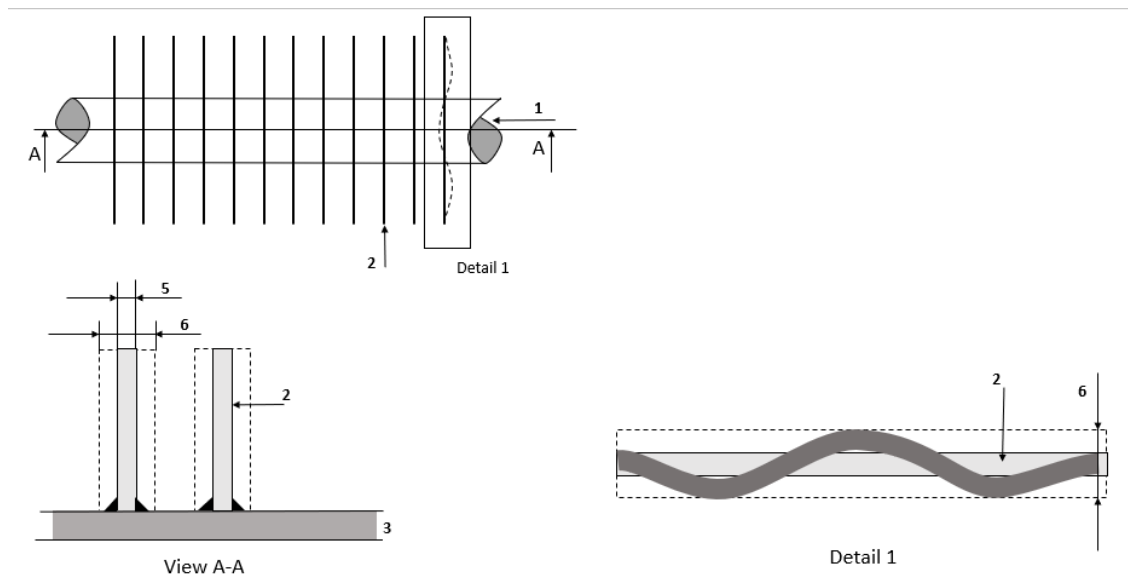


Figure G.4--Fin Corrugation

Key

- 1 tube
- 2 fin
- 3 tube wall
- 4 tube wall thickness
- 5 fin thickness, t
- 6 maximum corrugation, max. = $3 t$

G.3.6 Serrated Fins

G.3.6.1 Segment width shall be as specified with a maximum tolerance of ± 0.25 mm (± 0.010 in.), excluding burrs.

G.3.6.2 The segment cut shall be till a point 6 mm (0.25 in.) ± 1.7 mm from the tube surface, unless otherwise specified.

G.3.6.3 The degree of twist of individual segments shall be limited to an apparent thickness of less than 1.75 times the specified fin thickness. See Figure 5.

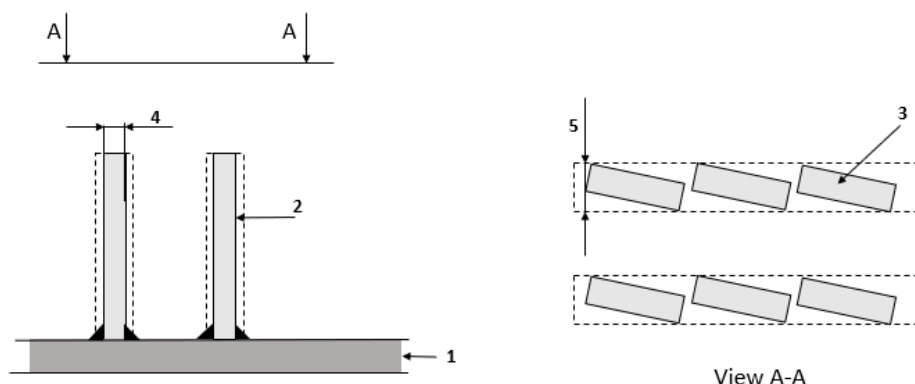


Figure G.5--Serrated Fin Apparent Thickness

Key

- 1 tube wall
- 2 fin
- 3 fin segment
- 4 maximum serrated fin apparent thickness, max = $1.75 t$

G.4 Requirements for Finned Tubes

G.4.1 Straightness

G.4.1.1 The finished fin tube shall be straight with a maximum deviation of 5.0 mm (0.20 in.) for every 3 m (10 ft) of tube length. A straight (metal) ruler shall be placed on the fins to determine the most extreme deviation.

G.4.1.2 For tubes shorter than 3 m (10 ft) the deviation shall be reduced proportionally to the length of the tube. See Figure 6.

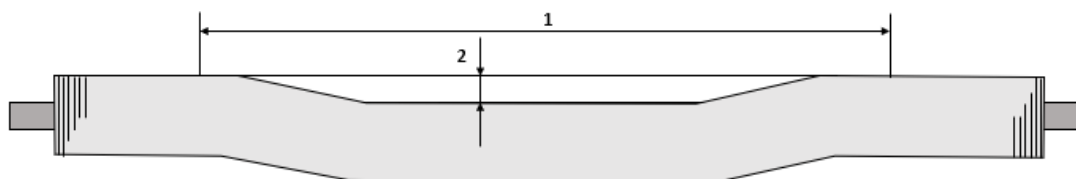


Figure G.6--Straight Length After Finning.

Key

- 1 length of 3 m (10 ft)
- 2 maximum deviation, 5 mm (0.20 in.)

G.4.2 Bare Tube End

G.4.2.1 The bare end section shall be as specified with a tolerance of ± 6 mm (0.25 in.) or one fin spacing, whichever is the greater.

G.4.2.2 Tube end dimensions (including ovality) after finning shall comply with the specified bare tube dimensions.

G.4.2.3 The finished finned tube overall length shall comply with the specified bare tube length and tolerance.

G.5 Manufacturing and Weld Requirements

G.5.1 The attachment of the fin to the tube shall be by the high frequency electric resistance welding process (250 kHz minimum).

G.5.2 The high frequency electric resistance fin welding process shall not change the tube wall or OD beyond the tube specification acceptable limits and adds only the weight of the fin material to the finned tube.

G.5.3 The average width of the weld bond between the fin and the tube shall be a minimum of 90 percent.

G.5.4 Interruptions in welding shall:

- not exceed 2.5 percent of the finned length on any one tube;
- not exceed five consecutive fin wraps, and;
- not occur within 6 in. (150 mm) of another interruption or the end of a finned section.

G.5.5 Unwelded lengths at the end of fin sections shall be trimmed back to the fin-to-tube weld. Unwelded fin length shall not exceed 12.5 mm ($\frac{1}{2}$ in.). See Figure G.1

G.5.6 The heat affected zone in the tube wall and fin adjacent to the fin-to-tube weld shall be of very low penetration and shall only result in superficial changes in the tube and fin material properties.

G.6 Inspection and Testing

G.6.1 Weld Bond

G.6.1.1 During production, the weld bond on every fifth tube shall be tested by removing one wrap of fin from the trailing end of the tube. The fractured surface of the fin-to-tube weld shall be visually inspected, and the arithmetic average width of the weld bond as evidenced by the white metal exposed shall be no less than 90 percent of the measured fin thickness.

G.6.1.2 If the arithmetic average width of weld bond is less than 90 percent, the weld bond of the previously finned tube shall be checked, (back to the previously inspected fifth tube, if necessary), until weld bond that averages 90 percent is found.

G.6.1.3 In the event of disagreement on the visual inspection, a tensile test of the fin-to-tube weld on a representative sample yielding the minimum average values based on the measured fin thickness, shall be considered evidence of an acceptable weld.

G.6.2 Dimensional Inspections

G.6.2.1 Inspections of tube and fin dimensions shall be performed on the first piece and at regular intervals during manufacturing.

G.6.2.2 Inspection intervals shall be as follows unless otherwise agreed between purchaser and supplier:

- overall tube length: every 2nd hour;
- fin thickness: every 2nd hour, then every 4th hour;
- fin height: every 2nd hour;
- fin pitch: every 2nd hour;
- bare "A" end: every 2nd hour;
- bare "C" end: every 2nd hour;
- fin length: every 2nd hour;
- fin inclination: 2nd hour, then every 4th hour;
- weld bond: every 5th tube;
- degree of twist: first piece only;
- fin corrugation: every 2nd hour (solid fin only);
- serration/uncut base: after serrated cutter change;
- serration/width: after serrated cutter change.

G.6.3 Fin Damage

G.6.3.1 Fin damage due to material handling shall not exceed 2 % of total peripheral area.

G.6.3.2 Individual fin damage areas shall not exceed 0.03 m² (6 in.²).

NOTE Fin damage is defined as fins bent or crushed to the extent they are in contact with adjacent fins.

G.7 Labelling and Packing

G.7.1 Labelling

G.7.1.1 Weather resistant labels shall be applied to each finned tube.

G.7.1.2 Labels shall contain the following information:

- job number,

- customer name,
- customer purchase order number;
- finning division item number;
- customer mark number;
- finning division name, and heat code (for traceability to heat number); and,
- any additional information as specified by purchaser.

G.7.2 Packing

- G.7.2.1** Tubes shall be packed in wooden crates with wooden saddle to support tubes.
- G.7.2.2** Tubes shall be secured using steel banding at maximum spacing intervals of 3 m (10 ft.)
- G.7.2.3** Fins of individual tubes shall not touch each other.
- G.7.2.4** Tubes shall be capped.
- G.7.2.5** The tubes shall be coated after finning as per purchaser specified. When no coating is specified, the finning company shall propose suitable coating.