

Heat Recovery Steam Generators for Combustion Turbine Exhaust Applications

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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 units are included in brackets for information.

A bullet (●) at the beginning of a clause or subclause 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 E) 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 (HRSGs) downstream of combustion turbines in oil and gas application.

The scope of this standard covers water tube drum type HRSG with typical operating conditions up to 14000 kPa(g) (2030 psig) 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 and Petrochemical Services*

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

API Standard 607, *Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats*

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

API Standard 6FA, *Standard for Fire Test of Valves*

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

ANSI S1.4-1983 (R2006) ¹, *Specifications for Sound Level Meters*

ANSI/ISA 75 ² (all parts), *Control Valve Standards*

ASME Boiler and Pressure Vessel Code (BPVC) ³, *Section I, Rules for Construction of Power Boilers*

ASME BPVC, *Section VIII, Division 1, Rules for Construction of Pressure Vessels*

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

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

ASME CRTD-81, *Consensus on Operating Practices for the Sampling and Monitoring of Feedwater 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 National Standards Institute, 1899 L Street, NW, Washington, DC 20036, www.ansi.org.

² International Society of Automation, 3252 S. Miami Blvd., #102, Durham, NC 27703, www.isa.org.

³ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

ASTM A123/A123M ⁴, *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 A153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

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 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 10204 ⁵, *Metallic Products—Types of Inspection Documents*

IAPWS IF97 ⁶, *Industrial Formulation for the Thermodynamic Properties of Water and Steam*

IEC 60534 (all parts) ⁷, *Industrial-process control valves*

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

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

ISO 1461 ⁸, *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*

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

ISO 10684, *Fasteners—Hot dip galvanized coatings*

NB-27 ⁹, *A Guide for Blowoff Vessels*, 2012 Edition

⁴ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

⁵ European Committee for Standardization, Rue de la Science 23, B-1040, Brussels, Belgium, www.cen.eu.

⁶ International Association for the Properties of Water and Steam, www.iapws.org.

⁷ International Electrotechnical Commission, 3 Rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁸ International Organization for Standardization, Chemin de Blandonnet 8, CP 401 - 1214 Vernier, Geneva, Switzerland, www.iso.org.

⁹ National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229, www.nationalboard.org.

NFPA 85 ¹⁰, *Boiler and Combustion Systems Hazards Code*

SSPC SP 6/NACE No. 3 ¹¹, *Joint Surface Preparation Standard: Commercial Blast Cleaning*

UNS N06625 ¹², *Cable, Safety, Nickel Alloy, Corrosion Resistant*

UNS R30006, *Non-Galling High Temp Alloy*

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 multidisciplined 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 an HRSG. These definitions are intended to build upon the typical definitions of the purchaser and the 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 multidisciplined 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 subcontracted work by them.

3.1.2

owner

purchaser

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

NOTE The owner or the 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 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, subcomponents, or services for the project work.

NOTE Vendors, 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 subcomponents, such as burners, fans, dampers, instrumentation,

¹⁰ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, 02169, www.nfpa.org.

¹¹ Association for Materials Protection and Performance, 15835 Park Ten Place, Houston, Texas 77084, www.ampp.org.

¹² SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

pipe hangers, castings, refractory, pipe/tubes, and fittings, etc. A vendor may also provide specialty engineering services, such as finite element analysis. 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

Man-made vitreous fiber 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

attenuator

A piece of equipment to control the steam outlet temperature to a maximum temperature. It is often also referred to as “desuperheater.”

3.2.4

augmenting air

Supplemental air typically introduced at the duct burner element.

NOTE 1 Used to increase the turbine exhaust gas (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 with 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 TEG 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.

NOTE Excess air is expressed as a percentage.

3.2.16**flame impingement**

Any visible part of the flame or any part of the flame envelope 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 (GT) 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 for 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 (LHV) 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 slides 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 HHV 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 heating value****LHV****net heating value**

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

3.2.30**pegging steam**

Steam used to enable degasification of O₂ and CO₂ in the deaerator. It is also used to increase the deaerator/feedwater tank pressure if required for operation.

3.2.31**pressure design code**

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

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

3.2.32**pressure drop**

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

3.2.33**pressure relief valve**

Valve designed to open and relieve excess pressure and to reclose and prevent the further flow of fluid after normal conditions have been restored.

NOTE Other terms used for pressure relief valve include “pressure safety valve,” “relief valve,” “safety valve,” and “safety relief valve.”

3.2.34**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.

3.2.35**stack**

Vertical conduit used to discharge flue gas to the atmosphere.

3.2.36**startup vent valve**

A controlled vent on the steam system, typically used during startup to control the steam pressure.

NOTE In industry, this valve is also called “sky vent.”

3.2.37**structural design code**

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

EXAMPLE International Building Code.

3.2.38**structural welding code**

Recognized structural welding code specified or agreed by the purchaser.

EXAMPLE AWS D1.1/D1.1M.

3.2.39**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.

3.2.40**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.

3.2.41**total pressure**

Static plus dynamic pressure.

3.2.42**total temperature**

Static temperature plus kinetic impact.

NOTE Also called "stagnation temperature."

3.2.43**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.

3.2.44**velocity**

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

NOTE 1 For GT exhaust, typically three velocity directions are defined as follows:

- 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 2 As an alternative, a GT supplier may provide velocity expressed in x, y, and z 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
CFD	computational fluid dynamics
CHP	combined heat and power
CT	caustic treatment
DCS	distributed control system
FAC	flow-accelerated corrosion
FAF	fresh air firing
FAT	factory acceptance test
GT	gas turbine
HAZOP	hazard and operability study
HHV	higher heating value
HRSG	heat recovery steam generator
IPF	instrumented protective functions
ITP	inspection and test plan
LHV	lower heating value
MCR	maximum continuous rating
MP	magnetic particle testing
NDE	nondestructive examination
NDT	nondestructive testing
NWL	normal water level
ORP	oxidation reduction potential
P&ID	piping and instrumentation diagram
PMI	positive material identification
PQR	procedure qualification record
PT	phosphate treatment
RT	radiographic testing

SCR	selective catalytic reduction
SI	International System of Units
SIS	safety instrumented system
SSOV	safety shutoff valve
TEG	turbine exhaust gas
TSOV	tight shutoff valve
USC	United States customary
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 datasheet 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.

NOTE 3 The purchaser should refer to the terminal points and scope list in Annex F 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 GT ramp rates shall be specified by the purchaser. This includes any fast startup requirement for cold, warm, and hot startup.

4.1.7 The purchaser shall specify startup philosophy with respect to using steam bypass and/or startup vent valve.

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

4.1.9 The purchaser shall specify firing margin in sizing the duct burner if any (e.g. overfiring capacity, fuel variations, etc.).

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

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

4.1.12 The purchaser shall provide a list of approved subsuppliers, fabricators, or component vendors.

4.1.13 The purchaser shall specify the hazardous area classification.

4.1.14 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).

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 the purchaser.

4.2.3 The supplier's proposals shall include the following:

- 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 and subcontractors/subsuppliers;
- h) guarantees and warranties;
- i) piping and instrumentation diagram (P&ID);

- j) operation and maintenance manual;
- k) safety life cycle 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 be 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 nondestructive 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 be 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 computational fluid dynamics (CFD) report when specified;
- b) an engineering quality plan for the design phase of work that addresses quality assurance for the coordination of the multidisciplinary 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 (ITP) 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 (PQRs), examination, test procedures, and welder qualification record 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 datasheets, including control valves and analyzer;
- b) wiring diagram, if in scope.

4.4 Approved for Construction Documentation

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 datasheets 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 the 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

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) datasheets 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 datasheets for fans, drivers, duct burners, and other auxiliary equipment;
- i) bill of materials;
- j) noise datasheets when specified by the purchaser;
- k) factory acceptance test (FAT) certifications;
- l) as-built safety requirement specification and safety integrity level calculations;
- m) test procedures.

5 Design Requirements—General

5.1 Heat Recovery Steam Generator Gas Path Orientation

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_x 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 pressure relief 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) maximum continuous rating (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 a minimum, shall be used for the design:

- 2 cold starts a year;
- 10 warm starts;
- 10 hot starts.

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

NOTE This includes any fast startup requirement for cold, warm, and hot startup.

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 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 GT, 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 GT operating conditions shall, as a minimum, cover the load range from the minimum emissions compliant load to base load.

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

5.5.3 GT 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_t/V_{tavg});
- d) radial velocity (V_{rad}/V_{tavg});
- e) tangential velocity (V_{tan}/V_{tavg});
- f) axial velocity (V_{ax}/V_{tavg}).

NOTE The flow profile data are used to assist proper design and determine need for any flow distribution grids or other means of ensuring proper operation of the HRSG. Alternative to using radial, tangential, and axial velocity, an x, y, z system may be used.

where

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

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

- 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 (GT 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 GT 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 The 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 ($\frac{3}{32}$ in.).

6.1.9 When ovality is not addressed in the specified pressure design code, the requirements of ASME *BPVC*, Section I shall apply.

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, the 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.

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.

Table 3—Fouling Factors

	Fouling Factor	
	m ² K/W	h ft ² °F/Btu
External fouling:		
Natural gas	0.000176	0.0010
No 1 and No 2 oil (also when oil is used during commissioning)	0.000352	0.0020
No 6 oil	0.00088	0.0045
Internal fouling:		
Economizer	0.00025	0.00140
Evaporator	0.00016	0.00091
Superheater	0.00008	0.00045

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

EXAMPLE ASME SA-515/SA-515M Grades 60/65/70.

6.1.17 The applied piping shall use standardized sizes/schedules except where calculations show that nonstandard 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.), $t_{\min} > 16 \text{ mm } (\frac{5}{8} \text{ in.})$].

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 and 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 a 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 fins continuously high-frequency 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 GT and supplemental firing, where applicable. Both normal and backup 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 the supplier and the 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 the 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 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.

6.3.2 Dissimilar welds between tube and header shall be avoided. Where dissimilar welds between tube and 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.

6.3.3 Welding and material selection, as a minimum shall comply with API 582 and API 938-B.

6.3.4 The supplier shall perform lifetime analysis for fatigue and creep life assessments based on the pressure design code.

EXAMPLE EN 12952-3 for fatigue assessment; EN 12952-4 for creep life assessment.

6.3.5 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.

6.3.6 When a superheater section is applied directly downstream of a supplemental 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.

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

6.3.8 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.).

6.3.9 No multiple pass superheater harps (i.e. up and down flow in one harp) shall be used.

6.3.10 The minimum tube outside 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 calculations.

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

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

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

6.4.7 For evaporator systems 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 downcomer 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 downcomer.

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 noncondensable 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 the 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 waterside bypass systems are allowed as a solution to prevent steaming but shall have a pilot-operated pressure 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 and 240 °C (between 165 °F and 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 and 240 °C (between 165 °F and 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 dew point shall be determined considering all the fuels used for the GT supplemental 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 dew point.

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 582 and API 938-B.

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 holdup) 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/cutout shall be 3 minutes for high-pressure and 5 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 1 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 a 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 blowdown. 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 ensure 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 datasheet 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 covers 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 BFW supply to the drum shall be uniformly distributed over the 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 carryover into the blowdown 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 the 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 of 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 the CFD report 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 BFW 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 attemperator internals 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*, Section 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 datasheet 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 NWL 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 noncondensable 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 nondeaerated 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 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 the 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 toward 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 toward 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 startup 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.

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

6.11.7 The drain time for the complete HRSG assembly shall not exceed 4 hours unless otherwise specified.

6.11.8 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.

6.11.9 Drain and vent lines shall be labeled.

6.11.10 The supplier shall properly review operating conditions and choice of material for drains and vents, including atmospheric sections.

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

6.11.12 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 Pressure Relief Valves

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

6.12.2 Steam pressure relief valves shall be spring loaded.

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

6.12.4 Pressure 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 pressure relief valve capacity shall be based on the maximum possible heat input.

6.12.6 The superheater pressure 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 pressure relief valves).

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

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

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

NOTE The specified minimum pipe sizing relates only to the water/steam side services.

6.12.9 Pressure 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 pressure 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 pressure relief valves.

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

6.12.13 The pressure 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 pressure relief valve shall have a lever handle.

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

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

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

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

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

6.12.20 Pressure relief valves shall have valid factory test.

- **6.12.21** When required by the pressure design code or specified by the purchaser, pressure relief valves shall be tested on-site during system commissioning.

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

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

6.12.23 Only certified pressure relief valves shall be used.

6.13 Startup Vent Valves and Electronic Relief Valves

6.13.1 The HRSG shall be equipped with an automated steam startup vent 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.

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 shutoff (stop) valve and non-return valve shall be as close as possible to the economizer inlet.

6.14.6 The steam shutoff (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 shutoff valve bypass is required for warm-up 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. 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 gaskets 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 582 and API 938-B 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/E165M; acceptance criteria as per ASME *BPVC*, Section VIII, Division 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 (40,175 psi) yield strength minimum; the extent of testing shall be same as for the tension tests required by ASTM A182/A182M;
- f) transverse V-Notch impact test;
- g) microexaminations that indicate a structure of 100 % tempered martensite required.

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

6.14.46 Post-weld heat treatment 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 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 ($\frac{1}{4}$ 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 handwheels.

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-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.

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) BFW (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).

6.16.2 Drum water sampling shall be taken from a separated connection and not from the blowdown lines.

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

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

6.16.4 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.

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

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

6.16.7 Samples lines shall be designed for continuous flow.

6.16.8 For sampling of saturated and superheated steam, the supplier shall supply isokinetic sampling nozzles and associated valves.

EXAMPLE ASTM D1066-11.

6.16.9 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, but are not limited to, the following:

- a) ASME, *Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle and Cogeneration Power Plants*, 2012;
- b) ASME, *Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers*, CRTD vol. 34, 1998;
- c) IAPWS, Technical Guidance Document: *Phosphate and NaOH treatments for the steam-water circuits of drum boiler of fossil and combined cycle/HRSG power plants*, September 2011;
- d) IAPWS, Technical Guidance Document: *Volatile treatment for the steam-water circuits of fossil and combined cycle/HRSG power plants*, July 2010;
- e) EPRI, *Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs)*, 2006;
- f) EPRI, *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 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, *Water-tube boilers and auxiliary installations—Part 12: Requirements for boiler feedwater and boiler water quality*, September 2003;
- 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 and Cogeneration Power Plants*; however, each OEM steam turbine manufacturer should be consulted prior to finalization of the specifications.

6.17.4 The purchaser and the 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 BFW stream.

NOTE Sodium and TOC analyzers should be considered for online condensate monitoring.

- **6.17.6** The purchaser shall state makeup water quality, demineralized or softened water, and BFW 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 (BFW 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 the owner/purchaser for approval.

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

- 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 ensure availability of deaerated feedwater for startup of the HRSG and steam blows to clean new steam lines.

6.17.10 BFW 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). BFW 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 BFW sampling connections are within the scope of HRSG supplier.

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

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 BFW 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, *Consensus on Operating Practices for Control of Water and Steam Chemistry in Combined Cycle and Cogeneration Power Plants*, 2012;
- b) EPRI, *Cycle Chemistry Guidelines for Combined Cycles/Heat Recovery Steam Generators (HRSGs)*, 2006;
- c) EPRI, *Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs)*;
- 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, freestanding 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 GT trip pressure, with a minimum 5 kPa(ga) (0.725 psig).

7.2.4 The HRSG casing shall be a minimum of 6 mm ($\frac{1}{4}$ 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 freestanding 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 ($\frac{1}{4}$ 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 Appurtenances 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 a 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** The 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 4 years.

7.4.3 Expansion joint design at the cold end of the HRSG shall include both positive and negative differential pressure.

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 the 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** The purchaser shall specify the minimum lifetime of the casing penetration bellows. Bellows design life of expansion joint shall be a minimum of four years. Lifetime shall include commissioning cycles.