

GENERAL SPECIFICATION

PIPING VALVES VESSELS

GS EP PVV 511

Waste Heat Recovery Unit

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1. Scope

This General Specification covers the process design, thermal/hydraulic design, mechanical design, fabrication, inspection/testing, shipment, site erection and site performance test of Waste Heat Recovery Units (WHRUs) to be installed in Oil and Gas complexes (offshore, onshore and LNG facilities).

Note: WHRUs form a part of the exhaust system of the gas turbines used to generate electric power or to drive field gas compressors. They recover the sensible heat from the exhaust gas to raise the temperature of a fluid such as water, hot oil or any fluid used in the process units, without phase change for the heating medium throughout the heating process.

Note: This specification considers that all WHRU's fall within the relatively standard conditions listed below:

- Temperature of the exhaust gas from the turbine: 420 to 550°C
- Heating medium: liquid (water, water/glycol solution or hot oil) or gas without phase change
- No additional heat input using duct burners installed on the WHRU casing: the use of ducts burners to supplement heat creates potential problems of flame impingement on the casing, dampers and bundles
- Gas Turbine fuel: fuel gas with little or no sulphur and liquid fuel used over a limited period of time (start-up).

Special cases, outside these conditions, will be given due consideration taking into account the effect of temperature and corrosion for the selection of materials and the mechanical design.

The present Specification also covers exhaust systems without heat recovery since all the requirements which apply to the ducts, stacks, insulation, and supporting structure of WHRU also apply to exhaust systems which are simply used to drive the exhaust gas to the atmosphere.

This specification does not cover Heat Recovery Steam Generation (vaporization of feed water) downstream a gas turbine.

WHRU delivered under this specification shall be of a proven design and the Vendor shall provide references of existing equipment that have been running trouble free for at least three years.

Unless otherwise specified in the project documents design life will be 20 years minimum with no major maintenance operation that would require the removal of essential pieces like the dampers or the bundles.

The aim of the specification is to get a safe, robust and trouble free equipment with performances that will not decline with time. It's not meant to limit the Vendor ability to make progress in terms of innovative design changes, cost reduction or to prevent him from looking for solutions that might noticeably reduce the weight of the equipment. The Vendor may submit any deviation to this specification that he considers justified. Any deviation can only be implemented after the Client's written approval.

The Vendor shall be aware of the difference in constraints between on shore and offshore applications.

Note: Offshore applications are in general more demanding and ask for more innovative steps in the thermal and mechanical design to accommodate requirements such as weight and space limitations or specific dynamic loads associated with FPSO.

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Note: This specification does not necessarily covers in full details the requirements of the specialities (process, structural, electrical, instrumentation, material selection/corrosion, pressure vessels and piping) involved in the design and fabrication of this equipment.

The purchaser shall establish a project particular specification dedicated to the supply. The project particular specification shall complement the present general specification with also specific equipment data sheets for all significant components that are part of the supply.

The project specification will also clarify the scope of work for the engineering, manufacturing and quality control tasks related to the structural, electricity and instrument disciplines with due reference to applicable Company specifications, quoted or not by the present general specification.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published at the effective date of this document.

Reference	Title
API STD 530	Calculation of Heater-tube Thickness in Petroleum Refineries
API STD 560	Fired Heaters for General Refinery Services
API STD 616	Gas Turbines for the Petroleum, Chemical and Gas Industry Services
ASME B16.5	Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
ASME B16.9	Factory-Made Wrought Buttwelding Fittings
ASME BPVC Section II	ASME Boiler and Pressure Vessel Code (BPVC) - Section II: Materials
ASME BPVC Section IX	ASME Boiler and Pressure Vessel Code (BPVC), Section IX: Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators
ASME BPVC Section V	ASME Boiler and Pressure Vessel Code (BPVC), Section V: Nondestructive Examination
ASME BPVC Section VIII Div 1	ASME Boiler and Pressure Vessel Code (BPVC), Section VIII: Rules for Construction of Pressure Vessels - Division 1
EN 10204	Metallic products - Types of inspection documents

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Reference	Title
GS EP MEC 010	Rotating Machine Package Specification - Turbogenerator
GS EP MEC 020	Rotating Machine Package Specification - Turbopump
GS EP MEC 030	Rotating Machine Package Specification - Turbocompressor
GS EP MEC 212	Gas Turbines for the Petroleum, Chemical and Gas Industry Services According to API Standard 616
GS EP PVV 211	Design and fabrication of pressure vessels according to ASME VIII
GS EP PVV 611	Welding of pressure containing piping and equipment
GS EP STR 001	Weight monitoring and weighing offshore and onshore units
GS EP STR 103	Design and fabrication of skids and equipment supporting structures
GS EP STR 108	Requirements for evaluation of finite elements analysis and results
GS EP STR 201	Materials for offshore steel structures
GS EP STR 401	Loadout, seafastening, transportation and installation of offshore structures

The following priority rules shall apply:

1. Laws and Regulations of the Country of installation shall be applied wherever more stringent than the other contractual documents
2. Project contractual documents
3. The specification
4. Codes and Standards listed in the contractual documents and in the specification.

Any divergence between any of the Contractual Reference Documents, or between this specification and any other Contractual Reference Document, shall be reported to the Company for decision. In such a case, and unless otherwise agreed or decided by the Company, it is understood that the more stringent requirement shall apply.

3. Definitions of terms

The following definitions applies to the present Specification:

Contractor The party that is responsible for all the activities of the project (engineering design, procurement, construction and commissioning).

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Gas turbine vendor The party that supplies equipment, materials, goods and/or services for the Gas Turbine. The party that is responsible for the complete supply (design and manufacturing) of the Gas Turbine.

WHRU Vendor The party that supplies equipment, materials, goods and/or services for the WHRU. The party that is responsible for the complete supply (design and manufacturing) of the WHRU.

The WHRU may be purchased either directly by the Contractor or by the Gas Turbine vendor.

- If the WHRU is purchased by the Gas Turbine vendor:
 - The Contractor is fully responsible for the integration of the complete package (i.e. gas turbine, electric generator and WHRU) within the Oil & Gas complex.
 - The Gas Turbine vendor is fully responsible for the overall performances of the complete package (i.e. gas turbine, electric generator and WHRU) in terms of:
 - . Electrical output of the generator
 - . Thermal performances of the WHRU
 - . Noise levels
 - . Emissions to the atmosphere
 - . Efficiency.
 - The Gas Turbine vendor shall manage the interface with the WHRU vendor under the Contractor's supervision.
 - The Gas Turbine vendor shall provide the required dimensional, acoustical, thermal, flow characteristics and mechanical information to the WHRU vendor as specified in this standard.
- If the WHRU is directly purchased by the Contractor:
 - The Contractor is fully responsible for the integration and the overall performances of the complete package (i.e. gas turbine, electric generator and WHRU) within the Oil & Gas complex. The Contractor shall manage the interface between the Gas Turbine vendor and the WHRU vendor.
 - The Gas Turbine vendor is fully responsible for the overall performance of the gas turbine package.
 - The WHRU vendor is fully responsible for the thermal performances of the complete WHRU package.
 - It becomes the Contractor's responsibility to obtain from the Gas Turbine vendor the required dimensional, acoustical, thermal, flow characteristics and mechanical data and pass it to the WHRU vendor.

4. Scope of Supply

The supply includes all the studies and calculations necessary for the dimensioning of the WHRU elements in order to reach the performances indicated on the data sheet.

The supply also includes the final documentation listed in Appendix 3.

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The WHRU shall be a complete assembly package and shall comprise (but shall not be limited to) the following elements properly assembled together. The following list of main components and sub-assemblies corresponds to the cases where the outlet heating medium temperature is regulated through the use of dampers.

- **An expansion joint** connecting the outlet flange of the Gas Turbine with the WHRU. Other expansion joints should be installed when needed in between some of the ducts in order to prevent excessive mechanical stresses due to differential thermal expansion.
- **An inlet duct** to distribute the exhaust gas between the bundle duct and the bypass duct.
- **A silencer** only when specified in the project documents. In that case the silencer will be housed in the inlet duct.
- **A set of two dampers** (one bundle damper and one bypass damper) with their actuators, connecting rods, instrumentation and all other appurtenances for controlling their opening and closure, the sealing air fans (if any) with relevant electric motors, electric cables and sealing air piping and the local panel for local manual operation.
- **A bundle duct** to house the bundles.
- **One or several bundles** complete with their headers, tubes and their extended surface, return bends, tube sheets and any frame or support required to install the bundles in the casing and prevent vibration. When the bundles are arranged in series the connecting piping shall be supplied.
- **A bypass duct**
- **An outlet duct** which collects the exhaust gases coming from the bundle duct and the bypass duct and which receives the stack.
- **A stack.** For vertical WHRU the stack may be an extension of the outlet duct.
- **Control valves and field instrumentation** necessary for safety, monitoring and control as indicated on the WHRU PID's.
- **Instrumentation and electrical junction boxes** as well as earthing bosses and aircraft warning light.

There are special cases where the temperature is regulated in a different way and no dampers (and no bypass) are required. For these cases the list shall be modified accordingly.

The ducts, dampers and stack shall be provided with a suitable internal thermal insulation system. The ducts comprise the inspection and visiting doors as defined on the drawings.

The supply shall include all the gaskets and bolting to join the elements together as well as all the lifting lugs necessary for the assembly and the lifting of the complete WHRU package.

The supply shall include all valves, vents and drains as well as the sampling connections indicated on the drawings.

The supply shall include all the structural steel to support the equipment as well as the stairs, ladders and platforms.

The supply shall include surface preparation, primer and final painting for all carbon and low alloy steel structures and piping.

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5. Process/Thermal/Hydraulic Design

5.1 Process Design

The Contractor will supply the WHRU Vendor with the data of the process fluids (heating medium) that shall recover the heat from the exhaust gas of the turbine by filling the first part of the WHRU data sheet.

For each process fluid the minimum data to be supplied are the following:

- Fluid designation (water, hot oil, regeneration gas or other) and any characteristic having an influence on the performance and reliability of the bundles (corrosive elements, maximum temperature to avoid fluid degradation or alternatively maximum local heat flux density)
- Mass flow rate (kg/s), inlet and outlet temperature (°C), allowable delta P (kPa) from inlet header flange to outlet header flange
- Inlet pressure (kPa)
- Physical properties of the fluids at inlet and outlet temperature (specific gravity, viscosity, thermal conductivity, heat capacity)
- Fouling factor in heating medium side ($\text{m}^2 \text{ } ^\circ\text{C/W}$).

The WHRU Vendor shall also provide the characteristics of the exhaust gas consistent with the data provided by the gas turbine Vendor. This includes and is not limited to:

- Mass flow rate of the exhaust gas (kg/s)
- Molar composition
- Inlet and outlet temperature of the exhaust gas to and from the bundles (°C) as well as the thermal duty (MW)
- Pressure drop from the inlet flange of the casing to the outlet of the bundles (bypass damper fully closed). This value has to be agreed upon with the gas turbine Vendor
- Fouling factor in exhaust gas side ($\text{m}^2 \text{ } ^\circ\text{C/W}$)
- Percentage of overdesign required if any. This percentage can be expressed either in term of duty or of heat transfer area.

The cases where several bundles with different process fluids are installed shall be carefully investigated from the process outlet temperature control point of view. The dual damper system allows to properly control only one service.

If different process cases are considered (for instance different heat duty and/or outlet temperatures for the same fluid) each of them shall be recorded on the data sheet with the indication of the design case for which the bundles will be sized up.

5.2 Thermal/hydraulic design

Thermal/hydraulic design shall be performed by the WRHU Vendor using a recognised software package.

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Note: The main objective of the thermal/hydraulic design is to determine the total heat transfer area to be installed in order to recover the thermal duty. Other calculations such as for instance the maximum skin temperature of the tubes or the maximum temperature at the tip of the fins are performed to assess the proper selection of materials.

The design shall also be used in determining the main dimensions (length, width, height) of the ducts constituting the WHRU.

The WHRU design shall ensure that the heating medium fluid has no phase change throughout the heating process.

The skin temperature of the last row of tubes at the exit side of the bundle shall be at least 15°C above the exhaust gas acid dew point.

The thermal properties of the exhaust gas (specific heat, thermal conductivity, viscosity...) will be derived from the molar composition in the data sheet.

An important aspect of the thermal/hydraulic design is the selection of the way of controlling the outlet temperature of the process fluid. The choice of the controlling method shall be made at an early stage and brought to the attention of Company along with all the consequences.

Note: The following three methods are acceptable:

- 1st method: control of the thermal fluid temperature is achieved by controlling the amount of the gas turbine exhaust gas flow circulating through the WHRU bundle. In this case, the heating medium fluid flow through the WHRU is constant. The flow rate of the exhaust gas through the bundle is adjusted by means of a bypass duct and two dampers.
- 2nd method: the exhaust gas flow rate is constant (i.e. the total flow rate from the gas turbine) and the process fluid inside the bundle varies. Part of the process fluid flow is bypassed to the WHRU. This will result in a simpler mechanical design for the WHRU (no bypass duct, no dampers with all their accessories) but care should be exercised in carefully evaluating the mechanical design pressure and temperature of the bundle since in some operating cases the flow rate inside the bundle can be low or very low with the skin temperature of the tubes approaching the temperature of the exhaust gas.
- 3rd method: the exhaust gas flow rate is constant (i.e. the total flow rate from the gas turbine) and the thermal fluid flow through WHRU bundle is also maintained constant. Temperature supply to the users is controlled by a trim cooler installed on WHRU's outlet fluid flow. The trim cooler is part of the Contractor's scope of supply.

Different bundles configurations are acceptable if they fit the purpose. Nevertheless the specification considers that the bundles shall have the features described below and that any deviation shall be justified and receives written approval.

The typical bundle consists in rows of straight tubes connected by short radius return bends. The tubes ends are connected on one side to an inlet header and on the other side to an outlet header.

The bundle is installed in a cross flow position with regard to the exhaust gas travel.

The terms vertical and horizontal usually refers to the direction of the exhaust gas flow. In a vertical configuration the inlet and outlet headers are usually horizontal and in a horizontal configuration the headers are vertical. This insures that the bundles are self-draining.

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In order to optimize the heat transfer area the process fluid flows counter current to the exhaust gas. The inlet header is located on the cold side of the casing and the outlet header on the hot side.

The tube pitch and layout selection shall be a compromise between the following targets and constraints:

- Maximizing the heat transfer coefficient
- Increasing the compactness of the exchanger
- Lowering the pressure drop on the TEG side
- Giving access for external cleaning of the tube.

Company preference is to have the tubes arranged on an equilateral triangular pitch. Other tube pitches and layouts are acceptable if they are the most performant and the most economical.

To enhance the heat transfer on the exhaust gas side the tubes receive an extended surface in the form of circular fins. Circular fins can be plain (solid) or serrated.

The outside diameter of the tubes, the height and spacing of the fins are selected among standard values as defined in [API STD 530](#) and [API STD 560](#).

The length of the tubes shall be selected to have a compact design in order to optimize the size of the casing and to avoid sharp variation in sections between the inlet/outlet duct and the part of the casing that houses the bundles.

Typical values for the average liquid velocities inside the tube shall be in the range of 1 to 2 m/s.

Typical value of the average exhaust gas velocities ahead of the bundles shall be in the range 15-25 m/s.

Additional calculations using dedicated software are required:

- To insure that the exhaust gas is properly distributed over the bundle (Computational Fluid Dynamics (CFD) modelling).
- To insure that the WHRU will not experience undue vibrations (such as bundle tubes vibrations or casing sonic vibrations). In any case the unsupported length of the tubes shall not exceed 35 times their diameter.

The WHRU Vendor will check the fabrication drawings of the bundles, of the casing and of the assembly drawing to see if all the requirements of the thermal/hydraulic design are satisfied and that there is no excessive by passing of the exhaust gas around the bundle.

6. Design conditions

6.1 General requirements

Whether the project includes one or several gas turbines the best use of the waste heat of the exhaust gas shall be evaluated at an early stage in order to optimize the number and the size of the WHRUs. The heat requirement for the process of the oil and gas complex shall be matched against the waste heat production and temperature level of the gas turbines.