PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº :** I-ET-3010.2D-5147-413-P4X-001	
	CLIENT: AGUP		**SHEET** 1 **of** 29
	JOB: HIGH CAPACITY FPSO - GAS EXPORTATION ALL ELECTRIC		
	AREA: ATAPU 2 AND SÉPIA 2		
SRGE	**TITLE:** **WASTE HEAT RECOVERY UNIT (WHRU)**		INTERNAL
			ESUP

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0	ORIGINAL ISSUE
A	Revised item 4.1
B	Revised item 2.4, 4.2.1, 5.3 and 6.6

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SUMMARY

1 INTRODUCTION

This specification covers the minimum requirements of design, engineering, materials, fabrication, inspection, testing, preparation of shipment, installation, pre-commissioning and commissioning of the Turbogenerator Waste Heat Recovery Units, which will be installed in the exhaust of gas turbines driven power generation package.

2 NORMATIVE REFERENCES

All equipment shall comply with the requirements of this technical specification, applicable documents and standards stated below

2.1 CLASSIFICATION

PACKAGER/ MANUFACTURER shall perform the work in accordance with the requirements of Classification Society. PACKAGER/ MANUFACTURER is responsible for submitting to the Classification Society all documentation in compliance with stated Rules.

2.2 CODES AND STANDARDS

The equipment shall comply with the following codes and standards as guidelines for design.

AISC 325	Steel Construction Manual
API RP14 C	Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems for Offshore Production Facilities
API STD 530	Calculations of Heater Tube Thickness in Petroleum Refineries
API STD 560	Fired Heaters for General Refinery Service
ASME B16.47	Large Diameter Steel Flanges
ASME B16.5	Pipe Flanges and Flange Fittings
ASME B31.3	Process Piping
ASME BPVC Section VIII-1	Rules for Construction of Pressure Vessels
ASME BPVC Section II	Boilers and Pressure Vessel Code: Material Specification
ASME BPVC Section V	Boiler and Pressure Vessel Code: Non-destructive Examination
ASME BPVC Section IX	Welding, Brazing, and Fusing Qualifications
AWS D1.1	Structural Welding Code - Steel
IEC 60092-502	Electrical Installation in Ships – Tankers – Special Features
IEC 61892-6	Mobile and Fixed Offshore Units – Electrical Installations – Installation
ISO 15156	Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production

2.3 BRAZILIAN GOVERNMENT REGULATION

NR-12 Segurança no Trabalho em Máquinas e Equipamento (*Safety on Labour in Machines and Equipment*).

NR 13 Caldeiras e Vasos de Pressão *(Boilers and Pressure Vessels)*

NR 26 Sinalização de Segurança *(Safety Signaling)*

NR-37 Segurança e Saúde em Plataformas de Petróleo *(Safety and Health in Oil Platforms)*

2.3.1 Brazilian Government regulations are mandatory and shall prevail, if more stringent, over the requirements of this specification and other references herein.

2.3.2 PACKAGER/MANUFACTURER shall comply with any other government regulations stated in the Contract and not listed above

2.4 APPLICABLE DOCUMENTS

DR-ENGP-I-1.15	COLOR CODING
DR-ENGP-M-I-1.3	SAFETY ENGINEERING
I-DE-3010.00-5140-700-P4X-003	GROUNDING INSTALLATIONS TYPICAL DETAILS
I-DE-3010.2D-1200-942-P4X-001	GENERAL ARRANGEMENT
I-DE-3010.2D-1423-942-P4X-001	M-12 – POWER GENERATION – EQUIPMENT LAYOUT PLAN
I-DE-3010.2D-1424-942-P4X-001	M-13 – POWER GENERATION – EQUIPMENT LAYOUT PLAN
I-DE-3010.2D-1424-942-P4X-002	M-13B – POWER GENERATION – EQUIPMENT LAYOUT PLAN
I-DE-3010.2D-5125-943-P4X-001	UTILITY FLOW DIAGRAM - HOT WATER SYSTEM
I-DE-3010.2D-5125-944-P4X-002	TURBOGENERATOR WASTE HEAT RECOVERY "A”
I-DE-3010.2D-5125-944-P4X-003	TURBOGENERATOR WASTE HEAT RECOVERY "B"
I-DE-3010.2D-5125-944-P4X-004	TURBOGENERATOR WASTE HEAT RECOVERY "C"
I-DE-3010.2D-5125-944-P4X-005	TURBOGENERATOR WASTE HEAT RECOVERY "D"
I-DE-3010.2D-5125-944-P4X-006	TURBOGENERATOR WASTE HEAT RECOVERY "E"
I-DE-3010.2D-5125-944-P4X-007	TURBOGENERATOR WASTE HEAT RECOVERY "F"
I-ET-3010.00-1200-431-P4X-001	THERMAL INSULATION FOR MARITIME INSTALLATIONS
I-ET-3010.2D-1200-200-P4X-001	PIPING SPECIFICATION FOR TOPSIDE
I-ET-3000.00-1200-940-P4X-001	TAGGING PROCEDURE FOR PRODUCTION UNITS DESIGN.
I-ET-3010.00-1200-940-P4X-002	GENERAL TECHNICAL TERMS
I-ET-3010.00-1200-956-P4X-002	GENERAL PAINTING
I-ET-3010.00-5140-700-P4X-001	SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS
I-ET-3010.00-5140-700-P4X-002	SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS
I-ET-3010.00-5140-700-P4X-003	ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS

I-ET-3010.00-1200-800-P4X-002	AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS
I-ET-3010.2D-1200-800-P4X-014	AUTOMATION INTERFACE OF PACKAGED UNITS
I-ET-3010.2D-5147-332-P4X-101	TURBOGENERATOR PACKAGE SPECIFICATION
I-ET-3010.00-5400-947-P4X-002	SAFETY SIGNALLING
I-ET-3010.00-1350-940-P4X-001	SYSTEMS OPERATION PHILOSOPHY
I-ET-3A36.00-1000-941-PPC-001_F	METOCEAN DATA
I-ET-3A26.00-1000-941-PPC-001_F	METOCEAN DATA
I-FD-3010.2D-5147-413-P4X-001	TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F)
I-RL-3010.2D-1350-960-P4X-002	MOTION ANALYSIS

2.5 CONFLICTING REQUIREMENTS

As a general guideline, in case of conflicting requirements between this technical specification and other cited references, the most stringent shall prevail. If necessary, the PACKAGER/ MANUFACTURER may revert to PETROBRAS for clarification.

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

All terms and definitions are established in the latest revision of I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS

3.2 ABBREVIATIONS

Class	Classification Society
FPSO	Floating Production Storage and Offloading Vessel
MT	Magnetic-Particle Testing
PT	Liquid Penetrant Testing
SS	Stainless Steel
TGCP	Turbo-generator Control Panel
WHRU	Waste Heat Recovery Unit
GTG	Gas Turbine Generator

4 GENERAL

This technical specification covers the minimum requirements for the design, material procurement, fabrication, inspection and testing, preparation for shipment and PACKAGER/ MANUFACTURER documentation requirements of SIX sets of Waste Heat Recovery Unit (WHRU) and relevant auxiliaries, on turbo-generators units exhaust ducts. The waste heat recovery unit (WHRU) will be used for superheated water production.

The WHRU shall be mounted on offshore FPSO unit, in safe area and in a marine tropical ambient having frequently rain storm.

WHRU shall be a vertical or horizontal combined unit (by-pass /recovery coil) complete with all ancillary equipment built in it.

Additionally PACKAGER/ MANUFACTURER shall be responsible for all coordination and collection of all details, drawings and data to achieve optimum design and full submission of all documents requested.

Waste Heat Recovery Unit Packages shall be provided with all necessary instruments to operate safely, adequately and without interruption.

4.1 SCOPE OF SUPPLY

The supplier of the WHRU shall include in its scope of supply the equipment, instruments and what is necessary for a good design, construction, test and operation of the system.

PACKAGER/ MANUFACTURER shall be responsible for supplying complete and fully operational equipment in accordance with the requirements of this specification and I-FD-3010.2D-5147-413-P4X-001 - TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F).

The SCOPE OF SUPPLY shall include as a minimum the main equipment and services listed in the following list:

- Waste heat recovery unit including heat recovery coil and insulated housing;
- Exhaust gas diverter system with sealing system
- Exhaust gas diverter valve assemblies with position switches;
- Exhaust duct from turbine outlet to diverter valves;
- Exhaust duct from diverter to silencer, unless silencer is integrated with WHRU;
- Exhaust duct from diverter to WHRU;
- Exhaust outlet duct from WHRU (stack);
- Exhaust outlet duct from silencer (stack) unless silencer is integrated with WHRU;
- Exhaust silencer;
- Thermal insulation;
- Drains and venting connections;
- Grounding devices;
- Clips for thermal insulation as necessary for heat conservation and personnel protection;
- Maintenance lifting beams and hoists;
- All required gaskets, bolting and seals for the total assembly of WHRU, ducting and accessories, in according to I-ET-3010.2D-1200-200-P4X-001 (PIPING SPECIFICATION FOR TOPSIDE);
- All necessary instruments, ancillaries and instrument support;
- Inspection and observation doors or manholes;
- Complete design of all components in the scope of supply;
- Structural and thermal calculation;
- Drawings, documents and manuals for all items;

- The necessary studies as required by Classification Society;
- Certification by Classification Society;
- Postweld heat treatment, if applicable;
- Inspection, testing and the quality assurance of the equipment;
- Painting proper for offshore installations;
- Non-destructive examination, if applicable;
- Hydrostatic test;
- Spare parts recommended for commissioning, pre-operation and start up;
- Spare parts recommended by the Classification Society;
- Consumables and special tools for assembly, disassembly, maintenance, commissioning and start up;
- Nameplates in Portuguese language made in AISI 316 and indelibly engraved;
- Safety signaling in Portuguese language;
- Packing, protection and marking for shipment for all items;
- Preservation, including equipment handling conditioning and storage at job site;
- Guarantee WHRU performance under the conditions described in the I-FD-3010.2D-5147-413-P4X-001;
- Technical assistance with unit price for working and mobilization/demobilization;
- Training;
- Data books;
- Installation, operation and maintenance manuals in Portuguese language
- Commissioning supervision at job site during system assembly and turbogenerators full load test;
- Transportation.

4.2 OPERATION ENVIRONMENTAL / MOTION REQUIREMENTS

4.2.1 Operation Environment

The equipment supplied shall be suitable for the environment and range of ambient condition including, atmospheric pressure, relative humidity, rainfall, air temperature (dry bulb), and wind motions defined at the documents I-ET-3A36.00-1000-941-PPC-001_F and I-ET-3A26.00-1000-941-PPC-001_F - METOCEAN DATA. For more details, please see I-FD-3010.2D-5147-413-P4X-001 - TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F).

4.2.2 Motion Requirements

The necessary design data and information on motion requirements are given in I-RL-3010.2D-1350-960-P4X-002 – MOTION ANALYSIS.

PURCHASER shall inform to PACKAGER/ MANUFACTURER any data from the model tests, which contradicts the specified data. Any action on the revised data will be subject to agreement with the PURCHASER.

4.3 CALCULATIONS

PACKAGER/ MANUFACTURER shall include the following calculations for approval:

- Thermal and mechanical design including dampers operations;
- Thickness calculations at the design pressure for piping components;
- Maximum and minimum tube wall metal temperatures;
- Maximum and minimum fin tip temperature;
- Maximum and minimum tube film temperature;
- Turbine exhaust pressure drop calculations;
- Nozzle reinforcement calculations;
- Wind and dynamic loading calculations;
- Lifting lug calculations;
- Motion calculations;

4.4 DESIGN REQUIREMENTS

It is MANUFACTURER's/PACKAGER's responsibility to submit to the Classification Society the documentation in compliance with Rules in force.

All elements of the package, including sub orders, shall be of field proven design and well within the manufacturer's actual experience.

4.5 DESIGN LIFETIME

PACKAGER/ MANUFACTURER shall design and fabricate the complete packages for a minimum lifetime of 30 years.

4.6 MANUFACTURER

Additionally PACKAGER shall be responsible for all coordination with manufacturers and collections of all details, drawings and data to achieve optimum design and full submission of all documents requested in the specification.

5 DESIGN DATA

5.1 GENERAL CONDITIONS

PACKAGER/ MANUFACTURER shall design, fabricate, assembly, test and code stamp the tube bundle and related header system in accordance with codes and standards herein referenced.

The heat recovered from waste hot gases from gas turbine shall be used to heat water for utilities purpose.

Waste Heat Recovery Unit shall meet the full range of operational conditions specified in the process data sheet I-FD-3010.2D-5147-413-P4X-001 - TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F).

The thermal design of the WHRU shall be established taking into account the risk of acidic corrosion caused by the condensation of the exhaust gas. All metal surfaces in contact with the exhaust gas shall be at least 10°C above the acid dew point of the exhaust gases. It shall be considered the alternative to design with parallel flow in order to keep tube wall temperature above acid dew point.

WHRU shall be designed considering dry operation (without water inside tubes) at maximum temperature of gas turbine exhaust gases.

Bundle passes shall be designed for uniform heat distribution and equal flow distribution without the use of flow controllers or restriction orifices.

PACKAGER/ MANUFACTURER shall define the utility requirements and consumption of the WHRU. This information shall be included in the quotation.

The materials of construction for each component shall be suitable for operation in a salt laden marine environment during 30 years. Dissimilar materials shall be isolated to avoid galvanic corrosion. The proposal shall describe a complete list of the materials of the main parts as well as inspection required. All WHRU components exposed to turbine exhaust gases shall be suitable to H2S content of 170ppmv and CO2 content of 25% in the fuel gas for continuous operation.

The Waste Heat Recovery unit shall be designed for easy removal and reinstallation of the tube bundle without disturbing the casing, insulation and exhaust piping. Slip-on flanges shall not be used.

The Gas Turbine must be capable to operate independently from the WHRU without causing overheating of trapped water inside tube bundle, including during process shutdown when circulation pumps stop. For this purpose, a double-blade damper (Lower Damper) with sealing air shall be installed upstream and downstream of the WHRU and a single-line damper shall be installed in the by-pass. A system with automatic damper(s) shall be installed, which is used when the WHRU is out of operation. The damper(s) shall be fitted with solenoid(s) to force damper(s) in open position (see I-DE-3010.2D-5125-943-P4X-001 - UTILITY FLOW DIAGRAM -HOT WATER SYSTEM).

The Waste Heat Recovery Unit shall allow start up of the Turbogenerators, through the by-pass operation, without hot water circulation or with trapped water in coils. It shall be ensured a complete seal of gas exhaust to WHRU when the gas turbine is operating and WHRU is not. In case of ESD-2, when hot water demand ceases, or ESD-3P, where TG continues to operate and WHRU does not, water overheating is not allowed.

In order to minimize the leakage of the hot gases through the dampers when the WHRU is out of operation, the preferred gas exhaust path shall be the WHRU bypass, as indicated in schematic below. WHRU arrangement shall be selected to minimize the backpressure to the gas turbine and keep the maximum backpressure lower than the maximum backpressure allowed by the turbogenerator (trip).

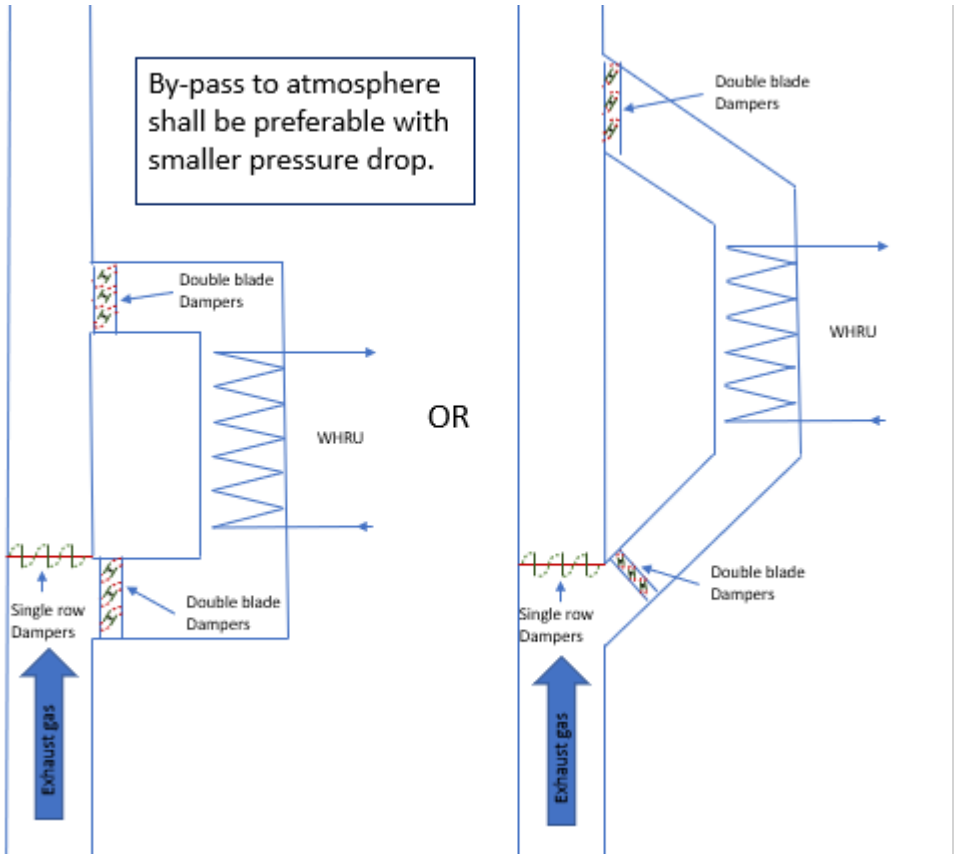

Figure 1 Schematic arrangements.

The system that automatically controls process heating water temperature and isolates the WHRU from Turbogenerators gas exhausts must be easy to operate, easy to maintain and must withstand the operating conditions described in I-FD-3010.2D-5147-413-P4X-001 - TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F).

The manufacturer shall evaluate the gas recirculation in the exhaust during the by-passing event to avoid the water overheating into the tube bundles.

5.2 EQUIPMENT LOCATION

The packages will be installed outdoors, on main deck, in the location defined on the drawings mentioned below.

The design of the exhaust system has been carefully considered in order to not restrict the access for maintenance by means of overhead crane and lifting gear. For more details see I-DE-3010.2D-1200-942-P4X-001 - GENERAL ARRANGEMENT, I-DE-3010.2D-1423-942-P4X-001 - M-12 - POWER GENERATION - EQUIPMENT LAYOUT PLAN, I-DE-3010.2D-1424-942-P4X-001 - M-13 - POWER GENERATION - EQUIPMENT LAYOUT PLAN and I-DE-3010.2D-1424-942-P4X-002 - M-13B - POWER GENERATION - EQUIPMENT LAYOUT PLAN.

The steel frame runs above the gas turbine throughout its length.

5.3 DESIGN LOADS

In addition to the loads described in CODES and STANDARDS sections and loads due to equipment motions defined on I-RL-3010.2D-1350-960-P4X-002 – MOTION ANALYSIS, the following loads must be considered where relevant:

- Equipment transportation and erection loads;
- Nozzle loads;
- Thermal loads;
- Wind loads (see I-ET-3A36.00-1000-941-PPC-001_F and I-ET-3A26.00-1000-941-PPC-001_F – METOCEAN DATA for wind data);
- Weight loads.

6 EQUIPMENT DESCRIPTIONS AND REQUIREMENTS

PACKAGER/ MANUFACTURER shall engineer the WHRU to be compatible with the gas turbine exhaust and shall be responsible for all WHRU to gas turbine interfaces and interference.

WHRU shall be provided with an integral by-pass duct built in it. The by-pass shall be sized for the appropriate velocity and dimensional constraints.

WHRU internal coils may have an API 560 style with header boxes. In this case tube sections can be removed individually instead of the entire bundle at once.

Manhole shall be provided in both transition pieces, downstream and upstream the WHRU, to allow final cleaning and inspection of the entire duct system before operation.

6.1 STRUCTURAL REQUIREMENTS

All individual equipment items shall incorporate lifting lugs. For ducting sections, lifting lugs shall be provided for both vertical and horizontal lift orientations. In addition, lifting lugs shall also be provided to lift the fully assembled coil enclosure, i.e., the enclosure, the bypass duct, and the inlet and outlet transitions. Lifting lug markings and designs shall ensure that lugs installed to lift unit components cannot be inadvertently used to lift the assembled unit. Stacks and duct selection shall be provided with two lifting lugs

The WHRU shall be supported on a steel frame independently carrying the full weight of the tubes and headers. The frame shall permit lateral and vertical expansion of all parts of the WHRU at temperatures that may exist at various sections in the WHRU. WHRU shall be supported to allow lateral as well as axial growth due to temperature changes.

All casing plate shall be sufficiently stiffened against internal design pressure, damage during transport, erection and vibration. Stiffening shall not interfere with expansion.

All structural steel attached to steel plates shall have continuous seal welds. The structure shall be designed to prevent flexing of the walls.

When a horizontal WHRU is specified, the base framing shall include wide flange perimeter members for seal weld attachment by the SUPPLIER to the deck plate.

WHRU, internal coils, and all duct pieces and major components shall include pad eyes suitable for single point lift to facilitate loading, unloading and erection.

The bundle shall be divided into parts, so that it can be removed by cargo handling equipment for maintenance.

Equipment deck mounting connections shall be designed to adequately resist all combined static and dynamically induced loads, including influence of roll, pitch, yaw and heave of the facility to which it is affixed, in addition to wind loading.

Inspection openings for inspection of the heat exchanger tubes and return bends and other critical components shall be provided. All openings shall be sealed to prevent leakage of exhaust gases and shall be watertight.

Duct supports shall remove all ducts loads to the gas turbine and the exhaust stack. The ducting and supports shall be designed to remain stationary when sections near the gas turbine are removed to provide access for maintenance.

6.2 ELECTRICAL REQUIREMENTS

Electrical equipment and materials shall comply with requirements of I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS.

Electrical installations inside the package and the voltages to be supplied for electrical loads (motors, heaters, control panels, etc.) shall comply with requirements of I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

Grounding installations inside the package shall comply with requirements of I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS and I-DE-3010.00-5140-700-P4X-003 - GROUNDING INSTALLATIONS TYPICAL DETAILS.

6.3 THERMAL AND HYDRAULIC DESIGN

The flows and heat duties shown on the process data sheet (I-FD-3010.2D-5147-413-P4X-001 - TURBOGENERATOR WASTE HEAT RECOVERY UNIT (P-TG-5147001A/F)) shall be the required performance of a single WHRU. The maximum pressure drop on the gas turbine exhaust gas due to the WHRU package and other components listed on item 4.1 shall be no more than 2.5 kPa or as otherwise noted on the process data sheet.

The liquid side of the heat recovery system shall be designed for sufficiently high fluid velocity to avoid “hot spots” in the heating coil.

If MANUFACTURER’s/PACKAGER’s design results in an approach temperature of less than 24°C, the PACKAGER/ MANUFACTURER shall demonstrate by satisfactory performance of existing equipment that this approach temperature can be achieved.

The heat recovered will be used for utility water heating.

The limiting pressure available for the tube bundle shall adjust the ducting sizing to meet the allowable exhaust pressure drop. The exhaust gas pressure drop through the equipment shall not limit the power available from gas turbine. For additional information see I-ET-3010.2D-5147-332-P4X-101 - TURBOGENERATOR PACKAGE SPECIFICATION.

All materials shall be resistant to corrosion/oxidation from exhaust gases, the high temperature and the external environment.

PACKAGER/ MANUFACTURER shall indicate any temperature restrictions for the equipment proposed in his proposal.

Thermal insulation shall be considered to temperatures of 60ºC and above and shall be supported by SS 316 corrosion resistant steel anchor studs.

In order to avoid damages during transportation and erection, insulation mounting shall be carried out by PACKAGER/ MANUFACTURER after final installation in place.

6.4 HEAT RECOVERY COIL

6.4.1 Tube Supports

The heat recovery coil shall include sufficient supports to ensure that it does not suffer from thermal distortion during operation or mechanical damage from reasonable handling during shipment, installation or replacement.

Tube supports shall be provided for each tube and shall be suitable for the maximum exhaust gas temperature of gas turbine.

Tube loads shall not be supported on the fin tip surface.

PACKAGER/ MANUFACTURER shall:

- Select the tube supports materials;
- Design (geometry and thickness) tube supports;
- Consider, in the tube support mechanical design, loads of tube and accessories added to hot fluid weight and the allowable coils movement and loads;
- Consider, in the tube support mechanical design, when applicable, friction loads due to tube expansion and contraction in transient conditions (start-up and shut-off);
- Consider coil test hydrotest conditions in the mechanical design;
- Consider corrosion allowance in the mechanical design;
- Tube support shall allow free thermal expansion of tubes during normal operation;
- Supply the detailed drawings of tube support.

6.4.2 Tubes and Tube Bundles

Tubes and tube bundles shall be designed to withstand dry operation at maximum exhaust gas temperature.

The tube coil design shall consider uniform heat and feed distribution.

Tubes between headers and return bends shall be continuous lengths of seamless pipe with no interim circumferential welds.

The minimum clearance between adjoining tubes shall be 12mm including fin height.

The minimum distance from fin tips to the waste heat recovery unit wall or surface of the wall insulation or refractory shall be 19mm. Fins must be minimum 1.3mm thick with a maximum height of 25mm and no more than 1 fin for every 5mm must be applied.

Each horizontal or vertical row shall have a minimum of four tubes, or the number of tubes equal to the number of passes, whichever is greater.

Tubes shall not be longer than 6 meters in length. For tube sizes 50 mm and less, Schedule 80 is required.

All tubes shall be of a material suitable for the application according to API Standard 530. SA-106 Gr. B seamless pipe shall be used as a minimum. ERW seam welded pipe is not allowed. Return bends shall be of the same material as the tubes. They shall match or be taper bored to match the I.D. of the connected tubes. Metal backing rings in completed coil assemblies are not acceptable. Rolled return or header connections are not allowed.

Minimum tube wall thickness shall not be less than the nominal thickness of sch. 40 pipe. Tubes shall be selected from standard pipe sizes available. Tubes shall be designed for a minimum life of 100,000 hours using API RP-530 or per ASME Section VII for water wetted services.

Corrosion allowance shall be 3mm for carbon steel coil materials, 2.5mm for chrome alloy coil materials and 1.27mm for austenitic stainless coil materials.

All welds made on coils shall be 100% inspected using radiography.

The design of tube banks and shell shall be such that the possibility of exhaust gas bypassing coil is minimized.

Minimum fluid velocity in any segment inside tube shall be no less than 0.61 meters per second. There shall be no fluid “dead spots” or low velocity areas exposed to high temperatures exhaust gases.

The design temperature of tubes shall be the calculated maximum tube metal temperature using API Standard 530 including fouling plus a minimum temperature allowance of 4°C.

PACKAGER/ MANUFACTURER shall design the area of heat exchange with an excess of 10% to account for fouling, unless otherwise state in the process data sheet.

The tubes shall be accessible for inspection, cleaning, and/or repair.

Drains and vents must dispose safely without causing damage to equipment or persons.

PACKAGER/ MANUFACTURER shall:

- Select the tube coil materials;
- Define the tube diameter;
- Calculate the tube wall thickness;
- Analyze tube coil flexibility;
- Determine the allowable loads (forces and moments) on terminals;
- Supply a complete detailed design of tube coils, headers, crossovers, drains and vents, issuing bevel and welding specification, inspection and testing procedures, etc;
- Analyze tube wall thickness, considering, where applicable, hoop and longitudinal stresses and strains due to internal or external pressure, dead loads, space between supports, allowable loads and movements in terminal, etc.

6.5 PLENUM

The plenum section, if applicable, for the heat recovery unit shall be of a double wall design, consisting of an outer shell, a thermal insulation barrier, and an inner liner.

The outer shell shall be weatherproof and completely seal welded, with the exception of the bundle flange.

PACKAGER/ MANUFACTURER shall verify that his casing design is sufficient to withstand the maximum exhaust gas pressure of gas turbine.

Design thermal growth (of coil, exhaust components, etc) shall be based on the temperature differential between minimum ambient temperature and design outlet temperature as stated in the process data sheets.

All access doors (minimum size 600mm diameter) shall be provided in the plenum above and below the coil to allow inspection and cleaning of all heat transfer surfaces without removing the coil section from the plenum.

WHRU bundle cover shall be bolted to allow tube bundle removal. WHRU bundle cover to allow the closing of the WHRU's casing while bundle is removed for maintenance, and in this way permitting the GTG to operate without the WHRU bundle.

WHRU plenum shall be designed with internal baffling, as required, to evenly distribute the hot gas over the surface of the heating coil and eliminate low flow areas within the plenum.

6.6 DUCTWORK

Maximum prefabrication of WHRU is preferred in order to minimize field erection labor.

All bolts, nuts and washers shall be 316L Stainless steel.

Ductwork insulation design, supply, and installation shall be the responsibility of the PACKAGER/ MANUFACTURER. The exhaust ductwork shall be insulated to ensure that the external surface temperature of the ducting does not exceed the limit of 60°C for personnel protection.

The external insulation and jacketing shall be anchored (or shall be fixed) properly to withstand the climatic conditions described in I-ET-3A36.00-1000-941-PPC-001_F and I-ET-3A26.00-1000-941-PPC-001_F - METOCEAN DATA.

Ducting shall be made of plate steel with a minimum thickness of 4.8mm, supported by structural steel, and shall be externally insulated. To prevent corrosion under insulation, only non-hygroscopic insulation material shall be used. In order to avoid damages during transportation and erection, insulation shall be carried out after final installation in place.

WHRU inlet ducting shall comprise the complete ducting from the gas turbine exhaust flange to the WHRU inlet flange (or plenum) and the ducting to the bypass stack.

The exhaust gas ducting shall comprise the complete ducting from the WHRU outlet flange to the stack.

The silencer ducting shall comprise the complete ducting from the silencer outlet flange to the bypass stack.

Ducting, including bends and inlet plenum shall have a design pressure not less than 380mm of water column.

Guide vanes shall be designed to avoid resonance and the formation of eddies in the exhaust stream. Attachment to ducting shall be by welding and allowance shall be made for differential thermal expansion.

Ducting shall be sufficiently stiffened against mechanical vibration and distortion. Stiffening shall not restrict the free expansion of the ducting in any direction.

All ducting shall be designed such that the free cross-sectional area provides stable gas flow and acceptable pressure loss.

Transition pieces between duct sections of different cross-sectional areas shall be provided as necessary. These shall be designed with the objective of preventing flow detachment from the duct wall and providing the most economical pressure loss.

Diverging sections shall be designed commensurate with maintaining gas flow uniformity across the cross-sectional area. If necessary, guide vanes shall be used to maintain flow uniformity.

Duct supports, expansion joints, brackets, nuts packing, pipe supports, etc., shall be provided as required.

Provision to continuously drain all rainwater that enters the stack during periods of shutdown or inactivity of the unit shall be made. PACKAGER/ MANUFACTURER shall propose a suitable method for PURCHASER review and acceptance.

PACKAGER/ MANUFACTURER shall further provide a detailed, step-by-step written procedure for the installation/erection of the exhaust gas ducting system. Such procedure shall be submitted to the PURCHASER for review.

Duct supports shall be placed along the unit to remove all duct loads towards the gas turbine exhaust / exhaust stack flange. The ducts shall be supported to allow lateral as well as axial grow due to temperature changes. Ducts shall be sufficiently rigid to avoid vibration.

The duct system shall be arranged so that the minimum number of changes in direction is made.

The housing drainage design shall ensure that water does not stand inside the unit at any time. The drainage system shall be designed such that exhaust gas is not allowed to be drawn into the stream through the drain piping.

Stack height shall be sufficient to meet the Local Environmental Control Legislations requirements and shall be confirmed on Detailing design by SUPPLIER, due to interference of the exhaust gases on the Helideck.

Inspection openings shall be provided and also a 2" nozzle on the exhaust stack, fitted with blind flange, for future emissions monitoring.

Stack design shall prevent rain ingress into the gas turbine exhaust manifold.

To prevent exhaust gases from leaking into the acoustic enclosure, all drains from the exhaust manifold shall terminate in a water trap with sufficient height to maintain a water column not less than the maximum exhaust back pressure.

Ducting shall be designed to withstand distortion under the maximum expected back pressure without leaking.

PACKAGER/ MANUFACTURER shall specify outlet stack support requirements that will be imposed on the silencer outlet flange.

All required supporting system (including spring supports, structure, etc.) shall be supplied (on-skid elements) and specified with all design requirements, as loads, position, etc. by PACKAGER/ MANUFACTURER for all items inside his scope of supply.

6.7 EXPANSION JOINT

Expansions joints manufactured of metal bellows shall be provided to limit thermally induced forces and moments to values acceptable to the turbine, three-way diverter valve and silencer manufacturers, if applicable.

Expansion joint shall be supplied with flow liners.

All expansion joints shall be shipped with removable braces to hold the expansion joint in the cold installed position.

The expansion joint shall be capable of both axial and lateral deflection.

They shall be of high temperature fabric multi-layered and reinforced with stainless steel wires. The fabric shall be protected internally by insulation and metal sleeves. External protection shall be by stainless steel wire mesh and a ventilated rain shield. All metal parts in contact with the expansion joint fabric shall have rounded edges. The expansion joints shall be designed for continuous operation under the most severe operating conditions, and for ease of maintenance.

Expansion joints shall be provided in the exhaust gas ducting, as necessary. The fabric type as described above may be applied or, alternatively, the joints may be of the steel-bellows type with inner sleeves and shall be insulated externally to prevent the temperature of the metal in contact with the exhaust gas falling below the dew point of the exhaust gas.

6.8 EXAUST GAS DIVERTER VALVES (Louvres or Dampers)

6.8.1 General

The exhaust gas ducting from each turbine shall include diverter valve to control exhaust gas flow to the heat recovery section.

The diverter valves shall be designed for continuous operation at any position between the fully opened or closed position using a single pneumatic actuator. WHRU dampers shall be able to modulate enough to supply only 10% of the heat generated by the turbine when it is operating at 100% load.

Dampers supports shall allow free movement along damper axis due to duct thermal expansion. The dampers shall also be provided with a manual device allowing its manual operation.

The dampers bearings and shafts gaskets shall be designed to allow easy removal and reinstallation.

The diverter valves positioned on the bypass and on the waste heat recovery inlet shall have a mechanical interlock connecting the valves. The interlock shall insure that both valves cannot close simultaneously.

The diverter valves shall not allow more than 1% total mass flow leakage, across the full range of exhaust gas flow, at the design temperatures. Additional sealing devices such as air blowers shall be provided to block the 1% mass flow that may leak through diverter valves when in closed position.

In order to minimize warpage, binding and leakage, the diverter frame, blade(s) and shafting shall, insofar as practical, be produced from materials having similar expansion coefficients.

PACKAGER/ MANUFACTURER shall provide the calculated backpressure for the WHRU when turbine exhaust is in full load operation.

The units shall have interlocking between the position of modulating dampers and the start-up of the turbo-generator.

6.8.2 Seals

The diverter seals shall be fabricated of materials that are not adversely affected by the temperature, composition and corrosive or erosive environment of the exhaust gas system.

The design and construction of the diverter seals shall consider the differential expansion of the various components, including the blade(s), shaft, frame and seals.

6.8.3 Blades, Shaft Bearings, and Packing Glands

The pivot shaft shall be of a one-piece design and manufactured of solid stainless steel.

The bearings may be of either ball or sleeve type, and shall be selected on the basis of the pivot shaft temperature and the ambient conditions at the installation. Bearing shall be lubrication free, and suitable to operate whilst exposed to the temperature of the exhaust gases.

Bearing shall be mounted outboard of the packing gland, to avoid exhaust gas contamination and overheating in the event of packing gland failure. Safe access to the lubrication point shall be provided. Bearings mounting shall allow easy access for replacement.

The use of Polyamide or any other synthetic cage material design is not allowed.

6.8.4 Actuator

The actuator shall be double-acting piston type and shall be suitable to operate whilst exposed to high temperatures around it.

Each diverter valve actuator shall be supplied with solenoid valves, positioners, air supply filter/regulators, pressure gauges for supply, input, and output to actuator, and limit switches to indicate when the diverter valves are closed or open, and automatically control the process heating water temperature, according I-DE-3010.2D-5125-944-P4X-002/007 - TURBOGENERATOR WASTE HEAT RECOVERY note 10.

6.9 INSTRUMENTATION AND CONTROLS

6.9.1 Interface with FPSO Control and Safety System

The FPSO control and safety interface signals are shown in the I-DE- 3010.2D- 5125- 944- P4X- 002 - TURBOGENERATOR WASTE HEAT RECOVERY "A", I-DE-3010.2D-5125-944-P4X-003 - TURBOGENERATOR WASTE HEAT RECOVERY "B", I-DE-3010.2D-5125-944-P4X-004 - TURBOGENERATOR WASTE HEAT RECOVERY "C", I-DE-3010.2D-5125-944-P4X-005 - TURBOGENERATOR WASTE HEAT RECOVERY "D", I-DE-3010.2D-5125-944-P4X-006 - TURBOGENERATOR WASTE HEAT RECOVERY "E", and I-DE-3010.2D-5125-944-P4X-007 - TURBOGENERATOR WASTE HEAT RECOVERY "F", and shall be implemented in the TGCP logic system, in addition to the controls and interlockings required by WHRU system PACKAGER to guarantee the safety operation. The WHRU control shall be performed by TGCP. Hardwired and network signals from WHRU and CSS shall be according to I-ET-3010.2D-1200-800-P4X-014 - AUTOMATION INTERFACE OF PACKAGED UNITS.

The WHRU system package classification is defined in I-ET-3010.2D-1200-800-P4X-014 - AUTOMATION INTERFACE OF PACKAGED UNITS and I-ET-3010.00-1350-940-P4X-001 - SYSTEMS OPERATION PHILOSOPHY, and shall be in accordance with the I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS and all control and interlocking shall be carried out to the Topsides CSS.

6.9.2 Internal Control and Safety Requirements

PACKAGER/ MANUFACTURER shall be responsible for providing all necessary instruments, valves, devices and control and safety strategies for the WHRU system, in order to operate adequately and without interruption and to ensure safe operations.

PACKAGER/ MANUFACTURER shall develop the control and safety strategies for the WHRU system taking into account at least the following aspects and requirements:

All requirements and recommendations mentioned in this specification, specially item 6 and its sub items;

WHRU divert valves shall be modulated in order to achieve the specified temperature set point, referred to the temperature at the outlet pipeline or connection. A temperature transmitter will be located in the outlet piping or connection of the WHRU.

WHRU diverter valves shall fail to the position routing all exhaust gas to the silencer;

The operation of the WHRU shall modulate the divert valves to the silencer;

Water flow inside the heating coils shall be established prior to performing any action.

The external shutdown signal (ESD-3P or ESD-3T) shall lead the WHRU system to safe condition.

WHRU control and safety interlocking strategies shall also provide status, alarm, malfunction, and shutdown signals to the turbo-generator control panel. This information shall be confirmed and updated by PACKAGER/ MANUFACTURER and shall be provided to PURCHASER at BID stage;

In order to achieve the best performance of WHRU, PACKAGER/ MANUFACTURER shall inform all necessary signals from the Turbo-generator Control Panel (TGCP). PACKAGER/ MANUFACTURER shall confirm the need of a run permissive signal from the turbo-generator control panel.

Where necessary, on hot spots, monitoring transmitters (4-20 mA) shall be included in the WHRU.

6.9.3 Other Requirements

Draft gauge connections (50mm, 150#, RF with blind flanges) shall be installed at the inlet and outlet of the plenum and in the ductwork at the upstream and downstream sides of both diverter assemblies.

Thermowell connections (50mm, 150#, Carbon Steel) shall be installed at the inlet and outlet of the plenum section.

All switches and sensors shall be suitable for high temperature applications.

All instrument connections shall be clear of thermal insulation.

The pipe sleeves shall be seal welded to exhaust gas containing surfaces, to prohibit leakage to the atmosphere.

6.10 DESIGN AND FABRICATION (PRESSURE VESSELS)

6.10.1 Pressure Vessels Design

For all intents and purposes throughout this specification, pressure containing parts of the WHRU will be referred to as “Pressure Vessel” or “Vessel”.

WHRU shall comply with requirements of NR 13 where applicable.

The facing and holes of all nozzle flanges shall be in accordance with standard ASME B16.5 or B16.47.

Each vessel shall have its own support and shall not be supported by piping even in the case of small vessels.

6.10.1.1 Material requirements

Steels for pressure parts shall present a carbon content not exceeding 0.30 %, and for shell and head plates the carbon content shall not exceed 0.26 %. Steels having a carbon content exceeding the above limits may be used only in the following circumstances:

a) non-welded parts, such as blind flanges and manhole covers;

b) plates more than 50 mm in thickness.

The use of steels containing other alloy elements besides manganese and silicon and/or with tensile stress exceeding 485 MPa (70 ksi), nominal stress value given in the material specification, as well as the use of quenched and tempered steels shall be subject to PURCHASER previous approval.

When using austenitic stainless, only materials that are not susceptible to sensitization shall be used (low C steels, types L and ELC or stabilized steels).

The use of cast parts shall be kept to a minimum and this has to be submitted at all times to PURCHASER previous approval.

To avoid corrosion under insulation only non-hygroscopic insulation material must be selected for personal protection.

6.10.1.2Pressure vessels connections/flanges

For nozzles less than 2” in nominal diameter, forged steel couplings may be used. Couplings shall be at least class 6000#, for socket weld.

All nozzles having a nominal diameter of 2” or over, shall be flanged, except when specified for butt weld in the piping.

The minimum nominal diameter of nozzles intended for any purpose shall be 3/4”. Flanges having a nominal diameter up to and including 1 1/2” may be of the following types:

a) long welding neck flange;

b) welding neck flange with a neck sch. 160 or XXS.

Flanges having a diameter from 2” to 12”, inclusive, shall be of the forged steel welding neck type.

6.10.2 Pressure Vessels Fabrication

6.10.2.1 Welding

Welding must be done following the requirements of API RP 582: Welding Guidelines for the Chemical, Oil, and Gas Industries.

6.10.2.2 Welding inspection

For radiography examination the PACKAGER/ MANUFACTURER must follow ASME Section VIII, part UW (REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY WELDING), with the exceptions and addends below.

(TABLE UW-12) The Degree of Radiographic Examination: 100% RADIOGRAPHY (FULL).

(TABLE UW-12) Besides those joints shown in TABLE UW-12, any case of pressure weld which fulfill the requirements below must be radiographic tested:

- Full penetration tee or corner-type joints including nozzle attachment welds shall be 100% nondestructively tested by either radiographic or ultrasonic examination.
- Welds of any parts, regardless of the material, thickness or service, shall be fully (100 %) radiographed before any severe deformation (thickness to local radius ratio greater than 5 %), by any process, such as spinning, pressing and rolling.
- Welds used for closing guide holes at the center of formed heads shall be fully (100%) radiographed.
- Shell welds hidden by reinforcement plates shall be ground, examined by magnetic particles or liquid penetrant and be fully (100%) radiographed.

6.10.2.3 Other NDT tests

For other NDT tests, PACKAGER/ MANUFACTURER must follow ASME Section VIII, part UG (Inspection and Tests), with the addends below.

- Visual examination (UG-97): All welds must be subjected to a visual inspection, internal and externally.
- Magnetic particle and liquid penetrate examination (UG-103):
  a) Welds: See tables 1 and 2 below for detailed requirements.
  b) Temporary welds: Temporary welds shall be removed and the metal surface shall be restored to a smooth contour. The area shall be inspected by magnetic particle or liquid penetrant test for the detection and elimination of defects (note: use the same criteria for full penetration welds).
- Positive materials identification: required as indicated below.
  a) The PMI shall be carried out with equipment capable to identify the specified type of material in accordance with established procedure. The equipment shall not make burn marks to the pipe material.
  b) The PMI shall be done prior to the welding to identify the materials which will be welded.
  c) Positive materials identification must be done on:
- All stainless steel and chrome-molly steel pipes up to (and including) 2”,

- All stainless steel and chrome-molly steel fittings up to (and including) 2”,
- Any nickel steel or nickel alloy material,
- Any internal welded support rings, lugs or other internal permanent attachment to a stainless steels or Nickel alloy pressure vessel.

a) If any non-conformance in material type is reported, the extent shall be increased pipes and fittings higher than 2” to ensure that all mix of material is discovered.

TABLE 1- INSPECTION CLASSES FOR CARBON STEEL (notes 3 and 11)

Inspection class (see tables 3,4,5 and 6)	P number materials	Any welds (pressure and non-pressure welds)	Internal non-Pressure Welds	Pressure Welds					External non-Pressure Welds	
			Welded supports on shell or heads	Butt welds and full penetration corner and nozzle welds (notes 4,10)				Fillet welds	Lug welds (UG-55)	lifting lugs and any lifting device
		Visual examination (note 1)	Magnetic particle (MT) Note 2	Magnetic particle (MT) Notes 2, 7	Hardness	Liquid penetrant (PT) of weld root pass	Ultrasonic test (UT)	Magnetic particle (MT) (note 2)	Liquid penetrant (PT) Note 2	Magnetic particle (MT) Note 5
I	1	100%	None	10%	Note 8	None	None	10%	10%	100%
II		100%	10%	50%	Note 8	None	None	100%	100%	100%
III		100%	100%	100%	Note 8	100%	Note 6	100%	100%	100%
IV		100%	100%	100%	Note 8	100%	Note 6	100%	100%	100%

TABLE 2 - INSPECTION CLASSES FOR STAINLESS STEELS INCLUDES AUSTENITIC, FERRITIC AND AUSTENITIC-FERRITIC STAINLESS STEELS(notes 3 and 11)

Inspection class (see tables 3,4,5 and 6)			I	II	III	IV
P number materials			6, 7, 8			
Any welds (pressure and non-pressure welds)		Visual examination (note 1)	100%	100%	100%	100%
Internal non-Pressure Welds	Welded supports on shell or heads	Liquid penetrant (PT)) or Magnetic particle (MT) Notes 2, 9	None	10%	100%	100%
Pressure Welds	Butt welds and full penetration corner and nozzle welds (notes 4,10)	Liquid penetrant (PT) or Magnetic particle (MT) Notes 2,7,9	10%	50%	100%	100%
		Hardness	Note 8	Note 8	Note 8	Note 8
		Liquid penetrant (PT) of weld root pass	None	None	100%	100%
		Ultrasonic test (UT)	None	Note 6	Note 6	Note 6
	Fillet welds	Liquid penetrant (PT) or Magnetic particle (MT) Notes 2, 9	50%	100%	100%	100%
External non-Pressure Welds	Lug welds (UG-55)	Liquid penetrant (PT) or Magnetic particle (MT) Notes 2, 9	50%	100%	100%	100%
	lifting lugs and any lifting device	Liquid penetrant (PT)) or Magnetic particle (MT) Notes 5, 9	100%	100%	100%	100%

Notes (for tables 1 to 2):

1- The visual examination includes weld inspection (after completion) and visual inspection of weld bevels prior to welding.

2- For MT or PT examination consider both sides of the weld (internal and external) for butt welds and weld side for fillet welds. The tested area must be 200 mm width (centered on weld) by the appropriated length of weld.

3-All plate repairs welds shall also be inspected by MT or PT test.

4- Corner joints: 100% MT or PT examination for plates thicker than 13mm (see UG-93).

5- Any lifting device and its respective weld to pressure vessel must be inspected by MT or PT test.

6- Nozzles having a nominal diameter equal to or larger than 4” and self-reinforced nozzles with the opening in the shell having a diameter equal to or greater than 100 mm shall undergo ultrasonic examination at the following welded joints:

a) full penetration welded joint between nozzle neck and vessel shell;

b) welded joint between nozzle neck and reinforcement pad (if any).

7- For nozzles having reinforcement pad, a liquid penetrant or magnetic particle examination shall be carried out after the completion of the nozzle-to-neck weld, before the installation of the reinforcement pad.

8- Hardness limits criteria according to qualified welding procedure. Obligatory to follow the requirements of ISO 15156 or API RP 945 when it is required.

9- Magnetic particle (MT) test for ferritic or martensitic stainless steels.

10- Bevels shall be visual tested and completed by the liquid penetrant or magnetic particle test, in the following cases:

a) Vessels inspection class IV or III;

b) Any bevels recovered by welding;

c) Pressure vessels made of materials other than P-1 materials.

11- Temporary welds in pressure parts, being fillet or butt weld, shall be liquid penetrant or magnetic particle tested.

TABLE 3 - FLUID CATEGORIES

Category	Fluid	Notes
1	**Flammable or toxic gas**	**H_2S content classify the gas as toxic**
2	**Other gases**	
3	**Explosive, flammable, oxidizing or toxic liquid**	**If a fluid has a vapour pressure at the maximum allowable temperature of the equipment of greater than 0.5 bar above normal atmospheric pressure (1 013 mbar), it is treated as a gas, otherwise it is treated as a liquid.**
4	**Other liquids**	

TABLE 4- PRESSURE CATEGORIES FOR LIQUID FLUIDS

Category	Design Pressure
A	**Up to 0,5 bar**
B	**Higher than 0,5 bar to 10 bar**
C	**Higher than 10 to 350 bar**
D	**Higher than 350 bar**

TABLE 5- PRESSURE CATEGORIES FOR GAS FLUID

Category	PV = Design Pressure (bar) x internal volume (liters)
A	**Up to 25**
B	**Higher than 25 to 50**
C	**Higher than 50 to 200**
D	**Higher than 200**

TABLE 6- INSPECTION CLASSES FOR PRESSURE VESSELS

PRESSURE Category	FLUID CATEGORY			
	1	2	3	4
A	**II**	**I**	**II**	**I**
B	**III**	**II**	**II**	**II**
C	**IV**	**III**	**III**	**III**
D	**IV**	**IV**	**IV**	**IV**

Notes
1) For vessels containing two phase fluids (gas and liquid) adopted the inspection class for gas fluid or, if the liquid is class 3 and gas class 2, adopted the inspection class for liquid.
2) Any combination of fluid and material that can be prone to stress corrosion cracking according to ISO 151546 or API RP 945, must be adopted the more stringent class for fluid classification (3 for liquid or 1 for gas).
3) Inspection class IV shall be adopted for pressure vessels made of materials which requires impact test or for pressure vessels for vacuum service.

6.10.2.4 Penalties

Hardness above the maximum established: Heat treat the equipment, limited to the maximum two heat treatments.

Weld defects: In case of detection of weld defects not approved by the construction code, increase the inspection for 100% of the welds.

7 PAINTING

Paint system shall be according to I-ET-3010.00-1200-956-P4X-002 – GENERAL PAINTING.

Color code adopted shall be in accordance with DR-ENGP-I-1.15 – COLOR CODING.

8 NAMEPLATES

PACKAGER/ MANUFACTURER shall attach corrosion resistant SS 316 nameplates on each item of equipment in an accessible location, fastened with corrosion resistant pins.

The nameplate information shall include, as a minimum, the following items in the Portuguese language:

- Tag number

- Manufacturer and year built
- Ancillary equipment's serial number and type
- Capacity, volume, flow rate, heat exchange rate, etc.
- Design code
- Design temperature and pressure

9 TAG NUMBERING

Tagging of all instruments, electrical, mechanical and piping items, including valves, shall be in accordance with latest revision of I-ET-3000.00-1200-940-P4X-001 - TAGGING PROCEDURE FOR PRODUCTION UNITS DESIGN.

Tags shall be supplied with description in Portuguese language, unless otherwise stated in the project data sheets.

All tag labels shall be made from SS 316.

Valves and instruments shall be tagged with the applicable number only.

Tagging of all instruments, electrical, mechanical and piping items, including valves, shall be carried out by PACKAGER/MANUFACTURER and confirmed by OWNER.

10 SAFETY SIGNS

All safety signs shall be in Portuguese, and their layout, size, colors, fonts, materials etc. shall meet the requirements of I-ET-3010.00-5400-947-P4X-002 – SAFETY SIGNALLING.

11 CERTIFICATION REQUIREMENTS

11.1 CLASS CERTIFICATION

For each package, a Classification Society Certificate of compliance with Rules requirements shall be supplied.

11.2 MATERIAL CERTIFICATION

PACKAGER/ MANUFACTURER shall be responsible for obtaining all necessary certification of the equipment. The PACKAGER/ MANUFACTURER through the independent certifying authority shall supply all certificates related to the materials, inspections, tests and qualification activities detailed in the approved Quality Plan.

All castings shall have the material designation embossed and engraved on each part.

12 INSPECTION AND TESTING

12.1 INSPECTION

PACKAGER/ MANUFACTURER shall submit an Inspection and Test Plan (ITP) in the technical proposal.

PURCHASER shall identify all the required witnessed inspections on a marked up copy of the Inspection and Test Plan (ITP).

It is the PACKAGER/ MANUFACTURER responsibility to provide sufficient notice of testing/inspection to the respective classification society, such that a class certificate can be obtained.

All WHRU shall be subjected to inspections in manufacturer's shop by buyer/owner representatives.

12.2 TESTING

All WHRU coils shall be hydro tested in accordance with the ASME Code for a minimum duration of two hours.

WHRU coils of stainless steel shall be tested with water that does not exceed 100ppm chloride content. After testing, the coil shall be immediately drained and dried internally.

Copies of all test records and data shall be available to buyer/owner representative including manufacturer's data sheet, hydrostatic test records, radiographic film, etc.

12.2.1 Factory Acceptance Test (FAT)

PURCHASER requires witnessed testing for each major sub-component in the Waste Heat Recovery Unit.

The following items (and their spares, if applicable) shall be mechanically tested to the fullest extent possible in the manufacturer's shop prior to their release for shipment:

- Safety Valves
- Package WHRU Hydrostatic Test (including bundle coil and headers)
- Dampers operations and leakage

Tests shall take the form of a mechanical test performed in accordance with a mutually acceptable code or standard.

Copies of all test records and data shall be available to PURCHASER including MANUFACTURER'S/PACKAGER'S data sheet, hydrostatic test records, radiographic film, etc.

12.2.2 Field Testing

PURCHASER may elect to conduct performance tests on any or all components of the Waste Heat Recovery Unit. PACKAGER/ MANUFACTURER shall ensure that all instrumentation or test points required for testing are provided with the equipment. Test standards shall be in accordance with those listed in this specification.

13 PACKAGER/ MANUFACTURER RESPONSIBILITY

PACKAGER/ MANUFACTURER shall assume total engineering responsibility for the complete package.

MANUFACTURER'S/PACKAGER'S responsibility shall also include but not be limited to:

- Resolving all engineering questions and/or problems relating to design and manufacture.
- Providing details as requested of sub-vendors relating to design and manufacturing.
- In all cases of conflict between this specification and applicable documents listed herein, the more stringent requirements shall prevail. In such cases, PACKAGER/ MANUFACTURER shall inform PURCHASER of the conflict and seek clarification.

- Installation at site by others, however, presence of supervision will be required.

Compliance by the PACKAGER/ MANUFACTURER with the provisions of this specification does not relieve the PACKAGER/ MANUFACTURER of responsibility to furnish equipment and accessories of a proper mechanical design suited to meet the specified service conditions.

Any exclusion and/or alternative to what is specified in this Technical Specification, including the use of the PACKAGER/MANUFACTURER's standard and exclusive technology, shall be presented in a Deviation List, subject to PETROBRAS acceptance during the clarification phase, together with the proposal presentation. Otherwise the requirements herein will be considered as "Agreed", and so required.