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SUMMARY

1. PURPOSE

The purpose of this document is to provide input data and set minimum technical requirements to be considered during the design, manufacturing, assembly, inspection and testing, shipping, construction, commissioning, and startup for the **Combined Cycle Power Generation package** to be installed in FPSO Revit de Marlim Leste e Sul.

2. DEFINITIONS AND ABBREVIATIONS

2.1 Definitions

For the purposes of this document, the following definitions shall apply:

PETROBRAS	FPSO owner and operator company (end-user).
PURCHASER	The EPC Contractor company, responsible for the detail design, supply of materials, fabrication, erection, construction, commissioning, and startup of the entire FPSO vessel, including the lifting, hook-up, installation, and integration of all Modules in the FPSO topside, with complete and fully operative systems in accordance with the requirements of this specification, and other technical documents, codes and standards referenced herein.
CCPG PACKAGER	The Main Vendor company with unit responsibility for the whole Combined Cycle Power Generation system, and responsible for providing this system to the PURCHASER as a single and integrated package.
Unit Responsibility	Obligation for coordinating the documentation, delivery, and technical aspects of all the equipment and all auxiliary systems included in the CCPG package.

2.2 Abbreviations

ACF	Active Carbon Filter
AISI	American Iron and Steel Institute
AMS	Asset Management System
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AVR	Automatic Voltage Regulators
BFW	Boiler Feed Water
BoP	Balance of Plant
CC	Combined Cycle
CCPG	Combined Cycle Power Generation
CEP	Condensate Extraction Pump
CHP	Combined Heat and Power
DM	Demineralized
EDI	Electro Deionization
EPC	Engineering, Procurement and Construction
ESD	Emergency Shutdown
FAT	Factory Acceptance Test
FC	Flow Controller
FIT	Flow Indicator Transmitter
FRP	Fiber-Reinforced Plastics
FV	Flow Valve
FPSO	Floating, Production, Storage, and Off-loading
GT	Gas Turbine

GTG	Gas Turbogenerator
HAZOP	Hazard and Operability Study
HEI	Heat Exchange Institute
HFE	Human Factors Engineering
HM	Heating Medium
H&MB	Heat and Mass Balance
HP	High Pressure
IEC	International Electrotechnical Commission
INMETRO	Instituto Nacional de Metrologia, Qualidade e Tecnologia (Brazilian Institute of Metrology, Quality and Technology)
IOM	Installation, Operating and Maintenance
LG	Level Gauge
LI	Level Indicator
LIT	Level Indicator Transmitter
LP	Low Pressure
LSH	High-Level Level Switch
LSHH	Level Switch High-High
LSL	Low-Level Level Switch
LSLL	Level Switch Low-Low
MMS	Machinery Monitoring system
MPS	Machinery Protection System
MRT	Mechanical Running Test
NDE	Non-Destructive Evaluation
NR	Norma Regulamentadora (Brazilian Labor Regulatory Standard)
OEM	Original Equipment Manufacturer
OTSG	Once-Through Steam Generator
PAS	Package Automation System
PDI	Differential Pressure Indicator
PDIT	Differential Pressure Indicator Transmitter
PDSH	High-Differential Pressure Differential Pressure Switch
PFD	Process Flow Diagram
P&ID	Process and Instrumentation Diagram
PI	Pressure Indicator
PIT	Pressure Indicator Transmitter
PMS	Power Management System
PSL	Low-Pressure Pressure Switch
PSH	High-Pressure Pressure Switch
PSV	Pressure Safety Valve
RAM	Reliability, Availability and Maintainability
RIO	Remote Input Output
SCTA	Safety Critical Task Analysis
SI	International System of Units
SGFW	Steam Generator Feedwater
SLT	Sound Level Test

SPIE	Serviço Próprio de Inspeção de Equipamentos (In-house Equipment Inspection Service)
SPL	Sound Pressure Level
STG	Steam Turbogenerator
TEMA	Tubular Exchanger Manufacturers Association
TGCP	Turbogenerator Control Panel
TOC	Total Organic Carbon
VDDR	Vendor Drawing and Data Requirements
WHRU	Waste Heat Recovery Unit

3. REFERENCE DOCUMENTS

In addition to the requirements set out elsewhere in this specification, the design, materials, fabrication, assembly, inspection and testing, commissioning and startup of the equipment, materials, and services shall be in accordance with the latest issues and addenda in effect at the date of inquiry or contract, as agreed upon by PETROBRAS and the PURCHASER / CCPG PACKAGER, of the following documents:

3.1 PETROBRAS Technical Documentation

3.1.1 Drawings

I-DE-3010.00-5140-700-P4X-003	Grounding Installation Typical Details
I-DE-3010.00-5140-797-P4X-001	Electrical System Automation Architecture Diagram
I-DE-3010.00-5140-797-P4X-002	Electrical System Automation Typical Actuation Diagrams
I-DE-3010.2Q-1200-944-P4X-001	General Notes
I-DE-3010.2Q-5125-944-P4X-002	Turbogenerator Waste Heat Recovery A
I-DE-3010.2Q-5125-944-P4X-003	Turbogenerator Waste Heat Recovery B
I-DE-3010.2Q-5125-944-P4X-004	Turbogenerator Waste Heat Recovery C
I-DE-3010.2Q-5125-944-P4X-005	Turbogenerator Waste Heat Recovery D
I-DE-3010.2Q-5132-943-P4X-001	Combined Cycle System
I-DE-3010.2Q-5132-944-P4X-001	Combined Cycle Power Plant Package
I-DE-3010.2Q-5135-943-P4X-001	Fuel Gas System
I-DE-3010.2Q-5147-944-P4X-001	Gas Turbogenerator Interconnection A/B
I-DE-3010.2Q-5147-944-P4X-002	Gas Turbogenerator Interconnection C/D
I-DE-3010.2Q-5147-944-P4X-003	Steam Turbogenerator Interconnection
I-DE-3010.2Q-1200-947-P4X-001	Emergency Shut Down Diagram
I-DE-3010.2Q-5265-946-P4X-001	Topside UPS and DC Systems One-Line Diagram
I-DE-3010.2Q-5520-800-P4X-002	Automation and Control Architecture

3.1.2 Technical Specifications

I-ET-3000.00-1200-940-P4X-001	Tagging Procedure for Production Units Design
I-ET-3000.00-5400-947-P4X-007	Human Factors Engineering (HFE)
I-ET-3000.00-1000-941-PPC-001	Metocean Data
I-ET-3010.00-1200-200-P4X-003	Design, Construction and Assembly of FRP Piping
I-ET-3010.00-1200-200-P4X-115	Requirements for Piping Fabrication and Commissioning
I-ET-3010.00-1200-200-P4X-116	Requirements for Bolted Joints Assembly and Management
I-ET-3010.00-1200-251-P4X-001	Requirements for Bolting Materials

I-ET-3010.00-1200-310-P4X-001	API 610 Centrifugal Pumps Specification
I-ET-3010.00-1200-431-P4X-001	Thermal Insulation for Maritime Installations
I-ET-3010.00-1200-451-P4X-001	Requirements for Shell and Tube Heat Exchanger Design and Fabrication
I-ET-3010.00-1200-456-P4X-001	Requirements for Plate Heat Exchanger Design and Fabrication
I-ET-3010.00-1200-500-P4X-001	Non-Metallic Tanks and Pressure Vessels Design
I-ET-3010.00-1200-510-P4X-001	Metallic Tanks Design for Topside
I-ET-3010.00-1200-540-P4X-001	Requirements for Pressure Vessels Design and Fabrication
I-ET-3010.00-1200-800-P4X-002	Automation, Control and Instrumentation on Package Units
I-ET-3010.00-1200-800-P4X-010	Criteria for Establishing Cable Codes and Cable Gland Codes
I-ET-3010.00-1200-800-P4X-012	Criteria for Detailing Design Cause & Effect Matrix
I-ET-3010.00-1200-800-P4X-013	General Criteria for Instrumentation Projects
I-ET-3010.00-1200-850-P4X-002	Asset Management System (AMS)
I-ET-3010.00-1200-940-P4X-005	Chemical Injection Points
I-ET-3010.00-1200-956-P4X-002	General Painting
I-ET-3010.00-1200-956-P4X-003	Thermal Spray Coating Application of Aluminum
I-ET-3010.00-1200-970-P4X-012	Compliance with NR-12 Requirements
I-ET-3010.00-1200-970-P4X-013	Compliance with NR-13 And SPIE Requirements
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 for Offshore Units
I-ET-3010.00-5140-700-P4X-003	Electrical Requirements for Packages for Offshore Units
I-ET-3010.00-5140-700-P4X-004	PN-5140001 - Power Management System (PMS) for Offshore Units
I-ET-3010.00-5140-700-P4X-005	Requirements for Human Engineering Design for Electrical Systems of Offshore Units
I-ET-3010.00-5140-700-P4X-007	Specification for Generic Electrical Equipment for Offshore Units
I-ET-3010.00-5140-700-P4X-008	Specification for Lighting and Electrical Signalling for Offshore Units
I-ET-3010.00-5140-700-P4X-009	General Requirements for Electrical Material and Equipment for Offshore Units
I-ET-3010.00-5140-712-P4X-001	Low-Voltage Induction Motors for Offshore Units
I-ET-3010.00-5140-713-P4X-001	Specification for Transformers for Offshore Units
I-ET-3010.00-5140-714-P4X-001	Specification for Electrical Batteries for Offshore Units

I-ET-3010.00-5140-741-P4X-004	Specification for Low-Voltage Generic Electrical Panels for Offshore Units
I-ET-3010.00-5140-772-P4X-002	Specification for Low-Voltage Frequency Converters, Soft-Starters and Inverters for Offshore Units
I-ET-3010.00-5140-773-P4X-002	Specifications for Generic DC UPS for Offshore Units
I-ET-3010.00-5140-775-P4X-001	Requirements for Electrical Generation Excitation System for Offshore Units
I-ET-3010.00-5140-797-P4X-001	Electrical System Automation Architecture
I-ET-3010.00-5147-332-P4X-001	Gas Turbine Driver for Gas Turbogenerator Set
I-ET-3010.00-5147-711-P4X-001	Main Generator for Offshore Units
I-ET-3010.00-5400-947-P4X-002	Safety Signalling
I-ET-3010.00-5500-854-P4X-001	Machinery Monitoring System
I-ET-3010.00-5520-888-P4X-001	Automation Panels
I-ET-3010.2Q-1200-91A-P4X-001	Requirements for Operation and Maintenance Manuals and Databooks
I-ET-3010.2Q-1200-200-P4X-001	Piping Specification for Topside
I-ET-3010.2Q-1200-200-P4X-004	Requirements for Piping Support
I-ET-3010.2Q-1200-200-P4X-005	Requirements for Piping Mechanical Design and Layout
I-ET-3010.2Q-1200-200-P4X-006	Requirements for Piping Flexibility and Stress Analysis
I-ET-3010.2Q-1200-800-P4X-001	Instrumentation Additional Technical Requirements
I-ET-3010.2Q-1200-800-P4X-005	Field Instrumentation
I-ET-3010.2Q-1200-800-P4X-014	Automation Interface of Packaged Units
I-ET-3010.2Q-1200-919-P4X-001	Requirements for Vendors Training Content and Program
I-ET-3010.2Q-1200-940-P4X-001	Material Selection Philosophy for Detailed Design
I-ET-3010.2Q-1400-190-P4X-001	Topsides Architecture Materials and Equipment Specification
I-ET-3010.2Q-1400-196-P4X-001	Ergonomics Requirements for Topsides
I-ET-3010.2Q-5147-332-P4X-002	Steam Turbine Driver for Steam Turbogenerator Set
I-ET-3010.2Q-5147-413-P4X-001	Once-Through Steam Generator and Waste Heat Recovery Unit
I-ET-3010.2Q-5266-630-P4X-001	Topsides Mechanical Handling Procedures

3.1.3 Datasheets

I-FD-3010.2Q-5147-332-P4X-001	Gas Turbine Driver for Gas Turbogenerator Set
I-FD-3010.2Q-5147-332-P4X-002	Steam Turbine Driver for Steam Turbogenerator Set
I-FD-3010.2Q-5147-341-P4X-001	Gear Unit for Gas Turbogenerator Set
I-FD-3010.2Q-5147-341-P4X-002	Gear Unit for Steam Turbogenerator Set

I-FD-3010.2Q-5147-392-P4X-001	Oil System for Gas Turbogenerator Set
I-FD-3010.2Q-5147-392-P4X-002	Oil System for Steam Turbogenerator Set
I-FD-3010.2Q-5147-413-P4X-002	Once-Through Steam Generator and Waste Heat Recovery Unit
I-FD-3010.2Q-5147-854-P4X-001	Machinery Protection System for Gas Turbogenerator Set
I-FD-3010.2Q-5147-854-P4X-002	Machinery Protection System for Steam Turbogenerator Set

3.1.4 Lists

I-LI-3010.00-5140-700-P4X-001	Electrical Equipment Data-Sheet Models
I-LI-3010.00-5140-797-P4X-001	Electrical System Automation Interface Signals List
I-LI-3010.2Q-1200-940-P4X-002	Equipment List

3.1.5 Descriptive Memorandum

I-MD-3010.2Q-1200-800-P4X-002	Automation and Control System – Scope Definition
I-MD-3010.2Q-1200-940-P4X-005	Descriptive Memorandum - Process
I-MD-3010.2Q-1200-970-P4X-001	Commissioning Descriptive Memorandum
I-MD-3010.2Q-5520-800-P4X-001	Automation and Control System Functions
I-MD-3010.2Q-5520-800-P4X-003	Automation Net Work Description
I-MD-3010.2Q-5140-700-P4X-002	Electrical System Descriptive Memorandum
I-MD-3010.2Q-1200-320-P4X-001	Descriptive Memorandum - Turbomachinery

3.1.6 Reports

I-RL-3010.2Q-1200-940-P4X-001	General Specification for Available Utilities
I-RL-3010.2Q-1200-940-P4X-004	Process Simulation

3.1.7 Other Documents

DR-ENGP-I-1.15	Color Coding
DR-ENGP-M-II-P1-2.2	Safety Engineering Guideline

3.2 International Standards

API RP 14C	Recommended Practice for Analysis, Design, Installation, and Testing of Safety Systems for Offshore Production Facilities
API 521	Pressure-relieving and Depressuring Systems
API 560	Fired Heaters for General Refinery Service
API 610	Centrifugal Pumps for Petroleum, Petrochemical, and Natural Gas Industries
API 612	Petroleum, Petrochemical, and Natural Gas – Steam Turbines – Special-purpose Applications

API 613	Special-purpose Gears for Petroleum, Chemical, and Gas Industry Services
API 614	Lubrication, Shaft-sealing, and Oil-control Systems and Auxiliaries
API 616	Gas Turbines for the Petroleum, Chemical, and Gas Industry Services
API 670	Machinery Protection Systems
API 671	Special Purpose Couplings for Petroleum, Chemical, and Gas Industry Services
API 673	Centrifugal Fans for Petroleum, Chemical, and Gas Industry Services
API 675	Positive Displacement Pumps – Controlled Volume for Petroleum, Chemical, and Gas Industry Services
API 676	Positive Displacement Pumps – Rotary
API 681	Liquid Ring Compressors and Vacuum Pumps in Petroleum, Chemical, and Gas Industry Services
API 682	Pumps – Shaft Sealing Systems for Centrifugal and Rotary Pumps
API TR 684-1	API Standard Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals, and Rotor Balancing
API 686	Recommended Practice for Machinery Installation and Installation Design
API 687	Rotor Repair
API RP 14E	Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems
API RP 14F	Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities
API RP 14J	Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities
ASME B 16.34	Valves-Flanged, Threaded and Welding End
ASME B31.1	Power Piping
ASME B31.3	Process Piping
ASME BPVC	Section I – Rules for Construction of Power Boilers
ASME BPVC	Section VIII – Rules for Construction of Pressure Vessels
ASME BPVC	Section IX – Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators
ASME PTC 6	Performance Test Code on Steam Turbines
ASME PTC 22	Performance Test Code on Gas Turbines
ASME PTC 46	Overall Plant Performance
Energy Institute	Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework
HEI-2629	Standards for Steam Surface Condensers
IEC-60092-502	Electrical installations in ships - Part 502: Tankers - Special features
IEC 61892	Mobile and fixed offshore units - Electrical installations
IEC 60072	Dimensions and Output Series for Rotating Electrical Machines
IEC 61131	Programmable Controllers
TEMA	TEMA Book of Standards
IEEE 1309	IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes

IEEE 1688	Standard Requirements for the Control of Electromagnetic Interference Characteristics of Replaceable Electronic Modules
ISO 15156	Petroleum and Natural Gas Industries – Materials for use in H2S Containing Environments in Oil and Gas Production
ISO 1940-1	Mechanical Vibration – Balance Quality Requirements for Rotors in a Constant (Rigid) State
ISO 23936-2	Petroleum, Petrochemical and Natural Gas Industries — Non-metallic Materials in Contact with Media Related to Oil and Gas Production — Part 2: Elastomers
NACE MR0175	Sulfide Stress-Cracking Resistant Metallic Materials for Oilfield Equipment

3.3 Brazilian Local Rules and Regulations

3.3.1 Labor Regulations

All Brazilian labor regulations are mandatory and shall apply, mainly the following:

NR-1	Disposições Gerais e Gerenciamento de Riscos Ocupacionais
NR-10	Segurança em Instalações e Serviços em Eletricidade
NR-12	Segurança no Trabalho em Máquinas e Equipamentos
NR-13	Caldeiras, Vasos de Pressão, Tubulações e Tanques Metálicos de Armazenamento
NR-15	Atividades e Operações Insalubres
NR-17	Ergonomia
NR-26	Sinalização de Segurança
NR-37	Segurança e Saúde em Plataformas de Petróleo

3.3.2 INMETRO

INMETRO	Ordinance No. 115 of 03/21/2022 (including Annexes)

3.3.3 ABNT

NBR 16315	Instalação e Comissionamento de Máquinas

4. SITE DATA AND AVAILABLE UTILITIES

4.1 Site Data

4.1.1 Site Rated Conditions

Temperature: 30°C

Pressure: 1.013 bar abs

Relative Humidity: 80%

4.1.2 Other Site Conditions for CCPG Performance Evaluation

Temperature: 14°C (min.) / 37°C (max.)

Pressure: 1.013 bar abs

Relative Humidity: 80%

Note: For further information refer to *I-ET-3000.00-1000-941-PPC-001 – Metocean Data*.

4.2 Available Utilities

4.2.1 Operating and design conditions for sea water, cooling water, heating medium (hot water), instrument air, service air, inert gas (nitrogen), diesel oil and fuel gas are presented in *I-RL-3010.2Q-1200-940-P4X-001 – General Specification for Available Utilities*.

Note: Operational and design data shall be confirmed during Detail Design.

4.2.2 In Combined Cycle operation mode, it shall be considered that CCPG package will run only with fuel gas, in accordance with *I-RL-3010.2Q-1200-940-P4X-001 – General Specification for Available Utilities* and *I-DE-3010.2Q-5135-943-P4X-001 – Fuel Gas System*, and with a maximum H_2S content of 5 ppmv.

4.2.3 Fresh Water (to feed the CCPG package EDI system)

Fluid: Fresh Water

Pressure: 8 bar g

Temperature: 16°C to 25°C

Source: Treated seawater coming from the FPSO Reverse Osmosis Unit, with the following expected parameters:

Description	Value[(a)]
Total Exchangeable Anions (TEA as $CaCO_3$) including CO_2, mg/l	< 40
pH	5 to 8.5
Conductivity, µS/cm	< 43
Total Hardness (as $CaCO_3$) mg/l	< 1.0
Silica (SiO_2), mg/l	< 1.0
SDI (15 min)	< 1

Total Organic Carbon (TOC as C), mg/l	< 0.5
Total Chlorine (as Cl_2), mg/l	< 0.05
Fe, mg/l	< 0.01
Mn, mg/l	< 0.01
H_2S, mg/l	< 0.01
Na, mg/l	< 1.1
CO_2, mg/l	< 0.19
O_2, mg/l	<0.020[(b)]
SO_4	<0.014
HCO_3	<0.031
K	<0.054
Cl	<1.7
NO_3	<0.001
B	<0.56

Notes: a. values above to be confirmed by the FPSO Reverse Osmose Vendor during the detail design; b. obtained by Oxygen scavenger injection ($NaHSO_3$).

5. CCPG PERFORMANCE EVALUATION AND SIZING CRITERIA

5.1 The CCPG package shall comply with the following operational cases:

5.1.1 Case C1N118

5.1.1.1 3 GTGs/OTSGs/WHRUs running.

5.1.1.2 STG running.

5.1.1.3 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.1.4 Site rated conditions.

5.1.1.5 Overall CCPG gross output power shall be not less than 118 MWe.

5.1.1.6 FPSO heat demand: 55 MW.

5.1.1.7 HM temperature at WHRU inlet: 97.0 °C.

5.1.2 Case C1N

5.1.2.1 Up to 3 GTGs/OTSGs/WHRUs running.

5.1.2.2 STG running.

5.1.2.3 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.2.4 Site rated conditions.

5.1.2.5 Power demand, heat demand and HM temperature at WHRU inlet according to table below:

Scenario	Power demand (MW)[1]	Heat demand (MW)[2]	HM Temperature at WHRU inlet (°C)
1	57.6	17.1	117.9
2	77.3	37.8	102.6
3	90.2	43.1	104.5
4	105.9	49.3	100.3
5	107.7	50.4	99.5
6	110.3	50.7	96.7
7	112.8	53.7	97.3
8	115.5	55.0	97.0
9	109.6	55.9	98.4
10	99.3	57.2	98.9

Note 1: Gross output power to be delivered by the CCPG package to the FPSO electrical grid (including Cooling Water Booster Pump B-UG-5132001-07A/B, if required, as well as all other power consumers from the CCPG package).

Note 2: An additional intermittent heat demand of 18.6 MW shall also be evaluated and reported for Scenario 8 (not to be used as design case).

5.1.3 Case C2 (CCPG on "pure" combined cycle mode - for performance evaluation only)

5.1.3.1 3 GTGs/OTSGs/WHRUs running.

5.1.3.2 STG running at full condensing mode (no steam extraction).

5.1.3.3 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.3.4 Maximum site temperature (37ºC).

5.1.3.5 Overall CCPG gross output power shall be not less than 118 MWe.

5.1.3.6 Thermal duty given by the WHRUs in operation only.

5.1.3.7 HM temperature at WHRU inlet: 97.0 °C.

Note 1: Case C2 corresponds to an outlier operating condition that shall be used to validate the CCPG system behavior against the STG rated power specified in Section 11 of this document.

Note 2: For this case, the FPSO heat demand is assumed to be lower than 55 MW.

5.1.4 Case C3 (sizing case for HP/LP Letdown Station)

5.1.4.1 4 GTGs and 3 OTSGs/WHRUs running.

5.1.4.2 No GT degradation due to ageing and fouling.

5.1.4.3 Site rated conditions.

5.1.4.4 STG not in operation.

5.1.4.5 Thermal duty given by the Steam/Hot Water Heat Exchanger (via HP/LP Letdown Station) and WHRUs in operation.

5.1.4.6 Overall gross output power: 99.3 MWe.

5.1.4.7 FPSO heat demand: 57.2 MW.

5.1.4.8 HM Temperature at WHRU inlet: 98.9 °C.

5.1.5 Case C4

5.1.5.1 4 GTGs and up to 3 WHRUs running (OTSGs in dry run mode - no steam cycle).

5.1.5.2 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.5.3 Site rated conditions.

5.1.5.4 Overall gross output power shall be not less than 118 MWe.

5.1.5.5 FPSO heat demand: 55 MW.

5.1.5.6 HM Temperature at WHRU inlet: 97.0 °C (when operating with treated fuel gas).

Note 1: The CCPG PACKAGER shall inform the required HM Temperature at WHRU inlet to avoid acid condensation when operating with non-treated gas and diesel (compositions according to *I-RL-3010.2Q-1200-940-P4X-001 – General Specification for Available Utilities*).

Note 2: If hot HM recirculation is required to avoid acid condensation, this will be done outside of the CCPG package battery limits.

5.1.6 Case C5 (sizing case for sea water consumption)

5.1.6.1 4 GTGs and 3 OTSGs/WHRUs running.

5.1.6.2 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.6.3 Site rated conditions.

5.1.6.4 STG not in operation.

5.1.6.5 Thermal duty given by the Steam/Hot Water Heat Exchanger and WHRUs in operation.

5.1.6.6 Overall gross output power shall be not less than 118 MWe.

5.1.6.7 FPSO heat demand: 55 MW.

5.1.6.8 HM Temperature at WHRU inlet: 97.0 °C.

5.1.7 Case C7 (for performance evaluation only)

5.1.7.1 3 GTGs/OTSGs/WHRUs running.

5.1.7.2 STG running.

5.1.7.3 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.7.4 Minimum site temperature (14ºC).

5.1.7.5 Overall CCPG gross output power shall be not less than 118 MWe.

5.1.7.6 FPSO heat demand: 55 MW.

5.1.7.7 HM temperature at WHRU inlet: 97.0 °C.

5.1.8 Case C8 (for performance evaluation only)

5.1.8.1 3 GTGs/OTSGs/WHRUs running.

5.1.8.2 STG running.

5.1.8.3 Nominal degradation factor of 5% at the GTGs (due to gas turbine ageing and fouling).

5.1.8.4 Maximum site temperature (37ºC).

5.1.8.5 Overall CCPG gross output power: to be informed by the CCPG PACKAGER.

5.1.8.6 FPSO heat demand: 55 MW.

5.1.8.7 HM temperature at WHRU inlet: 97.0 °C.

6. CCPG PACKAGER´S SCOPE OF SUPPLY

6.1 The CCPG PACKAGER's scope of supply shall comprise, at least, but not limited to, the following:

Note: Any different configuration in terms of type or number of BoP equipment to better fit CCPG operations (e.g. 4 x 33% SGFW Pumps, 3 x 50% Condensate Extraction Pumps, etc.) shall be prior approved by PETROBRAS.

6.1.1 4 x 33% **Gas Turbogenerator Sets (TG-5147001A/D)**, with all required auxiliaries and accessories.

6.1.2 4 x 33% **Once-Through Steam Generators (GV-TG-5147001A/D)** and **Waste Heat Recovery Units (P-GV-TG-5147001A/D)**, in a series arrangement, each of them fitted with internal bypass, exhaust stack, and isolation and control dampers.

6.1.3 1 x 100% **Steam Turbogenerator Set (TG-5147002)**, with all required auxiliaries and accessories, including **Surface Condenser (P-UG-5132001-01)** and its auxiliaries.

6.1.4 2 x 100% **Vacuum Pumps (B-UG-5132001-04A/B)**.

6.1.5 2 x 100% **Steam/Hot Water Heat Exchangers (P-UG-5132001-02A/B)**.

6.1.6 3 x 50% **Steam Generator Feedwater Pumps (B-UG-5132001-02A/C)**.

6.1.7 2 x 100% **Condensate Extraction Pumps (B-UG-5132001-01A/B)**.

6.1.8 2 x 100% **Cooling Water Booster Pumps (B-UG-5132001-07A/B)**, if required.

6.1.9 2 x 100% **Steam Generator Feedwater Pre-Heaters (P-UG-5132001-03A/B)**.

6.1.10 1 x 100% **Start-up Electrical Pre-Heater (AQ-UG-5132001)**.

6.1.11 1 x 100% **HP/LP Steam Letdown/Desuperheating Station (Z-UG-5132001-04)**.

6.1.12 4 x 33% **HP Steam/Condenser Letdown/Desuperheating Stations (Z-UG-5132001-05A/D)**.

6.1.13 2 x 100% **Condensate Return ACF Units (FT-UG-5132001-02A/B)**, including 2 x 100% ACF Backwash Pumps.

6.1.14 2 x 100% **Condensate Polishing Units (Z-UG-5132001-03A/B)**.

6.1.15 2 x 100% **Demi Water ACF Units (FT-UG-5132001-01A/B)**, including 2 x 100% ACF Backwash Pumps (if different from B-UG-5132001-03A/B).

6.1.16 2 x 100% **EDI Units (Z-UG-5132001-01A/B)**.

6.1.17 1 x 100% **Demi Water Tank (TQ-UG-5132001)**.

6.1.18 2 x 100% **Demi Water Pumps (B-UG-5132001-03A/B)**.

6.1.19 1 x 100% **Chemical Injection System (Z-UG-5132001-02)**.

6.1.20 1 x 100% **Water/Steam Quality Monitoring System (Z-UG-5132001-07)**.

6.1.21 One set of PSVs, actuated on-off valves, and control valves (shipped loose).

6.1.22 One set of critical instrumentation from the CCPG system, including fuel gas online analyzer (gas chromatograph), flowmeters and transmitters.

6.1.23 One set of control panels and RIO panels for equipment and components of the CCPG package.

6.1.24 PMS.

6.1.25 Control system design.

6.1.26 Dynamic simulation to identify the behavior of the system under normal operation and transient conditions, including, but not limited to, the following:

6.1.26.1 Creation of a physical model that identifies the operating limits of the CCPG system in relation to the characteristics described in project documentation.

6.1.26.2 Evaluation of all CCPG operational and off-design cases to verify the adequacy of the control system.

6.1.26.3 Tuning the CCPG start-up and shut-down sequences and procedures with recommendations to solve all the issues, if any.

6.1.26.4 Verification of the adequacy of the CCPG design protection system (sets and actions).

6.1.26.5 Check the impacts of external transient events and conditions on the electrical power and heat to be produced by the CCPG system, and on the CCPG equipment operations.

6.1.27 Full project management, basic and detailed engineering and procurement activities related to all equipment, systems and components comprised in the CCPG PACKAGER's scope of supply, including shipped loose items.

6.1.28 Detail and procurement engineering of critical materials, and basic process engineering related to the full CCPG interconnecting scope by the PURCHASER, including, but not limited to, the following:

6.1.28.1 Basic process design, including datasheets, calculation reports, H&MBs, PFDs and P&IDs.

6.1.28.2 Prescription of requirements/restrictions/needs from the CCPG system to be followed by the PURCHASER regarding piping engineering, including those related to piping support and stress analysis.

6.1.28.3 Review, comments and approval on piping and layout documents (e.g. flexibility and stress analysis of steam piping systems), as well as on other relevant technical documentation issued by the PURCHASER during detail design.

6.1.28.4 Simulation of GTG and STG load steps to check if the voltage and frequency transient variations are within the limits foreseen in *I-ET-3010.00-5140-700-P4X-009 – General Requirements for Electrical Material and Equipment for Offshore Units* and Classification Society Rules.

6.1.28.5 Any other CCPG system-dependent technical information related to items out of the CCPG PACKAGER's scope of supply (such as piping specs for BoP interconnection lines).

6.1.28.6 Technical documentation (including list and datasheets) for instrumentation to be supplied by the PURCHASER.

6.1.28.7 Native files of 3D model elements for each equipment, system, and component (including shipped loose items) comprised in the CCPG PACKAGER's scope of supply, which shall be integrated by the PURCHASER in the overall FPSO 3D model.

6.1.28.8 Attendance from CCPG PACKAGER and OEM sub-vendors during HAZOP, design reviews and any others virtual or face-to-face events and meetings, as requested by the PURCHASER or PETROBRAS.

6.1.29 Capital spares and spare parts for commissioning and startup (as per applicable Contract Exhibits).

6.1.30 Complete technical documentation (including IOM manuals in Brazilian Portuguese language).

6.1.31 Technical assistance and supervision from CCPG PACKAGER and OEM sub-vendors during installation, commissioning, and start-up (including combined cycle integrated tests at FPSO integration shipyard and at FPSO final location).

6.1.32 Training for operation and maintenance personnel.

7. GENERAL REQUIREMENTS

7.1 All equipment, components, and materials shall be brand new. Refurbished equipment, components or parts thereof are not acceptable.

7.2 SI units shall be applied, except for piping and appurtenances diameters, which shall be indicated in inches.

7.3 The CCPG PACKAGER shall assume unit responsibility for the whole CCPG package and shall ensure that all sub-vendors comply with the requirements of this technical specification and all reference contractual documents.

7.4 The complete CCPG package shall be designed for a minimum of 30 (thirty) years of operation installed in the FPSO.

7.5 All components of the CCPG package shall be suitable for offshore environment, throughout the whole platform service life, under all operational conditions and submitted to the FPSO motions and accelerations described in PETROBRAS specifications and other applicable contractual documents, as issued for this project.

7.6 Hazardous and toxic materials with associated adverse health effects shall be avoided or minimized by the CCPG PACKAGER and the PURCHASER.

7.6.1 Asbestos shall not be used in the materials and equipment supplied. The CCPG PACKAGER and the PURCHASER shall undertake all necessary measures to ensure the use of asbestos is fully avoided throughout this project.

7.6.2 Material safety datasheets may be required by PETROBRAS any time, to demonstrate that a particular material has not been, is not and will not be used throughout all stages of this project.

7.7 The CCPG PACKAGER shall specify the products to be used for preservation of the equipment components and spare parts, their removal and reapplication methods and the application date. Such data shall be summarized on two tags to be securely fastened on all equipment and outside of each crate. If rust preventive is required, volatile products shall not be applied.

7.8 All equipment, components and panels shall have a nameplate easy to access, to view and read. Nameplate shall be made in stainless steel AISI 316L and bolted (with stainless steel elements) to the equipment. Nameplate drawings shall be submitted for PURCHASER´s approval. Nameplates shall contain the following information, in Brazilian Portuguese language:

- Client name
- Client job
- Client area
- Supplier name
- Series number and model
- Year of manufacturing
- Main design and test data: pressure, temperature, voltage, rotation, etc.
- Equipment/component/panel specific data
- Tag number
- PURCHASER’s Material Requisition number
- PURCHASER’s Request for Quotation number
- PURCHASER’s Order number
- Empty weight
- Design code

7.9 All safety signals shall be according to *I-ET-3010.00-5400-947-P4X-002 – Safety Signalling* and written in Brazilian Portuguese language.

7.10 All pending items from the shop punch lists shall be resolved and closed before shipment.

7.11 The CCPG package design shall be in accordance with API RP 14C.

7.12 The package (or parts thereof) installed in classified areas shall be provided in accordance with the requirements stated in ISO 80079-36 and ISO 80079-37. PACKAGER shall provide a certificate assuring that the equipment and components of the package are in conformity with the abovementioned standards, including as minimum:

7.12.1 Ignition Hazard Assessment Report as per ISO 80079-36;

7.12.2 Specific requirements for the design and construction of non-electrical and equipment type of protection as per ISO 80079-37;

7.12.3 Equipment nameplate including ISO 80079-36 marking requirements.

PACKAGER shall attest on his own responsibility that the equipment has been made in accordance with the applicable requirements of the relevant standards in safety matters.

8. PROCESS REQUIREMENTS

8.1 The CCPG package shall be capable of providing the required heat to the process and the required power demand to the FPSO electrical grid along the FPSO unit's lifecycle, with no disturbances on the redundancy philosophy of the entire system.

8.1.1 A configuration based on 4 x 33% GTGs **(TG-5147001A/D)**, 4 x 33% OTSGs **(GV-TG-5147001A/D)**, 4 x 33% WHRUs **(P-GV-TG-5147001A/D)** and 1 x 100% STG **(TG-5147002)** shall be considered for the CCPG package.

8.1.2 The CCPG package shall be provided with one stand-by Gas Turbogenerator, fitted with its own dedicated OTSG/WHRU, which shall be used as a spare set whenever another GTG, OTSG/WHRU or the STG is out of service.

8.1.3 STG site rated power shall not be greater than the site rated power of each GTG.

8.2 The minimum configuration of main equipment and systems of the CCPG package shall follow *I-DE-3010.2Q-5132-943-P4X-001 – Combined Cycle System*. Any additional equipment, system or component not shown in this document but required for proper operation of the CCPG system shall be included in the CCPG PACKAGER´s scope of supply.

8.3 The required heat to the FPSO HM circuit shall be provided by the CCPG package according to the following scenarios:

8.3.1 OTSGs and WHRUs in operation: hot water from the HM circuit shall be heated up by a combination of heat added by the WHRUs **(P-GV-TG-5147001A/D)** and the Steam/Hot Water Heat Exchanger **(P-UG-5132001-02A/B)** in operation. The required hot water temperature at the outlet of the Steam/Hot Water Heat Exchanger is 180ºC and shall be automatically obtained by means of temperature control actuating on the hot water stream.

Note: The CCPG PACKAGER shall ensure that HM outlet temperature is limited to 180°C, even when there is excess of flue gas energy.

8.3.2 WHRUs in operation and OTSGs out of service (or in dry run mode): as no steam is produced by the OTSGs in this scenario, hot water from the HM circuit shall be heated up only by the WHRUs in operation. The required hot water temperature at the outlet of each WHRU is 180ºC and shall be automatically obtained by means of temperature control actuating on the inlet control damper of each OTSG/WHRU.

Note: In this scenario, WHRUs shall be capable of providing the full amount of heat required by the FPSO at peak heat demand conditions.

8.4 The exhaust flue gases upcoming from each gas turbine generator set shall be directed to its corresponding OTSG/WHRU (in a series arrangement) and/or diverted to the internal bypass duct, by means of an inlet control damper.

8.5 Control dampers shall be provided upstream of each OTSG / WHRU assembly and at the entrance of each integrated by-pass duct, to manage scenarios of heat demands at cogeneration operation mode. For further data requirements for coils isolation, see *I-FD-3010.2Q-5147-413-P4X-002 – Once-Through Steam Generator and Waste Heat Recovery Unit*.

8.6 The CCPG package shall be provided with full steam turbine **(TB-TG-5147002)** bypass capability.

8.7 HP to LP process letdown station **(Z-UG-5132001-04)** shall be provided for operational flexibility purposes, specially at very high heat/low electrical demand scenarios or during steam turbine outages.

8.8 The CCPG package shall be provided with fully automated condensate recovery capability during normal operation and transient conditions (start-ups, shutdowns, etc.).

8.9 The CCPG package shall be provided with fully automated warm up of steam lines.

8.10 The FPSO has operation conditions in which the fuel gas to the gas turbines **(TS-TG-5147001A/D)** is automatically commuted to diesel oil. When this occurs only with part of the gas turbines in operation, their corresponding OTSGs shall be turned to dry run mode to avoid any possibility of acid corrosion. Otherwise, in the event of all gas turbines are turned to diesel fuel, the steam cycle shall be shutdown, including the complete condensate / feedwater systems.

8.11 The material specification of the piping and equipment included in the CCPG PACKAGER´s scope of supply shall be compatible with the pressure specification of the corresponding piping from outside the scope of supply, otherwise overpressure protection devices (e.g., Pressure Safety Valves, Pressure Control Valves) shall be provided by the CCPG PACKAGER.

8.12 The cooling medium for the Surface Condenser **(P-UG-5132001-01)** shall be sea water.

8.12.1 Estimated available pressure at the inlet of Surface Condenser is 2.0 bar-g (to be confirmed during detail design). If the available pressure upstream of the Surface Condenser is below the required operational pressure, additional 2 x 100% Cooling Water Booster Pumps **(B-UG-5132001-07A/B)** shall be included in the CCPG PACKAGER's scope of supply.

8.12.2 A FIT/FC/FV shall be provided by the PURCHASER/CCPG PACKAGER to ensure a constant sea water flow to the Surface Condenser, calculated as required by ***Case C5***, as indicated in section '*CCPG Performance Evaluation and Sizing Criteria*' of this technical specification.

8.12.3 The sea water stream outlet of the Surface Condenser is sent to overboard. Suitable devices shall be provided by the CCPG PACKAGER to ensure the required backpressure and avoidance of vacuum formation.

8.12.4 Other cooling medium users shall use cooling water.

8.13 High purity Nitrogen (O_2 content up to 1%) shall be used only during normal operation for blanketing of Demi Water Tank, pH Agent Control Tank and, if any, Oxygen Agent Control Tank. For other Nitrogen demand, such as purging, the CCPG PACKAGER shall use Nitrogen with O_2 content up to 4%.

8.14 The CCPG package shall be provided with flow rate control (FIT/FIC/FV) for each OTSG to distribute automatically and equally the feedwater flow rate among the steam generators in operation.

8.15 The CCPG package shall be provided with 2 x 100% permanent installed liquid ring vacuum pumps for plant start-up and normal operation.

Note: If the CCPG PACKAGER can demonstrate that the use of vacuum pumps compromises the required performance of the CCPG system due to vacuum level constraints, ejectors can be proposed as alternative vacuum devices during normal operation, provided they are prior approved by PETROBRAS.

8.16 Activated Carbon Filter Units **(FT-UG-5132001-02A/B)**, arranged in 2 x 100% configuration, shall be installed on the condensate return stream from the Steam/Hot Water Heat Exchangers. Filters shall have quick opening device and backwash facilities.

8.17 Manual valves at battery limits as well as spectacle blinds or paddle blanks according to *I-DE-3010.2Q-1200-944-P4X-001 – General Notes* shall be included in the CCPG PACKAGER´s scope of supply.

8.18 Insulation for personnel protection shall be provided in all portions of the CCPG package where temperatures are equal or higher than 60ºC.

8.19 Condensate Polishing System

8.19.1 The condensate polishing system shall be comprised of two Condensate Polishing Units **(Z-UG-5132001-03A/B)**, each of them sized for 100% of the condensate flow rate.

8.19.2 Each Condensate Polishing Unit (main and stand-by skids) shall be fitted with inlet, outlet, and by-pass automatic tight shutoff valves.

8.19.3 The condensate polishing system shall be of non-regenerative type with ion exchange resin.

8.19.4 Each Condensate Polishing Unit shall have filtration and ion exchange capability in a single or different equipment.

8.19.5 The ion exchange and filtration capabilities shall be sized for, at least, three weeks operation under total condensate flowrate.

8.19.6 If ion exchange resin precoating is required, the facilities to automatically receive, prepare, and transfer the resins shall be provided by the CCPG PACKAGER.

8.19.7 The operation of the system shall be completely automatic. When the resin is exhausted/saturated (detected by the measured inlet and outlet conductivity) and/or the filtration capability is deteriorated (detected by high differential pressure), it shall be initiated the auto changeover between the skids.

8.19.8 Each Condensate Polishing Unit shall have automatic operated valves to automatically switch operation from one skid to the other, or to place both in bypass mode whenever the chemical parameters of condensate water are within the limits.

8.19.9 The condensate polishing system shall be fitted with resin and filtration elements loading and unloading facilities.

8.19.10 If the exhausted/saturated resin need any treatment/facility before to be packed for disposal, it shall be included in the CCPG PACKAGER´s scope.

8.19.11 A flowmeter shall be installed at the inlet of each Condensate Polishing Unit skid. Indirect measurement from other flowmeters is also accepted.

8.19.12 Differential pressure transmitter (PDIT, PDI, PDSH) shall be installed at each Condensate Polishing Unit.

8.19.13 The equipment where new/fresh resin/filtering element will be loaded shall have quick opening device.

8.19.14 Any PSV installed on equipment/system that has no redundant equipment shall be duplicated (2 x100%).

8.20 Electro Deionization System

8.20.1 The Electro Deionization System shall include 2 x 100% ACF units **(FT-UG-5132001-01A/B)** to be installed upstream of the EDI units, completely automatized with backwashing facilities, and operation and recirculation modes actuated by level control of the Demi Water Tank.

8.20.1.1 Activated Carbon Filters (ACF) shall have quick opening device.

8.20.1.2 Each ACF shall have internal filter device (screen) or other PETROBRAS approved device to avoid fine particle to pass through the filters.

8.20.1.3 2 x 100% dedicated ACF Backwash Pumps shall be provided, if different from the Demi Water Pumps.

8.20.2 The EDI system shall be fitted with 2 x 100% EDI units **(Z-UG-5132001-01A/B)**, completely automatized (operation and recirculation mode) with recycle facilities actuated by level control of the demi water tank and by the hardness or total conductivity analyzer of inlet water.

8.20.3 The capacity of each EDI unit shall be, at least, 6 m^3/h.

Note: The maximum Fresh Water flowrate to be made available from the FPSO Reverse Osmosis Unit for sourcing the EDI system is 6 m^3/h.

8.20.4 Each EDI unit shall have total hardness and total conductivity online analyzer at the inlet.

8.20.5 Each EDI unit shall have total hardness and total conductivity analyzers at outlet stream, to automatically deviate the flow of the demi water tank to be discharged overboard, if the demi water is out of specification.

8.20.6 Each EDI unit shall have inlet pressure control to keep it constant.

8.20.7 A flowmeter shall be installed at the inlet of each EDI unit.

8.20.8 The metering of any continuous disposal water to the sea shall comply with IBAMA's regulation. One totalized flow transmitter and temperature transmitter shall be supplied, and signal shall be available at the control panel to be sent to topsides supervision and operation system.

8.20.9 The Demi Water quality at EDI outlet shall be, as minimum:

8.20.9.1 Specific Conductivity: <0.1 µS/cm

8.20.9.2 Total Silica: <0.01 mg/l

8.20.9.3 Sodium: <0.005 mg/l

8.20.9.4 Total Organic Carbon (TOC): <0.1 mg/l

Note: Different values can be accepted if prior approved by PETROBRAS.

8.21 Demi Water Tank (TQ-UG-5132001) and Pumps (B-UG-5132001-03A/B)

8.21.1 The Demi Water Tank shall be sized for whichever is greater from the following criteria:

8.21.1.1 In the event of Demi Water production system outages, the hold-up between LSL and LSH shall be sufficient to supply makeup water to the CCPG system for 24 hours, sustaining operation with three OTSGs and STG at full load conditions, considering both normal makeups and peak demi water consumption due to intermittent operations (such as those related to ACF backwashing).

8.21.1.2 During CCPG system startups, the hold-up between LSL and LSH shall allow the complete filling, with no interruptions, of the steam-water circuit (sequential startup of one OTSG at a time), considering the maximum capacity coming from the DM water production system. Water filling rate shall be high enough to not impose limitations on the CCPG system/OTSG startup times.

8.21.1.3 If there is an event in which the DM water consumption is higher than flowrate of one EDI unit, it shall be compensated by the volume storage in Demi Water Tank during this event.

8.21.2 The Demi Water Tank shall include, but not limited to, the following:

8.21.2.1 Pressure control valves for high purity Nitrogen blanketing.

8.21.2.2 Level control to automatically start the main EDI and/or the stand-by EDI unit and/or to put them on recycle mode.

8.21.2.3 Relief and vacuum pressure valves (2 x 100%).

8.21.2.4 Level instrumentation (LG, LIT, LI, LSL, LSLL, LSH, LSHH).

8.21.2.5 Pressure instrumentation (PIT, PI, PSL, PSH).

8.21.2.6 Drains and vents.

8.21.2.7 Tank overflow loop with level gauge, drain.

Note: Alternative tank overflow proposals shall be prior approved by PETROBRAS.

8.21.2.8 Man way.

8.21.3 The Demi Water Pumps (2 x 100%) shall include, but not limited to, the following:

8.21.3.1 Local and remote PI.

8.21.3.2 PIT/PSL at discharge to start the stand-by pump.

8.21.3.3 Minimum flow protection device.

8.21.3.4 Inlet filter with local and remote PDI.

8.22 Chemical Injection System (Z-UG-5132001-02)

8.22.1 The Chemical Injection System shall be comprised of two dedicated skids, one for the O_2 control agent (H_2O_2 or O_2), and another one for the pH control agent (NH_4OH).

8.22.2 The CCPG PACKAGER shall define concentration of each control agent.

8.22.3 The Chemical Injection System shall include, but not limited to, the following:

8.22.4 2 x 100% metering pumps for each chemical injection point, in accordance with API 675, and fitted with:

8.22.4.1 External relief valve.

8.22.4.2 Automatic stroke adjustment to automatically adjust chemical flowrate in relation to the measured process stream.

8.22.4.3 Automatic stop of the dosing pump when the chemical dosing concentration is achieved.

8.22.4.4 Pulsation suppression devices.

8.22.4.5 Manometer.

8.22.4.6 Calibration pot.

8.22.4.7 Double diaphragm with leakage detection and remote alarm.

8.22.4.8 Strainers with differential pressure transmitter and indicator at pump suction.

8.22.4.9 Skid drip pan (including tanks and pumps) with level alarm or other PETROBRAS approved solution.

8.22.5 Tanks:

8.22.5.1 Diluted solution/preparation storage tank for each product with capacity for 20 days operation.

8.22.5.2 The chemical tanks shall be provided with facilities to be refilled by gravity from tote bins located at higher elevation.

8.22.5.3 Tank level transmitter, low- and high-level alarms, tank level gauge.

8.22.5.4 Tank vent piping to Safe Location (by the PURCHASER).

8.22.5.5 Skid drip pan (including tanks and pumps) with level alarm or other PETROBRAS approved solution.

8.22.5.6 The Chemical Injection System shall be capable of draining the content of each chemical tank to drums or tote tanks (to be provided by others).

8.22.5.7 Connections for nitrogen injection shall be foreseen in each filling line, to allow purging of the tanks.

8.22.5.8 Tank overflow loop with level gauge, drain and filling connection.

8.22.6 If demi water is required, control valve and flowmeter shall be supplied.

Note: Alternative measurement proposals shall be approved by PETROBRAS.

8.22.7 Coriolis flowmeter type for each injection point.

8.22.8 Filling lines:

8.22.8.1 Filling lines shall size at least 2”.

8.22.8.2 Each individual line shall have a 10-mesh net strainer to avoid product contamination.

8.22.9 If cylinder of Oxygen is used as O_2 control agent:

8.22.9.1 The Oxygen cylinders/racks shall comply with the requirements of MODU code and with the Classification Society.

8.22.9.2 The O_2 control agent skid shall include, but not limited to, the following:

- 2 racks with cylinders for 30 days operation, each rack for 15 days.
- Pressure regulator valves.
- Pressure safety valves.
- Pressure transmitter and indicator.
- Isolation valves.

8.22.10 Each injection point shall comply with the requirements of *I-ET-3010.00-1200-940-P4X-005 – Chemical Injection Points*.

8.22.11 Injection tube nut shall be quill-type.

8.22.12 Chemical injection points shall be retrievable type.

8.23 Water/Steam Quality Monitoring System (Z-UG-5132001-07)

8.23.1 The Water/Steam Quality Monitoring System shall be a dedicated online analytical instrumentation system for automatic steam/condensate/demi water quality monitoring and control.

8.23.2 With exception of those sampling points associated to the live steam production at the OTSGs, the Water/Steam Quality Monitoring System shall be a centralized sampling system provided as a single and containerized panel, to be located at Module M-12 (same FPSO module where the STG and BoP equipment will be installed).

8.23.3 The Water/Steam Quality Monitoring System shall include, but not limited to:

8.23.3.1 Panel(s) comprised of sample cooler(s), online analyzers, and grab samples for all additional offline lab analysis.

8.23.3.2 Inlet filters, and automatic inlet/outlet valves.

8.23.3.3 Steam, condensate and Demi Water analyzer online system with alarm for:

- HP steam common header inlet (total/specific conductivity, cationic conductivity, pH and silica).
- BFW pumps discharge header (pH and, if required, total/specific conductivity, oxygen, cationic conductivity, Degassed Acid Conductivity).
- Condensate upstream of polishing unit (total/specific conductivity, cationic conductivity, pH, oxygen, sodium and, if required, silica).
- Condensate downstream of polishing unit (total/specific conductivity, cationic conductivity and, if required, TOC, oxygen, sodium and silica).
- Condensate downstream of activated carbon filter (total conductivity and TOC).
- In case of lack of analyzers at EDI unit outlet, makeup water header downstream of demi water pumps (total/specific conductivity and, if required, cationic conductivity, silica, sodium, and TOC).
  Note: Alternative proposal shall be prior approved by PETROBRAS.

8.23.3.4 Besides grab sample points associated to each online analyzer, the following manual sampling points shall also be provided by the CCPG PACKAGER/PURCHASER:

- HP steam outlet of each OTSG.
- Demi Water System inlet.
- Demi Water System outlet (makeup water line).
- Demi Water System outlet (concentrate line).
- Activated carbon filters inlet (if applicable).

9. PROCESS SAFETY REQUIREMENTS

9.1 Steam piping routing through FPSO shall be minimized for safety reasons. Steam shall be generated at OTSGs, and it shall be treated, conditioned, and used only to steam turbogenerators and to transfer heat to the heating medium (pressurized water).

9.2 Vents and pressure valves/PSVs/rupture disks discharging to atmosphere shall be routed to Safe Location, in accordance with the definition presented in *I-DE-3010.2Q-1200-944-P4X-001 – General Notes*.

9.3 The CCPG PACKAGER shall comply with the recommendations from the Consequence Studies to be carried out during the detailing design, to assure that the criteria of impairment of the Main Safety Functions is met, in accordance with item 8 of *DR-ENGP-M-I-1.3 R.8 – Safety Engineering Guideline*.

9.4 The system shall be equipped with safety interlocks to prevent and/or minimize leaked inventory in case of steam and/or hot water loss of containment.

10. RELIABILITY REQUIREMENTS

10.1 The CCPG PACKAGER shall provide PETROBRAS with expected maintenance downtime, consumption of spares and other assumptions and data of the equipment comprised in the CCPG package, with the aim of allowing PETROBRAS to incorporate such information into the RAM analysis of the entire FPSO unit.

11. ROTATING EQUIPMENT REQUIREMENTS

11.1 Equipment shall be designed to meet PETROBRAS requirements for unattended, fail-safe, continuous service as well as for idle periods up to several months in saline atmosphere (marine environment) on the FPSO.

11.2 Seals and labyrinths shall be designed to minimize instrument air and/or nitrogen consumption. XV valves with limit switch and any other required protection layer shall be used to automatically reduce instrument air/nitrogen consumption, whenever the use of such utilities is not required.

11.3 Equipment and piping served by cooling water shall also be designed with protections/detections against scenario of lack of supply and/or overpressure and/or high cooling water temperature.

11.4 Equipment and piping served by diesel (liquid fuel) shall also be designed with protections/detections against scenario of lack of supply and/or overpressure due to block of diesel return lines.

11.5 Proposal drawings and data shall not be certified or as built.

11.6 The approval of vendor´s drawings by PETROBRAS shall not exempt the PURCHASER and the CCPG PACKAGER from any responsibility for detail design, dimensioning and construction of equipment or deviations from specifications.

11.7 The CCPG PACKAGER shall provide weights, dimensions, and center of gravity for all equipment, including auxiliaries in different skids or shipped loose items, with accuracy of ± 10% in proposal phase and ± 3% after order. The CCPG PACKAGER shall also furnish required data for dry, operation, test, and maintenance cases.

11.8 The CCPG PACKAGER shall provide all structural supports including main structural skid, equipment supports and support frames, on-skid ladders, walkways, platforms, grating and drip trays/drip rims.

11.9 The CCPG PACKAGER is required to note on respective data sheets of main equipment the moments of inertia (kg.m²) of each rotor.

11.10 Centrifugal pumps shall comply with the requirements of *I-ET-3010.00-1200-310-P4X-001 – API 610 Centrifugal Pumps Specification*.

11.11 Specific Requirements for the Steam Generator Feedwater Pump (B-UG-5132001-02A/C)

11.11.1 In addition to the requirements of *I-ET-3010.00-1200-310-P4X-001 – API 610 Centrifugal Pumps Specification*, the Steam Generator Feedwater Pumps shall comply with the following requirements:

11.11.1.1 SGFW Pumps shall be BB5 type as per API 610.

11.11.1.2 SGFW Pumps Factory Acceptance Tests (FAT) shall be carried out at rated speed.

11.11.1.3 At least one unit of the supplied set of SGFW Pumps shall undergo a Complete Unit Test (String Test) as part of the FAT.

11.11.1.4 SGFW Pumps shall undergo a 4-hour Mechanical Running Test (MRT) at rated speed and flowrate as part of the FAT.

11.11.1.5 The same vibration and bearing temperature limits applicable to the Performance Test shall be applied for the MRT.

11.11.1.6 The original files containing all data recorded during the FAT shall be made available for PETROBRAS after the tests.

11.11.1.7 Disassembly of the pump for any head adjustment (including less than 5% diameter change) after test shall be cause for retest.

11.11.1.8 SGFW Pumps shall be driven by electric motors with Variable Speed Drives.

11.12 Specific Requirements for the Gas Turbogenerator Set (TG-5147001A/D)

11.12.1 The CCPG PACKAGER shall be the gas turbine OEM.

11.12.2 Each Gas Turbogenerator Set consists of a gas turbine, gearbox and electric generator and all auxiliary equipment integrated for perfect functioning of the required service (accessories, control panel, machinery protection system, oil system, start-up system, PMS, etc.). A total of 4 units shall be furnished. Each unit shall be designed according to *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set*. GTGs shall not share auxiliary systems. Although turbogenerator sets are 4x33% configuration, the CCPG package shall be designed to run all gas turbogenerators simultaneously, if needed.

11.12.3 Each of the four gas turbogenerators shall be driven by an aeroderivative or light-industrial type gas turbine in accordance with API 616.

11.12.4 A 33 MWe, at generator borne active power (@30ºC, 80% RH, 1 atm, 100/250 mm H2O inlet/outlet losses, project gas fuel), gas turbogenerator shall be selected. The CCPG PACKAGER shall include in the design the following degradation factors: Fouling 2% and Ageing 3%.

11.12.4.1 The required site power of 33MWe shall be available at generator borne for all gas compositions.

11.12.5 Electric generator shall be 60 Hz, 2 or 4 poles. The CCPG PACKAGER shall evaluate if gearbox is necessary to achieve the specified operation conditions. If not, the CCPG PACKAGER shall disregard all mentions to gearbox in PETROBRAS specifications for the Gas Turbogenerator Set.

11.12.6 The CCPG PACKAGER shall confirm capacity to run turbogenerator with all fuel gas and liquid data provided herein and in *I-RL-3010.2Q-1200-940-P4X-001 – General Specification for Available Utilities* and *I-RL-3010.2Q-1200-940-P4X-004 – Process Simulation*.

11.12.7 The minimum fuel gas pressure shown in *I-RL-3010.2Q-1200-940-P4X-001 – General Specification for Available Utilities* shall be suitable to allow changeover of fuel type for all gas compositions.

11.12.8 The CCPG PACKAGER shall optimize arrangement of turbogenerator skid considering that the four GTGs will be arranged on two modules. Each module with two GTGs, side by side.

11.12.9 According to *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set*, during ESD event, the ventilation fan shall be supplied by essential AC power in case of gas leakage inside the hood. However, components inside hood shall be designed to not require air ventilation during ESD event, since the ventilation will be turned on only if gas leakage is confirmed inside the hood.

11.12.10 Regarding UPS and battery banks, refer to the requirements stated on Section 19 of this technical specification. Special attention to additional impacts on FPSO design depending on gas turbine model selected, to which the PURCHASER shall be responsible.

11.12.11 The main oil pump shall be shaft-driven type.

11.12.12 Besides the documentation listed in Annex B of API 616, which shall be considered as required, the CCPG PACKAGER shall submit the documents described in *Annex A – Vendor Drawing and Data Requirements for Gas Turbogenerator Sets* of this technical specification. Different schedule can be proposed by the CCPG PACKAGER and submitted for the PURCHASER and PETROBRAS approval.

11.12.13 For this project, the following guidance table shall be used for the documents referred to in *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set*:

FROM:	**TO:**
SPECIFIC PROJECT TOPSIDES UPS AND DC SYSTEMS ONE-LINE DIAGRAM	*I-DE-3010.2Q-5265-946-P4X-001 – Topside UPS and DC Systems One-Line Diagram*
SPECIFIC PROJECT AUTOMATION AND CONTROL ARCHITECTURE	*I-DE-3010.2Q-5520-800-P4X-002 – Automation and Control Architecture*
SPECIFIC PROJECT PIPING SPECIFICATION FOR TOPSIDE	*I-ET-3010.2Q-1200-200-P4X-001 – Piping Specification for Topsides*
SPECIFIC PROJECT INSTRUMENTATION ADDITIONAL TECHNICAL REQUIREMENTS	*I-ET-3010.2Q-1200-800-P4X-001 – Instrumentation Additional Technical Requirements*
SPECIFIC PROJECT FIELD INSTRUMENTATION	*I-ET-3010.2Q-1200-800-P4X-005 – Field Instrumentation*
SPECIFIC PROJECT AUTOMATION INTERFACE OF PACKAGED UNITS	*I-ET-3010.2Q-1200-800-P4X-014 – Automation Interface of Packaged Units*
TOPSIDE´S MECHANICAL HANDLING PROCEDURES	*I-ET-3010.2Q-5266-630-P4X-001 – Topsides Mechanical Handling Procedures*
SPECIFIC PROJECT EQUIPMENT LIST	*I-LI-3010.2Q-1200-940-P4X-002 – Equipment List*
SPECIFIC PROJECT AUTOMATION AND CONTROL SYSTEM FUNCTIONS – TOPSIDES	*I-MD-3010.2Q-5520-800-P4X-001 – Automation and Control System Functions*
SPECIFIC PROJECT AUTOMATION NET WORK DESCRIPTION	*I-MD-3010.2Q-5520-800-P4X-003 – Automation Net Work Description*
DESCRIPTIVE MEMORANDUM – AUTOMATION AND CONTROL SYSTEM - SCOPE DEFINITION	*I-MD-3010.2Q-1200-800-P4X-002 – Automation and Control System – Scope Definition*
DESCRIPTIVE MEMORANDUM – PROCESS	*I-MD-3010.2Q-1200-940-P4X-005 – Descriptive Memorandum - Process*

11.12.14 For further details, refer to *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set* and other PETROBRAS documents related to the Gas Turbogenerator Set issued for this project.

11.13 Specific Requirements for the Steam Turbogenerator Set (TG-5147002)

11.13.1 The steam turbogenerator shall be driven by a condensing-type, special-purpose steam turbine in accordance with API 612.

11.13.2 The STG rated power (gross active power at generator borne) shall be 28 MWe.

11.13.3 The Steam Turbogenerator Set shall be arranged in an axial exhaust configuration, allowing location of STG train and Surface Condenser in a single floor level.

11.13.3.1 The Steam Turbogenerator Set (including the Surface Condenser and their auxiliaries) shall be installed at FPSO module M-12, which shall also comprise all equipment, piping, and components from BoP (UG-5132001).

11.13.4 Vacuum pumps shall be liquid-ring type in accordance with API 681.

11.13.5 For further details, refer to *I-ET-3010.2Q-5147-332-P4X-002 – Steam Turbine Driver for Steam Turbogenerator Set* and other PETROBRAS documents related to the Steam Turbogenerator Set issued for this project.

12. STATIC EQUIPMENT REQUIREMENTS

12.1 OTSG and WHRU assemblies

12.1.1 OTSG and WHRU assemblies shall be in accordance with *I-ET-3010.2Q-5147-413-P4X-001 – Technical Specification – Once-Through Steam Generator and Waste Heat Recovery Unit* and *I-FD-3010.2Q-5147-413-P4X-002 – Data Sheet – Once Through Steam Generator and Waste Heat Recovery Unit*.

12.2 Pressure Vessels

12.2.1 All pressure vessels, columns and filters shall comply with the requirements of NR-13 (Brazilian Regulatory Standard) and *I-ET-3010.00-1200-540-P4X-001 – Requirements for Pressure Vessels Design and Fabrication*.

12.2.2 Note: If the scope of supply includes any transportable pressure vessel connected with process plant or platform installations, these items shall be within the scope of NR-13 regulation. Furthermore, transportable containers shall be designed, constructed, inspected, and installed in accordance with the requirements addressed by specific rules of transportable equipment, such as ISO 9809, DOT-3A, or DOT-3AA.

12.3 Heat Exchangers

12.3.1 Heat exchangers shall comply with the requirements of *I-ET-3010.00-1200-451-P4X-001 – Requirements for Shell and Tube Heat Exchanger Design and Fabrication* or *I-ET-3010.00-1200-456-P4X-001 – Requirements for Plate Heat Exchanger Design and Fabrication*, as applicable for each case.

12.4 Electric Heaters

12.4.1 The material selection for electric heaters shall be suitable to operate with fluid being handled and shall follow the requirements of *I-ET-3010.2Q-1200-940-P4X-001 – Material Selection Philosophy for Detailed Design*. The terminal box shall be suitable for the marine atmosphere.

12.4.2 Electrical heaters shall be suitable to operate continuously with voltage variations (including overvoltage) defined in *I-ET-3010.00-5140-700-P4X-009 – General Requirements for Electrical Material and Equipment for Offshore Units*, without overload and keeping lifetime.

12.5 Metallic Tanks

12.5.1 Metallic tanks shall comply with the requirements of *I-ET-3010.00-1200-510-P4X-001 – Metallic Tanks Design for Topside*.

12.6 Non-Metallic Tanks and Non-Metallic Pressure Vessels

12.6.1 Non-metallic tanks and non-metallic pressure vessels shall comply with the requirements of *I-ET-3010.00-1200-500-P4X-001 – Non-Metallic Tanks and Pressure Vessels Design*.

12.7 Surface Condenser

12.7.1 The Surface Condenser shall comply with HEI-2629 with at least 10% extra tube bundle surface. Condenser tubes and tubesheet cladding shall be made of Titanium (other parts in contact with sea water shall also be in Titanium or other PETROBRAS approved corrosion resistant material).

13. PIPING REQUIREMENTS

13.1 All piping, support and piping elements shall be tagged according to *I-ET-3010.2Q-1200-200-P4X-001 – Piping Specification for Topside* and *I-ET-3000.00-1200-940-P4X-001 – Tagging Procedure for Production Units Design*.

13.2 All piping shall have valves (on/off valves), flanges (ASME B16.5 or ASME B16.47) and line blanks (according to *I-ET-3010.2Q-1200-200-P4X-005 - Requirements for Piping Mechanical Design and Layout*) at the end of unit limits (battery limit).

13.3 The PURCHASER and the CCPG PACKAGER shall follow the technical specification *I-ET-3010.2Q-1200-200-P4X-001 – Piping Specification for Topside*. Alternative piping specifications shall be prior submitted for PETROBRAS approval.

13.4 Piping layout shall observe the requirements presented in *I-ET-3010.2Q-1200-200-P4X-005 – Requirements for Piping Mechanical Design and Layout*.

13.5 Piping stress analysis shall be performed according to *I-ET-3010.2Q-1200-200-P4X-006 – Requirements for Piping Flexibility and Stress Analysis*.

13.6 All piping shall be properly supported considering the service loads, shipment, and transportation loads. Piping supports shall be in accordance with *I-ET-3010.2Q-1200-200-P4X-004 – Requirements for Piping Support*. The supporting and installation shall enable piping removal without disturbing structural members.

13.7 Socket welds are only permitted for piping sizes up to NPS 1½. All piping above NPS 1½ shall be butt-welded.

13.8 Lap joint, slip-on, and screwed joints area not acceptable.

13.9 Valves shall be selected in conformance with *I-ET-3010.2Q-1200-200-P4X-001 – Piping Specification for Topside*. Alternative valves specifications shall be prior submitted for PETROBRAS approval.

13.10 The use of concentric type butterfly valves and straight-through diaphragm valves with open body (open body tubular diaphragm valves) is not permitted.

13.11 Utility hose stations shall be installed throughout the CCPG package on strategic places for maintenance and cleaning purposes.

13.12 The piping design, assembly and inspection shall be according to *I-ET-3010.00-1200-200-P4X-115 – Requirements for Piping Fabrication and Commissioning* and *I-ET-3010.2Q-1200-200-P4X-005 – Requirements for Piping Mechanical Design and Layout*.

13.13 All other piping appurtenances/miscellanea which are required for proper operation of the CCPG system shall be provided by the PURCHASER/CCPG PACKAGER.

13.14 All fasteners (studs, bolts, tightening bolts, nuts, and U-bolts) shall be according to *I-ET-3010.00-1200-251-P4X-001 – Requirements for Bolting Materials*.

13.15 Bolted joints within the CCPG package shall be assembled and managed as established in *I-ET-3010.00-1200-200-P4X-116 – Requirements for Bolted Joints Assembly and Management*.

13.16 The PURCHASER shall provide a design book with all piping detailed design documentation, which shall include, but not be limited, to the following documents: isometrics, piping plan, support detail drawings, stress analysis report (with native program file), calculation report, list of supports, valve list, special item list, document list, stress analysis list, tie-in list, welding procedures, strainers datasheet, steam trap datasheet, piping material sheet with and piping elements datasheet.

13.17 All seawater piping lines shall be made of FRP. For FRP piping system requirements refer to *I-ET-3010.00-1200-200-P4X-003 – Design, Construction and Assembly of FRP Piping*.

13.18 Piping layout shall mitigate the possibility of steam/water hammer. A surge analysis shall be performed, including stress and vibration analysis.

14. MATERIAL SELECTION

14.1 General requirements

14.1.1 The CCPG PACKAGER shall be entirely responsible for the material selection of items not specified by PETROBRAS and shall inform material of all main parts according to ASTM code or, if needed, other equivalent internationally recognized standard previously approved by PETROBRAS.

14.1.2 Whenever the material selection indicates a suitability of a non-metallic material, this shall be preferred over a metallic.

14.1.3 The CCPG PACKAGER is responsible for the materials selection considering the philosophy detailed in *I-ET-3010.2Q-1200-940-P4X-001 – Material Selection Philosophy for Detailed Design*.

14.1.4 The CCPG PACKAGER shall submit the detailed material selection report, including all piping, equipment, and their components, for PETROBRAS approval prior to manufacturing activities.

14.1.5 The CCPG PACKAGER shall be responsible for obtaining all necessary certification of the equipment, work, and materials.

14.1.6 The CCPG PACKAGER, through the independent certifying authority, shall supply all certificates related to the materials, inspections, tests, and qualification activities detailed in the approved Quality Plan.

14.2 Coating

14.2.1 Coating requirements shall be in accordance with *I-ET-3010.00-1200-956-P4X-002 – General Painting*.

14.2.2 Color code adopted shall be in accordance with *DR-ENGP-I-1.15 – Color Coding*.

14.2.3 The coating of any equipment and pipping related to steam service (even steam condensate) shall be thermal sprayed in accordance with *I-ET-3010.00-1200-956-P4X-003 – Thermal Spray Coating Application of Aluminum*.

14.3 Thermal insulation

14.3.1 Equipment and piping subjected to a temperature of 60ºC and above shall receive a personal protection system by means of stainless steel 316 wire mesh / perforated plates. Alternatively, a thermal insulation may be applied. Equipment and piping in which heat conservation is necessary shall be thermal insulated. The thermal insulation shall be in accordance with *I-ET-3010.00-1200-431-P4X-001 – Thermal Insulation for Maritime Installations*.

14.3.2 Equipment and pipping related to steam services shall be insulated with aerogel.

15. ARRANGEMENT REQUIREMENTS

15.1 The CCPG package shall be installed outdoors in a marine environment on the modules M-12, M-13 and M-13B. The design of the equipment skids within the CCPG package shall comply with the available footprint of the standard module design, as indicated in Figure 1 below.

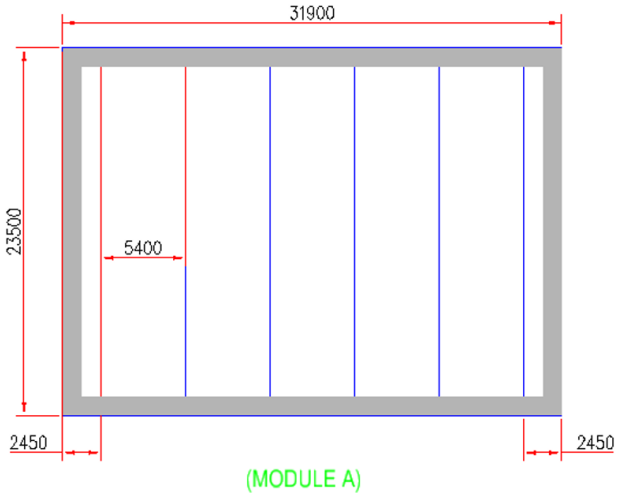

Figure 1 – Main Dimensions of the Standardized Module (mm)

15.2 The CCPG package shall be installed in three standardized modules with available footprint of 31.9 m x 23.5 m each. The Gas Turbogenerator Sets (TG-5147001A/D) and their corresponding OTSG/WHRU assemblies shall be installed in modules M-13 and M-13B, while the Steam Turbogenerator Set (TG-5147002) as well as all BoP equipment and components (UG-5132001) shall be installed in module M-12.

15.2.1 With exception of those sampling points associated to the live steam production at the OTSGs, the Water/Steam Quality Monitoring System shall be located at Module M-12.

15.2.2 The maximum height to be considered for the CCPG package in module M-12 is 30 m from the pancake level.

15.2.3 The CCPG package shall be designed in such a way that the STG and the entire BoP system (including their corresponding piping and components from interconnecting scope) are properly arranged within the limits of module M-12, as specified.

15.3 The CCPG package shall be designed considering that each deck in the modules shall have at least two escape routes.

15.4 The equipment within CCPG package shall be arranged to allow safe and adequate personnel access for all operation and maintenance activities. The arrangement shall comply with *I-ET-3010.2Q-1400-196-P4X-001 – Ergonomics Requirements for Topsides*.

15.5 The CCPG package layout shall be designed to provide necessary space for operability and maintainability during normal and emergency situations.

15.6 The PURCHASER shall provide permanent elevated work/access platforms for those areas where routine maintenance and inspection activities will be carried out. For access to perform non-routine tasks, the use of temporary access facilities, such as mobile work platforms or scaffolding, shall be prior approved by PETROBRAS.

15.7 The CCPG package shall be designed following the recommended module elevations to interconnect the module decks with other decks from adjacent modules, ensuring an easier access to maintenance and operation, wherever possible.

15.8 Any storage, maintenance or handling area/equipment/facility required for proper operation or maintenance of the CCPG package (such as those related to chemical products, resins, volume retrievals, OTSG or Surface Condenser tube repairs) shall be clearly located and provided within the available footprint for the CCPG package layout.

15.8.1 In module M-12 there is a handling way shared with module M-11 that leads to module M-09. In module M-13 there is a control panel room, as indicated in the 3D model of the project.

15.8.2 Chemical Injection skids of the CCPG package shall be located considering the compatibility among different chemical products. Chemical tanks shall be loaded by gravity.

15.9 The CCPG package/equipment support point(s) shall be provided including:

15.9.1 Position/coordinates versus the equipment datum point.

15.9.2 Type of support (i.e. welded / bolted).

15.9.3 Dimensions.

15.10 Regarding the height of OTSG/WHRU exhaust stack relative to the panels room structures in module M-13, the CCPG PACKAGER and the PURCHASER shall consider that a minimum height shall be provided to keep the panels rooms structures and HVAC items in a safe distance as depicted in Figure 2 below. The height of the OTSG/WHRU exhaust stacks shall not be shorter than the height depicted in the 3D model of the project.

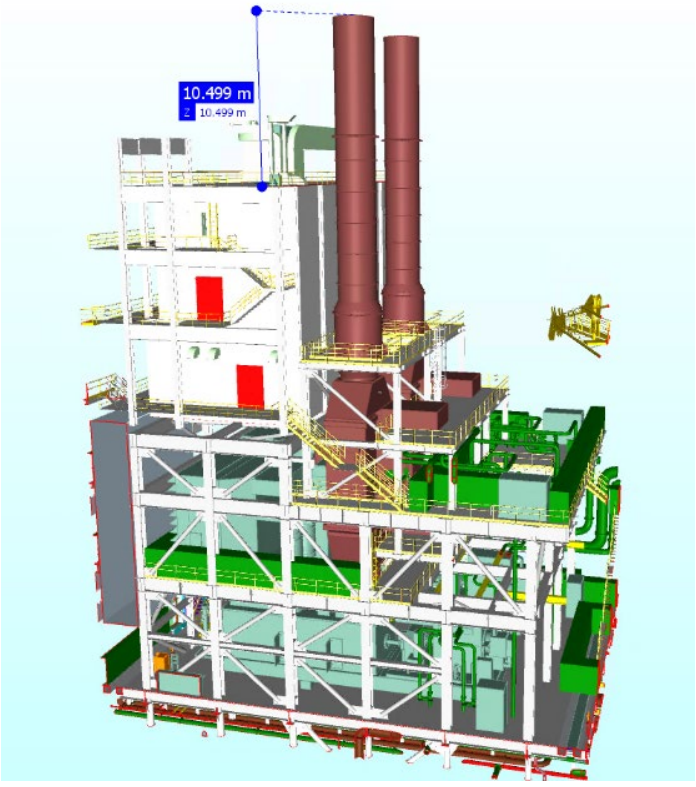

Figure 2 – Minimum OTSG/WHRU stack height in relation to the M-13 panel room structures

16. ARCHITECTURAL REQUIREMENTS

16.1 All architecture materials (doors, windows, hatches, insulation, mechanical protection, etc.) shall comply with *I-ET-3010.2Q-1400-190-P4X-001 – Topsides Architecture Materials and Equipment Specification* and *I-ET-3010.2Q-1400-196-P4X-001 – Ergonomics Requirements for Topsides*.

17. ERGONOMICS AND HUMAN FACTORS REQUIREMENTS

17.1 The CCPG package design shall be in accordance with all requirements stated in *I-ET-3010.2Q-1400-196-P4X-001 – Ergonomics Requirements for Topsides*, especially regarding manual valve categorization and accesses.

17.2 All safety critical procedure, including work involving toxic or asphyxiating gas/substances shall be subject to SCTA in accordance with *I-ET-3000.00-5400-947-P4X-007 – Human Factors Engineering (HFE)*.

18. AUTOMATION REQUIREMENTS

18.1 Package Automation System (PAS) shall fully supervise and control all CCPG package systems, equipment, and components, such as, but not limited to: GTG (TG-5147001A/D), OTSG (GV-TG-5147001A/D) and WHRU (P-GV-TG-5147001A/D), STG (TG-5147002), and BoP (UG-5132001).

18.2 The CCPG PACKAGER shall be responsible for all required control, interlocking interface, and communications architecture with the systems/process plant outside its scope of supply, to ensure the proper start-up, crank/purge, warm-up, loading, automatic or manual synchronization and load sharing, normal stop, and emergency shutdown sequences.

18.3 Package Automation System (PAS) shall be designed to ensure safe and reliable operation, performing sequencing, interlocking, protection, control, and monitoring during pressurizing, starting, operation, normal stop, emergency shutdown, pressurized stopped, depressurization and depressurized stop. The PAS shall not allow undesirable nor unsafe operations. PAS shall be furnished functionally assembled and tested.

18.4 As a minimum, the following panels shall be provided as shown in *Annex B – Preliminary CCPG Automation Architecture*.

Note: CCPG Package automation architecture with different panels configuration can be accepted, however, it shall be prior submitted for PETROBRAS approval.

18.5 All Turbogenerator Control Panels (TGCP) from both Gas and Steam Turbogenerator Sets, CCPG Control Panel, all Remote I/O Panels (RIO), any additional required Control Panel for BoP equipment and systems, Machinery Protection System (MPS), Machinery Monitoring System (MMS) interface, Asset Management System (AMS) interface and all instruments, instrumented valves, devices and associated accessories (such as, but not limited to tubing and thermowells) shall be part of Package Automation System (PAS) to be provided by the CCPG PACKAGER.

18.6 The CCPG Control Panel shall be responsible for the control and interlock of the BoP and for the orchestration of the CCPG package as a whole. Therefore, it shall communicate with other package control panels to achieve proper plant control.

18.7 PAS shall fully comply with the requirements of the following documents:

- *I-ET-3010.00-1200-800-P4X-002 – Automation, Control and Instrumentation on Package Units*
- *I-ET-3010.00-1200-800-P4X-013 – General Criteria for Instrumentation Projects*
- *I-ET-3010.2Q-1200-800-P4X-014 – Automation Interface of Packaged Units*
- *I-ET-3010.2Q-1200-800-P4X-005 – Field Instrumentation*
- *I-ET-3010.2Q-1200-800-P4X-001 – Instrumentation Additional Technical Requirements*
- *I-MD-3010.2Q-1200-800-P4X-002 – Automation and Control System - Scope Definition*

18.8 For additional information related to MMS interface, see *I-ET-3010.00-5500-854-P4X-001 – Machinery Monitoring System*.

18.9 Power Management System (PMS) shall comply with *I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - Power Management System (PMS) for Offshore Units*.

18.10 For additional information regarding turbogenerators, see *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set* and *I-ET-3010.2Q-5147-332-P4X-001 – Steam Turbine Driver for Steam Turbogenerator Set*.

18.11 For CCPG package automation type classification and additional interfaces see *I-ET-3010.2Q-1200-800-P4X-014 – Automation Interface of Packaged Units*.

18.12 All instrumentation and alarms/trips mentioned in the data sheets and process plant P&IDs are the minimum required by PETROBRAS. The CCPG PACKAGER and the PURCHASER are allowed to indicate other instrumentation and alarms/trip for general protection and monitoring according to their experience and to comply with Classification Society's requirements and submit in technical proposal for PETROBRAS approval.

18.13 The CCPG package shall not be restarted without manual acknowledgement of the shutdown conditions.

18.14 Networks for control, safety and monitoring shall be segregated from each other and redundant.

18.15 In case of power failure, system processor shall retain all programs and data as well as interface software for a minimum of six months, not being necessary to reconfigure the system after power restore. During a power failure, all outputs shall be automatically changed to their safe position.

18.16 Besides the remote TGCP HMI required in *I-ET-3010.00-5147-332-P4X-001 – Gas Turbine Driver for Gas Turbogenerator Set*, the CCPG PACKAGER shall supply another dedicated remote workstation to be installed at Central Control Room, to allow the operation and supervision of the Steam Turbogenerator Set and the rest of the CCPG package. This workstation shall be a 19" rack-mounted PC, shipped loose. Each workstation shall be fitted with ethernet ports to allow the communication with Steam Turbogenerator Control Panel and with CCPG Control Panel.

18.17 Despite the requirement from paragraph 5.2.1 of the document *I-ET-3010.00-5520-888-P4X-001 – Automation Panels*, each Turbogenerator Control Panel shall be built so that it may be transported in modules of at most two (2) sections at a time, i.e. maximum 1600 mm width x 1000 mm depth for transportation, due to constructability restrictions at Generators Control Panels Room. Internal wiring shall be minimized between these modules, to simplify reconstruction at final installation.

18.18 If motorized valves are required, they shall be fed from 690 VAC / 3 phases / 60 Hz normal power supply.

18.18.1 Alternative rated voltage in 220 VAC / 60 Hz is acceptable. In this case, motorized valves panel shall be supplied by the CCPG PACKAGER.

18.18.2 The PURCHASER and CCPG PACKAGER shall mutually agree on the location for this panel, solving all impacts related to this equipment (room space, heat dissipation, HVAC, feeders, functional units in upstream panel, etc.).

18.18.3 The use of normal power supply for this panel shall not impair the availability of the CCPG Package.

19. ELECTRICAL REQUIREMENTS

19.1 Electrical synchronous generators and their auxiliary systems that compose the CCPG package shall comply with requirements of I-*ET-3010.00-5147-711-P4X-001 - Main Generator for Offshore Units* and *I-MD-3010.2Q-5140-700-P4X-002 - Electrical System Descriptive Memorandum*.

19.2 Panels, electrical equipment, and materials shall comply with the requirements of the following documents:

- *I-ET-3010.00-5140-700-P4X-002 – Specification for Electrical Material for Offshore Units.*
- *I-ET-3010.00-5140-700-P4X-007 – Specification for Generic Electrical Equipment for Offshore Units.*
- *I-ET-3010.00-5140-700-P4X-008 – Specification for Lighting and Electrical Signalling for Offshore Units.*
- *I-ET-3010.00-5140-700-P4X-009 – General Requirements for Electrical Material and Equipment for Offshore Units.*
- *I-ET-3010.00-5140-713-P4X-001 – Specification for Transformers for Offshore Units.*
- *I-ET-3010.00-5140-741-P4X-004 – Specification for Low-Voltage Generic Electrical Panels for Offshore Units.*
- *I-ET-3010.00-5140-772-P4X-002 – Specification for Low-Voltage Frequency Converters, Soft-starters and Inverters for Offshore Units.*
- *I-ET-3010.00-5140-714-P4X-001 – Specification for Electrical Batteries for Offshore Units.*
- *I-ET-3010.00-5140-773-P4X-002 – Specification for Generic DC UPS for Offshore Units.*
- *I-DE-3010.2Q-5265-946-P4X-001 – Topside UPS and DC Systems One-Line Diagram.*
- *I-MD-3010.2Q-5140-700-P4X-002 – Electrical System Descriptive Memorandum.*

19.3 Electrical installations inside the CCPG 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, I-ET-3010.00-5140-700-P4X-001 Specification for Electrical Design for Offshore Units* and *I-MD-3010.2Q-5140-700-P4X-002 – Electrical System Descriptive Memorandum*.

19.4 Electrical motors shall comply with requirements of *I-ET-3010.00-5140-712-P4X-001 – Low-Voltage Induction Motors for Offshore Units* and *I-MD-3010.2Q-5140-700-P4X-002 – Electrical System Descriptive Memorandum*. The electrical motors shall be fed from platform panels.

19.5 The electrical communications interfaces of the CCPG package shall comply with requirements of *I-DE-3010.00-5140-797-P4X-001 – Electrical System Automation Architecture Diagram*, *I-ET-3010.00-5140-797-P4X-001 – Electrical System Automation Architecture*, *I-DE-3010.00-5140-797-P4X-002 – Electrical System Automation Typical Actuation Diagrams* and *I-LI-3010.00-5140-797-P4X-001 – Electrical System Automation Interface Signals List*.

19.6 Equipment, accessories, piping, and structures shall be grounded according to requirements of *I-DE-3010.00-5140-700-P4X-003 – Grounding Installation Typical Details*, *I-ET-3010.00-5140-700-P4X-001 – Specification for Electrical Design for Offshore Units*, IEC 61892-6 and IEC-60092-502. Besides these standards, for installations in hazardous area, the grounding requirements shall be as per IEC 61892-7.

19.7 All electrical panel shall comply with *I-ET-3010.00-5140-700-P4X-005 - Requirements for Human Engineering Design for Electrical Systems of Offshore Units*.

19.8 The excitation system shall comply with *I-ET-3010.00-5140-775-P4X-001 - Requirements for Electrical Generation Excitation System for Offshore Units*.

19.9 The CCPG PACKAGER shall provide accumulator batteries (BT-5147001A/B) and battery chargers (CB-5147001A/B) for all continuous and intermittent loads of the CCPG package that shall be fed in case of blackouts due to emergency shutdown, in accordance with *I-ET-3010.00-5140-714-P4X-001 - Specification for Electrical Batteries for Offshore Units*, *I-ET-3010.00-5140-773-P4X-002 - Specification for Generic DC UPS for Offshore Units*, *I-DE-3010.2Q-5265-946-P4X-001 – Topside UPS and DC Systems One-Line Diagram* and *I-MD-3010.2Q-5140-700-P4X-002 - Electrical System Descriptive Memorandum*.

19.9.1 Accumulator batteries shall be vented lead-acid.

19.9.2 The battery banks shall be full redundant (2x100%) and sized considering the following criteria:

19.9.2.1 Each battery bank shall be capable of supplying electric power for three out of four GTGs, for the STG and for any other equipment of the CCPG package that needs to be fed during equipment coastdown and cooldown periods to prevent damages and hot lockouts in case of blackouts (e.g. GTGs and STG emergency oil pumps, jacking oil pumps and turning gears).

Note 1: Although also connected to the battery banks of the CCPG package, loads related to the stand-by GTG can be disregarded for the purposes of sizing battery banks capacity.

Note 2: The GTGs and STG control panels (TGCPs) shall be fed by the FPSO DC UPS (not in CCPG PACKAGER scope) with autonomy of 30 minutes. If higher autonomy is required to prevent equipment damage during coastdown and cooldown periods, such control panels shall be fed by the battery banks (BT-5147001A/B). All other panels from the CCPG package that that need to be fed in case of blackouts can be disregarded for the purposes of sizing battery banks capacity.

19.9.2.2 Each battery bank shall be sized to ensure operation of these loads during the required time to prevent GTG hot lockouts as well as GTGs and STG damages in case of blackouts.

20. CONSTRUCTABILITY REQUIREMENTS

20.1 The CCPG PACKAGER shall clearly indicate in his technical documentation any design restriction related to the construction and assembly of the CCPG package (i.e., piping slopes, low/high points for piping drains/vents, minimum pump submergences, straight-pipe lengths, etc.) to be followed by the PURCHASER at shipyard.

20.2 The CCPG PACKAGER shall issue project-specific procedures for any required special welding execution, post-weld treatment or NDE inspection to be followed by the PURCHASER at shipyard for the CCPG interconnecting piping joints. Such procedures shall be prior approved by PETROBRAS.

21. OPERATION AND MAINTENANCE REQUIREMENTS

21.1 The CCPG package operation shall be fully automated to minimize people on board.

21.2 The CCPG package shall be designed to minimize the use of special tools during maintenance tasks. If required, special tools and devices shall be provided by the CCPG PACKAGER in accordance with the following requirements:

21.2.1 Spreader beams or other special lifting devices required for installation or maintenance shall be provided by the CCPG PACKAGER in accordance with *I-ET-3010.2Q-5266-630-P4X-001 – Topsides Mechanical Handling Procedures*.

21.2.2 Special tools shall be packaged in separate storage containers, rugged metal boxes, and shall be marked “special tools for (tag/item number)”. Each tool and respective container / toolbox shall be stamped or tagged to indicate the contents and use.

21.3 Equipment layout shall enable easy and safe access for maintenance to all components and parts.

21.3.1 The CCPG PACKAGER shall provide suitable on-skid lighting, walkways, ladders, and handrails for all equipment (as applicable to each case), including auxiliaries.

21.3.2 All equipment and auxiliaries (e.g., oil reservoirs, GT enclosures and inlet filter housings), shall have full access and inspection doors / hatches.

21.3.3 Instruments and piping accessories shall be grouped together and arranged in proper location to allow easy access by maintenance and operation personnel.

21.3.3.1 Installation of piping and cable supports next to couplings, bearings and seals of rotating equipment included in the CCPG package shall be avoided.

21.4 The CCPG PACKAGER and the PURCHASER shall prepare detailed assembly, disassembly, and maintenance procedures, describing the use of all involved lifting apparatus and including all required preventive and corrective maintenance tasks.

21.4.1 The CCPG PACKAGER and the PURCHASER shall inform the need for disassembling any component or equipment to facilitate access for maintenance.

21.4.2 Suitable maintenance routes shall be provided to remove the main components and auxiliaries, avoiding interference with structures, piping, cabling, electric conduits and supports, equipment, etc.

21.4.3 This plan shall be submitted for PETROBRAS approval.

21.5 Noise control requirements

21.5.1 Noise control analysis is a mandatory item to be carried out for each equipment included in the CCPG package and shall be a joint effort of the CCPG PACKAGER and the PURCHASER.

21.5.2 Unless otherwise specified, each equipment furnished by the CCPG PACKAGER shall conform to the maximum allowable sound pressure level of 85 dBA, measured at 1 (one) meter away from the equipment surfaces, including piping and auxiliary systems.

NOTE: the SPL limit stated above refers to all operating conditions, considering that 100% load may not necessarily be the noisiest one.

21.5.3 The following data shall be included by the CCPG PACKAGER in the technical proposal:

- Expected values for maximum SPL per octave band for each equipment included in the CCPG package.
- Sound pressure levels for each of the four main directions and at one point of the top.

21.5.4 If the expected SPL of any equipment included in the CCPG package is higher than the maximum allowable SPL above, the CCPG PACKAGER shall consider the use of removable acoustic blankets (or another suitable noise control design countermeasure), which shall be prior submitted for PETROBRAS approval.

22. INSPECTION AND TESTING

22.1 Combined Cycle Integrated Test

22.1.1 Besides all inspections and tests to be carried out for each equipment, auxiliary and component included in CCPG PACKAGER´s scope of supply (as required in the referenced standards and technical documentation issued by PETROBRAS), the PURCHASER shall also plan and execute with the CCPG PACKAGER technical assistance a **Combined Cycle Integrated Test** to be carried out at FPSO integration shipyard to verify the overall functionality of the CCPG system. This test shall be planned and executed in accordance with CCPG system commissioning procedures and *I-MD-3010.2Q-1200-970-P4X-001 – Commissioning Descriptive Memorandum*.

22.2 Offshore Combined Cycle Integrated Test

22.2.1 Besides all inspections and tests to be carried out for each equipment, auxiliary and component included in CCPG PACKAGER´s scope of supply (as required in the referenced standards and technical documentation issued by PETROBRAS), the PURCHASER shall plan and execute an **Offshore Combined Cycle Integrated Test**, to be carried out at the FPSO final location, to verify the overall performance of the CCPG system against the designed requirements. This offshore performance test shall be planned and executed in accordance with ASME PTC 46 and CCPG system start-up and operation procedures. For further details, refer also to *I-MD-3010.2Q-1200-970-P4X-001 – Commissioning Descriptive Memorandum*.

ANNEXES

Annex A - Vendor Drawing and Data Requirements for Turbogenerator Sets

Annex A - VDDR for Turbogen Sets.pdf

Annex B - Preliminary CCPG Automation Architecture

Annex B - Automation Archite