REVISION INDEX

REV.	DESCRIPTION AND/OR REVISED SHEETS
	Based on I-ET-3000.00-1500-310-PEK-002
0	ORIGINAL
A	Changes in 4.1.1, 4.1.2, 4.2.4.10, 4.1.2.13.5, 4.1.2.13.6, 4.2.5.3.1, where highlighted in GREY.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	18/10/2023	25/03/2024							
DESIGN	EES	EES							
EXEC.	B2N8	B2N8							
CHECK	MA9N	ES24							
APRROV,	UP65	U4SZ							

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FORM OWNED TO PETROBRAS N-381. L.

INDEX

1 INTRODUCTION

The objective of this technical specification is to establish the requirements for Subsea Raw Water Injection Systems — 10Kpsi.

1.1 Reference Documents

1.1.1 Codes, Standards, Rules and Regulations

The latest issue of the reference standards shall be used unless it is specified in the table below or otherwise agreed. Other recognized standards may be used, provided that the SUPPLIER provides evidence that they meet or exceed the requirements of the standards referenced below.

[1] Resolução ANP nº 41 – DOU 13.10.215	Sistema de Gerenciamento de Segurança Operacional de Sistemas Submarinos – SGSS (Management System for Operational Safety of Subsea Systems)
[2] ISO 13628-15:2011	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 15: Subsea structures and manifolds
[3] API SPEC 6A 2018	Specification for Wellhead and Tree Equipment
[4] API SPEC 17D 2019	Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment
[5] ISO 13628-1:2005	Petroleum and natural gas industries - Design and operation of subsea production systems – Part 1: General requirements and recommendations
[6] ISO 13628-8	Design and operation of subsea production systems - Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems
[7] ISO 10423:2009	Petroleum and natural gas industries - Drilling and Production Equipment - Wellhead and Christmas Tree Equipment
[8] ISO 12736:2014	Petroleum and natural gas industries — Wet thermal insulation coatings for pipelines, flow lines, equipment and subsea structures
[9] ISO 10816-3:2009	Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ
[10] API RP 11S8:2012	Recommended Practice on Electric Submersible System Vibrations
[11] API RP 17N, 2nd Ed., Addendum 1 – May 2018	Recommended Practice on Subsea Production System Reliability, Technical Risk, and Integrity Management
[12] API RP 17Q	Recommended Practice on Subsea Equipment Qualification

[13] API RP 17V	Recommended Practice for Analysis, Design, Installation, and Testing of Safety Systems for Subsea Applications - FIRST EDITION; ERTA 1: July 2015
[14] API STANDARD 17O	Standard for Subsea High Integrity Pressure Protection Systems (HIPPS)
[15] API RP 17H 3rd ed	Remotely Operated Tools and Interfaces on Subsea Production Systems
[16] DNVGL-RP-O501, Ed Aug 2015, Addendum 1 – Oct 2018	Managing sand production and erosion
[17] ISO 15156-3	Petroleum and natural gas industries — Materials for use in H2S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys
[18] ISO 14224	Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment
[19] 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
[20] ISO 23936-1	Petroleum, petrochemical and natural gas industries — Non-metallic materials in contact with media related to oil and gas production — Part 1: Thermoplastics
[21] Norsok M-710	Qualification of non-metallic materials and manufacturers – Polymers
[22] Norsok M-501	Surface preparation and protective coating
[23] ISO 17781	Petroleum, petrochemical and natural gas industries — Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels
[24] NACE MR0175	Petroleum, petrochemical, and natural gas industries — Materials for use in H2S-containing environments in oil and gas production —
[25] DNVGL-RP-F112	Duplex stainless steel - design against hydrogen induced stress cracking
[26] DNV RP B401	Cathodic protection design
[27] ISO 21457	Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems
[28] IEC 61511	Functional safety of electrical/electronic/programmable electronic safety-related systems

1.1.2 PETROBRAS Documents

The specific documents of the project corresponding to the ones listed below without number shall be described in the project specific RM or in the project specific LD

[29] RM	Material Requisition(s) with technical aspects and scope specific to the project
[30] Fluids TS	Technical Specification(s) with the characteristics of the fluids of the project
[31] Engineering Diagram	Base Case Engineering Diagram of the Equipment/System
[32] Anchoring System TS	Equipment Anchoring and Foundation Specification(s) of the project
[33] Subsea Field Layout Drawing	Subsea Field Layout Drawing of the project
[34] Control System TS	Control System Specification(s) of the project
[35] Subsea Electrical Power System TS	Subsea Electrical Power System Specification(s) of the project
[36] UTA TS	Umbilical Termination Assembly Technical Specification
[37] I-ET-3000.00-1500-310-PEK-003	SUBSEA SEAWATER PUMP
[38] I-ET-3000.00-1500-310-PEK-005	SUBSEA SEAWATER INTAKE AND SKIMMER 10.000 PSI
[39] Pump Datasheet	
[40] Inlet Choke Valves Datasheet	
[41] ET-3000.00-1500-600-PEK-005	Requisitos de Estruturas de Equipamentos Submarinos
[42] ET-3000.00-1500-600-PEK-006	Requisitos Gerais de Equipamentos Submarinos
[43] ET-3000.00-1521-600-PEK-001	Projeto de Interfaces para Operações com ROV / E&P
[44] ET-3000.00-1500-610-PEK-002	Eslingas e Skids para Transporte de Equipamentos Submarinos
[45] ET-3000.00-1500-251-PEK-001	Fixadores em Aço Baixa Liga de Alta Resistencia para aplicação Submarina / Instalações Submarinas
[46] ET-3000.00-1500-251-PEK-002	Rastreabilidade de Fixadores de Alta Resistencia para Utilização o Submarina / Instalações Submarinas
[47] I-ET-3000.00-1500-24A-PEK-003	Design and Test Requirements for Direct Vertical, Horizontal and Pivotable Subsea Connector Modules
[48] N-2037	Pintura de Equipamentos Submersos em Água do Mar
[49] N-1852	Estruturas Oceânicas - Fabricação e Montagem de Unidades Fixas
[50] N-133	Soldagem
[51] ET-3000.00-1500-600-PEK-004	Documentação Técnica para Equipamentos Submarinos
[52] ET-3000.00-1500-940-PEK-001	Projeto de Proteção Catódica para Equipamentos Submarinos
[53] ET-3000.00-1500-220-PEK-002	Requisitos Gerais de Projeto e Testes de Válvulas e Atuadores Submarinos
[54] ET-3000.00-1500-221-PEK-001	Requisitos Específicos de Projeto e Testes de Válvulas Gaveta para Aplicação Submarina.

[55]	ET-3000.00-1500-224-PEK-001	Requisitos Específicos de Projeto e Teste de Válvulas Esfera para Aplicação Submarina
[56]	ET-3000.00-1516-619-PEK-014	PADRONIZAÇÃO DE INTERFACES – BAP x Módulos de Conexão Vertical GLL/DL Pré-Sal - LDA 2500m – 10.000 psi
[57]	ET-3000.00-5535-941-PEA-001	Especificação Técnica para Instrumentação para Posicionamento de Equipamentos Submarinos
[58]	LD-3000.00-1500-600-PEK-001	Lista de Documentos Gerais de Projeto
[59]	LD-3000.00-1500-600-PEK-002	Lista de Documentos de Inspeção
[60]	LD-3000.00-1500-600-PEK-012	Lista de Documentos - Mecânica
[61]	LD-3000.00-1500-600-PEK-013	Lista de Documentos de Qualificação
[62]	ET-3000.00-1514-210-PEK-001	Tubulações para Equipamentos Submarinos
[63]	Special Operations Fluids TS	Fluids for Special Operations applicable in specific projects
[64]	I-ET-0000.00-0000-24A-P9U-002	TIE-IN SPOOL MANUFACTURING
[65]	ET-3000.00-1500-229-PEK-001	REQUISITOS DE PROJETO E TESTES DE VÁLVULAS CHOKE PARA APLICAÇÃO SUBMARINA
[66]	I-FD-3000.00-1500-229-PEK-001	CONTROL VALVES FOR APPLICATION IN SUBSEA EQUIPMENT
[67]	Aftermarket Services TS	Aftermarket Services and Technical Assistance Specification(s) of the project
[68]	ET-3000.00-1500-600-PEK-008	Instalação de Equipamentos Submarinos
[69]	Interface with Production Unit TS	Topside Module Interface with FPSO/FPU
[70]	Geophysics and Geologic Data Report	
[71]	Geotechnical Data Report	
[72]	ET-3000.00-1500-973-PEK-001	Teste de Aceitação de Fábrica nos Fornecedores de Equipamentos Submarinos
[73]	LD	List of Documents containing project specific inputs and requirements
[74]	ET-3000.00-1500-813-PEK-003	Medidor Submarino de Vazão de Fluido Multifásico
[75]	ET-3000.00-1500-813-PEK-004	Qualificação de Medidor Submarino de Vazão de Fluido Multifásico
[76]	I-ET-3000.00-1500-270-PEK-002	Requisito Para Swivel Submarino
[77]	ET-3000.00-1520-612-PEK-001	Dispositivo De Manuseio E Tombamento De Módulos De Conexão Submarina De Dutos E Umbilicais
[78]	I-FD-3000.00-1500-223-PEK-001	BACKPRESSURE VALVES FOR APPLICATION IN SUBSEA EQUIPMENT
[79]	ET-3000.00-1514-270-PEK-001	MANIFOLDS E EQUIPAMENTOS DE GRANDE PORTE

1.1.3 Order of Precedence

If there is any conflict between requirements the following order of precedence shall be applied ((i) being higher in the order):

i. Resolução ANP nº 41 – DOU 13.10.215
ii. RM (Material Requisition of the project).
iii. This Technical Specification.
iv. [34], [35], [37];
v. Other PETROBRAS documents.
vi. ISO-13628-15:2011 [2];
vii. API 6A [3].
viii. Other ISO Standards and RPs.
ix. API Standards and RPs.
x. Other Standards and RPs.

1.2 TERMS, DEFINITIONS, ACRONYMS AND ABREVIATIONS

1.2.1 Acronyms and Abbreviations

BFHPU: Barrier Fluid Hydraulic Power Unit

BSRWI: Subsea Seawater Pump

BPV: Back Pressure Valve

CAT: Component Acceptance Test

CFD: Computational Fluid Dynamics

CKM: Choke RETRIVABLE MODULE

CMAT: Complete Model Acceptance Test

CRA: Corrosion Resistant Alloy

Cv: Valve Flow Control Coefficient

CVM: Control Valve RETRIVABLE MODULE

DPIEF: Define, Plan, Implement, Evaluate, Feedback

DRS: Diverless Rigid Spool

ESRWI: Subsea Raw Water Injection Station

EFL: Electric Flying Lead

ET: Technical Specification (= TS)

FAT: Factory Acceptance Testing

FMECA: Failure Modes, Effects, and Criticality Analysis

FPSO: Floating Production, Storage and Offloading Vessel

HAZID: Hazard Identification

HAZOP: Hazard and Operability Study

HFL: Hydraulic Flying Lead

ID: Internal Diameter

IM-FMECA: Integrity Management Failure Modes, Effects, and Criticality Analysis

ITMM: Inspection, Testing, Monitoring, and Maintenance

MATIC: Manufacture, Assembly, Testing, Installation, and Commissioning

MAY: used when alternatives are equally acceptable

MBSRWI: SUBSEA SEAWATER PUMP Retrievable Module

MCV: Vertical Connection Module

MEG: Monoethylene Glycol

MRFB: Barrier Fluid Subsea Retrievable Module

NP: Part Number

NPS: Nominal Pipe Size

P-FMECA: Process Failure Modes, Effects, and Criticality Analysis

PDF: Portable Document Format

PSL: Product Specification Level, according to references [2] and [3].

PSV: Pressure Safety Valve

PVT: Performance Verification Testing

PFFM: SUBSEA SEAWATER PUMP FINE-FILTRATION MODULE

QA: Quality Assurance

QC: Quality Control

Q-FMECA: Qualification Failure Modes, Effects, and Criticality Analysis — ref [12]

RAM: Reliability, Availability, and Maintainability

RBD: Reliability Block Diagram

RBI: Risk Based Inspection

RIAD: Reliability and Integrity Assurance Document

RIM: Reliability and Integrity Management

RM: Material Requisition

ROV: Remotely Operated Vehicle

RP: Recommended Practice

SDV: Shut Down Valve

SEPS: Subsea Electrical Power System

SHALL: used when a provision is mandatory

SHOULD: used when a provision is not mandatory, but is recommended as a good practice

SIS: Safety Instrumented Systems. According to reference [14]

SIT: System Integration Test

SMAT: Subsystem Model Acceptance Test

SMYS: Specified Minimum Yield Strength

SQP: Standard Qualification Program

SRWI: Subsea Raw Water Injection

SRWI SYSTEM: Subsea Raw Water Injection System

SRWIFB: Subsea Raw Water Injection Flow Base

SRWIIS: SUBSEA RAW WATER INJECTION INTAKE SKIMMER

SVSD = SVFD: Subsea Variable Frequency Drive= Subsea Variable Speed Drive

TMA: Technology Maturity Level

TQP: Technology Qualification Program

TRAR: Technical Risk Assurance Review

TRC: Technical Risk Categorization

TRL: Technical Readiness Level

TS: Technical Specification (= ET)

UTA: Umbilical Termination Assembly

VFD= VSD: Variable Frequency Drive= Variable Speed Drive

XT: Subsea Christmas Tree

1.2.2 Definitions

1.2.2.1 SUPPLIER: Pumping System Supplier

1.2.2.2 Safety Critical Elements: any Critical Equipment, System or Procedure of Operational Safety, according to [1].

1.2.2.3 Safety Critical Equipment: any equipment or structural element of the system whose failure could cause or contribute to operational accidents, according to [1].

1.2.2.4 Safety Critical Procedure: any procedure or criteria used to control operational risks, according to [1].

1.2.2.5 Safety Critical System: any engineering control system designed to maintain the system inside its Safety Envelope, to stop partially or totally the system in case of operational safety failure, and to reduce risks to personnel and environment exposed to failure consequences, according to [1].

1.2.2.6 Package: A named system, subsystem, or defined set of components considered as a single entity for the purposes of a design study or for procurement (e.g., subsea tree, control system).

1.2.2.7 RETRIVABLE MODULE(S): According to 4.2.4

1.2.2.8 SIMULATIONS MEETING: According to **5.1**

1.2.2.9 Safety Envelope: Operational limits and conditions defined during system Detailed Design stage and complying with applicable industry standards that shall not be surpass and that guarantee the integrity and operational safety of the system, according to [1].

2 SUBSEA RAW WATER INJECTION SYSTEM APPLICATION CONDITIONS AND PARAMETERS

2.1 SUBSEA RAW WATER INJECTION SYSTEM shall be designed to withstand all conditions and parameters described in RM [29] and Fluids ET [30], including full range of pressures, temperatures and contaminants and other extreme conditions scenarios imposed by produced fluids and fluids injected from topside in permanent and in transitory conditions, also according to the RM [23] and the Fluids ET [24].

2.2 If the SUBSEA RAW WATER INJECTION SYSTEM is not mechanically fully rated (according to [13]), an instrumented safety system shall be applied according to [14].In case the SUBSEA RAW WATER INJECTION SYSTEM design cannot reasonably accommodate the requirements of item 2.1 above, additional protection based on subsea sensors for automatic real-time monitoring, detection, and protective action if an abnormal condition indicating an undesirable event is detected shall be implemented. The SMPS shall be protected by a dedicated SUBSEA SAFETY SYSTEM to provide the SAFETY INSTRUMENTED FUNCTIONS with their respective RISK REDUCTION FACTOR required, according to API RP17V [13] and IEC 61511 [14]. The SUBSEA SAFETY SYSTEM shall be designed and certified as a SAFETY INTRUMENTED SYSTEM (SIS) according to IEC 61511 [14] or more specifically to API STANDARD 17O [15] in the particular case of a HIPPS being required.

3 SUPPLIER RESPONSIBILITY

3.1 SUPPLIER shall perform the work in accordance with the requirements of all references in 1.1 of this TS.

3.2 SUPPLIER shall assume sole contractual and total engineering responsibility for the items supplied.

3.3 SUPPLIER's responsibility shall also include but not be limited to:

3.3.1 Resolving all engineering questions and/or problems relating to design and manufacturing.

3.3.2 Providing details as requested, for the main and auxiliary system and equipment, relating to design and manufacturing.

3.3.3 Services, maintenance, technical assistance and training according to [67].

3.4 Compliance by the SUPPLIER with the provisions of this specification and industry standards does not relieve the SUPPLIER's responsibility to furnish equipment and accessories of a proper mechanical design suited to meet the specified service conditions.

3.5 SUPPLIER is responsible for all coordination with MANUFACTURERS and collections of all details, drawings and data to achieve optimum design and full submission of all documents requested in the specification.

4 SUBSEA RAW WATER INJECTION SYSTEM TECHNICAL REQUIREMENTS

4.1 SUBSEA RAW WATER INJECTION SYSTEM

4.1.1 The SUBSEA RAW WATER INJECTION SYSTEM shall be intrinsically safe, with its equipment and components designed to mechanically withstand all internal fluid's process conditions according to the RM [29] and the Fluids ET [30], including overpressure, underpressure and other extreme conditions scenarios imposed by produced fluids and fluids injected from topside, also according to the RM [29] and the Fluids ET [30].

4.1.2 In case the SUBSEA RAW WATER INJECTION SYSTEM design cannot reasonably accommodate the requirements of item 4.1.1 above, requiring additional levels of protection based on subsea sensors for automatic real-time monitoring, detection, and protective action if an abnormal condition indicating an undesirable event is detected, the SMPS shall be protected by a dedicated SUBSEA SAFETY SYSTEM to provide the SAFETY INSTRUMENTED FUNCTIONS with their respective RISK REDUCTION FACTOR required, according to API RP17V [13] and IEC 61511 [28]. The SUBSEA SAFETY SYSTEM shall be designed and certified as a SAFETY INTRUMENTED SYSTEM (SIS) according to IEC 61511 [28] or more specifically to API STANDARD 17O [14] in the particular case of a HIPPS being required.

4.1.2.1 SUBSEA RAW WATER INJECTION SYSTEM shall be designed to have pressurization and depressurization rates more conservative than the ones in [29] and [30].

4.1.2.2 SUBSEA RAW WATER INJECTION SYSTEM base case is referenced in the Base Case Engineering Diagram [31].

4.1.2.3 Refs. [29] and [31] shall define how many inlet and outlet wells and flowlines shall be connected to the SUBSEA RAW WATER INJECTION SYSTEM, how many multiphase flow meters are required and how many inlet choke valves are required and the position of them.

4.1.2.4 SUBSEA RAW WATER INJECTION SYSTEM and equipment shall be designed by the SUPPLIER to be fully functional and optimized (including the process). The SUPPLIER shall carry out both dynamic and steady state process simulations interacting with PETROBRAS and submit all results for PETROBRAS approval according to section 5 of this TS.

4.1.2.5 SUBSEA RAW WATER INJECTION SYSTEM shall allow normal and safe production of the wells even without the MBMS(s) (considering other elevation methods required in [30] and [39]) and an additional safety barrier.

4.1.2.6 SUBSEA RAW WATER INJECTION SYSTEM includes SUBSEA RAW WATER INJECTION Topside Facilities and SUBSEA Raw Water Injection Subsea Facilities.

4.1.2.7 All SUBSEA RAW WATER INJECTION SYSTEM subsea equipment shall be fully diverless.

4.1.2.8 SUBSEA RAW WATER INJECTION SYSTEM Topside Equipment includes all utilities, facilities, and equipment in the FPSO needed to be installed topside to fulfill SUBSEA RAW WATER INJECTION SYSTEM safety and performance requirements within equipment and system safety envelope that are in the scope of the SUPPLIER. SUBSEA RAW WATER INJECTION SYSTEM Topside Equipment shall comply with [69]

4.1.2.9 During the SUBSEA RAW WATER INJECTION SYSTEM design, the SUPPLIER shall submit for PETROBRAS approval reports and numerical and engineering analysis considering at least process safety, operational safety and production efficiency according to sections 5, 5.1, 7, 8 and 12.

4.1.2.10 During the SUBSEA RAW WATER INJECTION SYSTEM Detailed Design phase, the SUPPLIER should propose optimization and changes in [31] and ESRWI design as soon as they are conceived. Optimization and changes shall be submitted for PETROBRAS approval together with calculations considering at least process safety, operational safety and production efficiency according to sections 5.1, 7, 8, 9,10,11 and 12. The modularization philosophy shall be optimized according to the best solution for the design proposed by SUPPLIER if submitted and approved by PETROBRAS.

4.1.2.11 SUBSEA RAW WATER INJECTION SYSTEM design life in years is in [29]. This refers to the number of years that the system shall be able to be fully operational after installed and commissioned.

4.1.2.12 SUBSEA RAW WATER INJECTION SYSTEM and all its components shall fully comply with [13]. The SUPPLIER shall verify if the base case in [31] complies with [13] and alert PETROBRAS of any deviation for written approval. At the end of the Detail Design Stage the SUPPLIER shall submit a report stating that the ESRWI final design fully complies with [13].

4.1.2.13 SUBSEA RAW WATER INJECTION SYSTEM and all its sub-components, spare parts, tools and all items in this technical specification shall comply with [42] and all technical specifications referenced in [41] and [42], considering:

4.1.2.13.1 Safe Installation by cable without heave compensation,

4.1.2.13.2 Fully diverless equipment,

4.1.2.13.3 All choke valves shall have inserts retrievable by cable with ROV support and ROV operated clamps. All choke valves shall be designed and tested according to [40] and [65]

4.1.2.13.4 All choke inserts shall be installed and retrievable by the same tool.

4.1.2.13.5 Only Vertical connectors are acceptable for retrievable modules.

4.1.2.13.6 Only Hydraulic connectors are acceptable.

4.1.2.13.6.1 All connectors shall comply with [42] and [79].

4.1.2.13.6.2 MCVs shall comply with [42], [47], 49], [76] and [77])

4.1.2.14 All flowlines connectors (suction and discharge) shall follow PETROBRAS Standard 10.000 psi hub profile according to [56] and the requirements in [47].

4.1.2.15 Vertical connectors different from PETROBRAS standard connectors (ref. [56]) are acceptable for retrievable modules. For each connector different from PETROBRAS standard connectors (ref. [56]) the SUPPLIER shall provide to PETROBRAS:

4.1.2.15.1 all technical details and manufacturing drawings of the interface between the hub and connector (hub profile, seal cavity and connector guidance system). Internal components of the connector may not make part of these drawings; and

4.1.2.15.2 use and share authorization letter with the objective of future standardization (license concession for use by PETROBRAS in any purchase purpose).

4.1.2.16 All SUBSEA RAW WATER INJECTION SYSTEM equipment and all surfaces wetted by production or injection fluids shall be minimum Trim HH with a minimum layer of 3mm and psl-3G as defined in [3]. SUPPLIER shall comply with all requirements from [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27] including all codes and requirements from [41] and [42].

4.1.2.17 The SUPPLIER shall guarantee and provide evidence during Detail Design Stage that all non-metallic materials in the SUBSEA RAW WATER INJECTION SYSTEM in contact with production fluids are compatible with the O_2 content of the fluid (psl-3G, according to [3]). High O_2 fluids are known to be aggressive to most elastomeric materials. The fluids are described in [30] and [63].

4.1.2.18 The SUPPLIER shall guarantee and provide evidence that all non-metallic materials in the SUBSEA RAW WATER INJECTION SYSTEM in contact with control system fluids, compensation fluids and pumps barrier fluids are compatible with those fluids.

4.1.2.19 The SUPPLIER must provide traceable and irrefutable evidence on the compatibility/ageing of the non-metallic materials considering:

4.1.2.19.1 Representative operational conditions (temperature, pressure, fluids like O_2, H2S, water and their concentrations and exposure time of the materials to the scenario/design lifespan);

4.1.2.19.2 Chemical products that may be in contact with non-metallic parts, considering representative treatment conditions (temperature, pressure, chemicals their concentrations and exposure time of the materials to these during equipment design lifespan);

4.1.2.19.3 Any events that may take place considering equipment operation (for instance, but not limit to, rapid gas decompression – RGD events);

4.1.2.20 Evidence in 4.1.2.19 must be provided considering representative experimental data based on renowned standards such as ref. [20] (thermoplastics) and/or ref. [19] (elastomers) or other representative standards, as conservative or more than the ones proposed herein. These results must evidence material overall performance in the application (for instance, but not limited to, compression set, stress relaxation, creeping, mechanical properties, RGD so on and so forth) taking into consideration material within equipment design (for instance, groove fill and squeeze that strongly influence RGD behavior of seals, so on and so forth).

4.1.2.20.1 A point of attention to be highlighted: the aforementioned standards and others as well (for instance, ref. [21]) propose in their scope the so-called "Standard gas mixtures", especially for RGD testing. Supplier must provide evidence on material performance considering bespoke mixtures, i.e., as agreed between interested parties, considering technical specifications. Moreover, if decompression events are expected for the application, those must be evaluated from the material performance point of view (regardless they are thermoplastics or elastomers or their composites) not only using representative scenarios, but also considering representative decompression rates (not necessarily the standardized ones – in ref. [19]: 20bar/min shall be compared with the ones in [29], [30], [39], [63] and [40] and the most conservative case shall be considered).

4.1.2.21 All SUBSEA RAW WATER INJECTION SYSTEM equipment, lines and piping shall be designed for the temperature range in [29].

4.1.2.22 All SUBSEA RAW WATER INJECTION SYSTEM equipment, lines and piping shall be designed for the water depth range in [29].

4.1.2.23 SUBSEA RAW WATER INJECTION SYSTEM Instrumentation and Control shall fully comply with [34].

4.1.2.24 All SUBSEA RAW WATER INJECTION SYSTEM equipment, lines and piping shall be designed for installation complying with the requirements of [68].

4.1.2.25 All SUBSEA RAW WATER INJECTION SYSTEM, subsystems, equipment, lines and piping shall comply with the requirements in [62]

4.1.2.26 All SUBSEA RAW WATER INJECTION SYSTEM, subsystems, equipment, lines and piping shall be designed to avoid dead legs.

4.1.2.26.1 For all remaining dead legs, chemical injection points or other hydrate prevention solution shall be provided and submitted for PETROBRAS approval.

4.1.2.26.2 If chemical injection is used as mitigation for dead legs, the final geometry shall be designed in a way that no fluid exchange between dead legs and working lines with live fluids is possible in order to reduce preservation chemical injection needs.

4.1.2.27 All SUBSEA RAW WATER INJECTION SYSTEM, subsystems, equipment, lines and piping shall be designed to have chemical injection in points where water can gather. PETROBRAS shall approve these injection points.

4.1.2.28 All SUBSEA RAW WATER INJECTION SYSTEM, subsystems, equipment, lines and piping shall be designed to withstand erosion in any of the foreseen operational procedures or possible incidental conditions.

4.1.2.29 All SUBSEA RAW WATER INJECTION SYSTEM equipment, including main vessels, scrubbers, pumps, motors, retrievable modules and valves shall be identified according to [42] (including QR Code on the external surface).

4.1.2.30 SUBSEA RAW WATER INJECTION SYSTEM painting, anti-fouling and coating shall comply with the requirements of [22], [42], and [48]. Sealing areas and/or surfaces with relative movement shall not be painted.

4.1.2.31 SUBSEA RAW WATER INJECTION SYSTEM shall de designed with adequate cathodic protection and comply with the requirements of [52].

4.1.2.32 SUBSEA RAW WATER INJECTION SYSTEM shall have thermal insulation fully complying with the parameters described in RM [29] and Fluids TS [30] and complying with [8]. CFD analysis according to 7.4 shall be used to verify if the thermal insulation is complying with those requirements.

4.1.2.33 SUBSEA RAW WATER INJECTION SYSTEM thermal insulation covering connections, seals, joints, bolts and movable parts shall be installed onshore and only after all leak tests and hydrostatic tests are concluded.

4.1.2.34 The minimum diameter for piping in SUBSEA RAW WATER INJECTION SYSTEM shall be calculated according to [16].

4.1.2.35 All SUBSEA RAW WATER INJECTION SYSTEM Foundation, Raw Water Injection Flow Base, RETRIEVABLE MODULES, Pumps, and all other piping and Equipment shall be designed to be installed by cable.

4.1.2.36 The “C Ring” concept shall not be used in any SUBSEA Raw Water Injection Equipment connector.

4.1.2.37 All block valves in ESRWI shall be designed and tested according to ref. [53], [54] and [55].

4.1.2.38 All choke valves in ESRWI shall be designed and tested according to ref. [53] and [65].

4.1.2.39 All check valves in ESRWI shall be designed and tested according to ref. [3], [4] and [42] (considering PR 2).

4.1.2.40 All ROV interfaces in ESRWI shall comply with [43].

4.1.2.41 Diameter reduction shall only be acceptable in ESRWI´s the pigging circuits if the solution is presented and accepted by Petrobras. The reductions, if approved shall be prepared to pigging using conical areas.

4.1.2.42 All Multiphase Flowmeters in the ESRWI shall comply with [74] and [75].

4.1.2.43 All components of SRWI System shall have TAGs and QR Codes according to [42].

4.2 SUBSEA RAW WATER INJECTION STATION

4.2.1.1 Each ESRWI is typically physically divided in three parts: [i] ESRWI Foundation (4.2.2.2), [ii] SRWIFB (4.2.3) with its RETRIVABLE MODULEs, [iii] MBSRWI (4.2.4) and [iv] INTAKE AND SKIMMER (4.2.2).

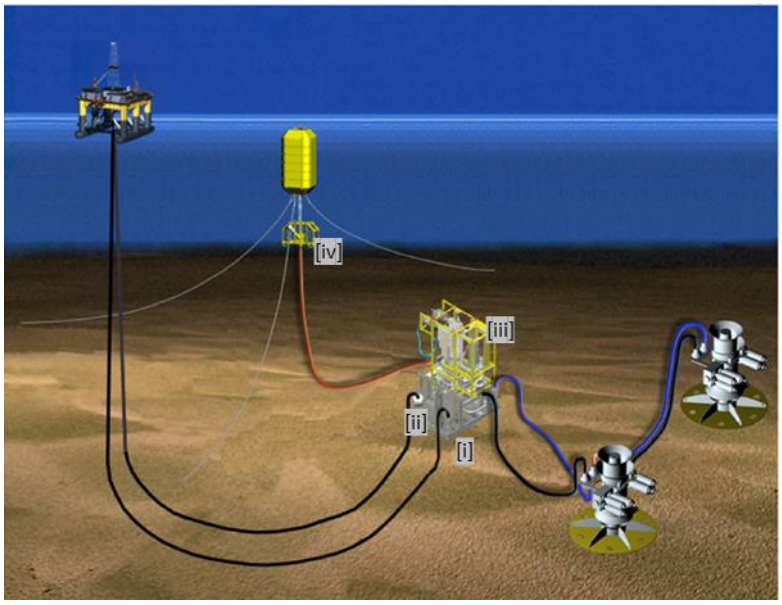

Figure 4-1 SRWI System Illustration

4.2.1.2 Each ESRWI (or ESRWI part), while onshore, in transportation, in the installation vessel or during installation shall comply with the size limit in [29].

4.2.1.3 Each ESRWI shall be designed to allow installation with the complete Control System, according to the requirements of [34]

4.2.1.4 Each ESRWI shall have a Foundation. Each Station Foundation shall follow all the requirements of 4.2.2.2.

4.2.1.5 Each ESRWI shall have a SRWIFB that includes all equipment that will not be retrievable (such as lines, connectors, tubing and non-retrievable valves, for example). Each SRWIFB shall follow all the requirements of 4.2.3.

4.2.1.6 Each ESRWI shall have a MBSRWI that includes the pumps and follow the requirements of [37].

4.2.1.6.1 If explicit in [29], the ESRWI could have more than one MBSRWI connected to SRWIFB.

4.2.1.7 Each ESRWI shall two retrievable MRFB per MBSRWI and follow the requirements of [37].

4.2.1.8 If the ESRWI Foundation and the SRWIFB combined weight and size is less than the limits [29] the supplier may join both physically.

4.2.1.9 ESRWI and equipment shall have multiple points for electrochemical potential monitoring. SUPPLIER shall propose these points and submit an numerical analysis for PETROBRAS approval following items 5.1, 7, 8 and 12 of this TS.

4.2.1.10 ESRWI and equipment shall have multiple points for thickness measurement by ROV. These points shall be easily accessible by ROV and located where cathodic protection is less effective. SUPPLIER shall propose these points and submit for PETROBRAS approval following items 5.1, 7, 8 and 12 of this TS.

4.2.1.11 SUBSEA RAW WATER INJECTION SYSTEM shall have one service downline hub in the ESRWI for MEG or Alcohol injection or depressurization.

4.2.1.11.1 The station and the point where this hub connects to SRWIFB piping shall be defined during DETAIL DESIGN PHASE and shall be submitted for Petrobras approval.

4.2.1.11.2 This hub shall have one hot stab connection according to ref. [15] considering high flowrate Type 3 .and passage diameter from 1" to 2" (to be defined during DETAIL DESIGN PHASE and to be submitted for Petrobras approval).

4.2.1.11.3 SUBSEA RAW WATER INJECTION SYSTEM service downline hub in the ESRWI shall have 2 (two) 2" ROV operated block valves (according to [31])

4.2.1.12 For each choke valve the SUPPLIER shall aim for one choke insert valid for the whole ESRWI design life. If more than one choke insert is needed during the design life, the SUPPLIER shall submit the calculations confirming the need for different Cv during life cycle for PETROBRAS approval.

4.2.1.13 SUPPLIER shall provide one spare insert for each choke insert design (different diameter or Cv) in the system including different chokes inserts used in the same position.

4.2.1.14 If any tool is needed for choke inserts installation or retrieval, this tool must be the same for all inserts in the System.

4.2.1.15 If the design needs different Cv for the same choke during the life, the supplier shall deliver all inserts needed for equipment lifecycle.

4.2.1.16 SUPPLIER shall have provided one spare insert for each choke insert design (different diameter or Cv) in the system including different chokes inserts used in the same position.

4.2.1.17 SUPPLIER shall design ESRWI to avoid hydrate formation. This prevention philosophy shall account for recirculation, bypasses and all operational modes and aim to avoid continuous or large volumes of chemical injection.

4.2.1.18 Each SUBSEA RAW WATER INJECTION SYSTEM pump shall have two individually retrievable Barrier Fluid Subsea Retrievable Modules (MRFB) according to [37] that shall be installed in SRWIFB.

4.2.1.19 Each MBSRWI shall be individually retrievable.

4.2.1.20 Each MRFB shall be individually retrievable.

4.2.1.21 ESRWI and all subcomponents including MBSRWI shall be designed to withstand internally and externally generated vibrations.

4.2.1.21.1 A report with vibration and modal analysis shall be sent for PETROBRAS approval according to [9] and [10].

4.2.2 SUBSEA RAW WATER INJECTION INTAKE SKIMMER

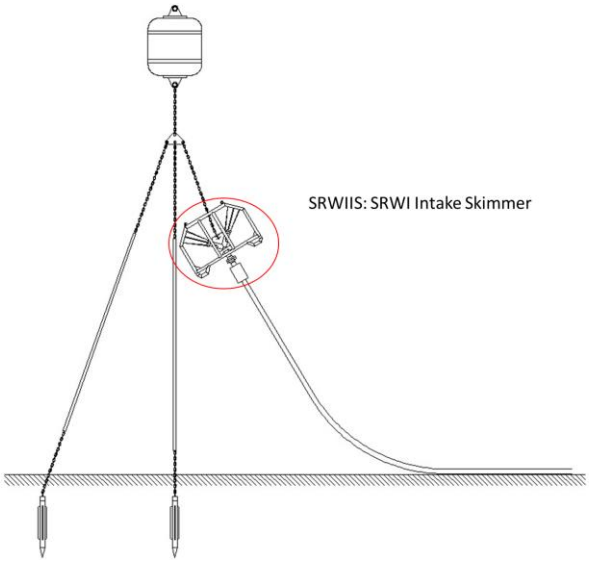

Figure 4-2SRWI Intake Skimmer

4.2.2.1 The SWRI System shall have a INTAKE SKIMMER (SRWIIS) designed according to [38].

4.2.2.2 ESRWI FOUNDATION

4.2.2.3 The ESRWI Foundation may be integral part or separated from the SRWIFB.

4.2.2.4 The ESRWI Foundation shall be designed to assure that the ESRWI shall not move after installed and during operation, to minimize settlement and to assure that the Station (Foundation + SRWIFB + MBSRWI + RETRIVABLE MODULEs) complies with the maximum inclination angle towards the horizontal in [29] even after installation, retrieve and reinstallation of the of the SRWIFB, MBSRWI and all RETRIVABLE MODULEs during the SUBSEA RAW WATER INJECTION SYSTEM design life.

4.2.2.5 The ESRWI Foundation shall be designed and manufactured to withstand all forces and stress involved in transportation, sea fastening and installation of itself and of the SRWIFB, MBSRWI (see 4.2.2.9 and 4.2.3.8) and all RETRIVABLE MODULEs through the SUBSEA RAW WATER INJECTION SYSTEM design life.

4.2.2.6 The ESRWI Foundation shall be designed and manufactured in a way that all its components are protected against impacts in transportation, sea fastening, installation, removal or reinstallation of itself and of the SRWIFB, MBSRWI (see 4.2.2.9 and 4.2.3.8) and all RETRIVABLE MODULEs.

4.2.2.7 The ESRWI Foundation shall be designed and manufactured in a way that no transportation skid is used or needed.

4.2.2.8 The combined size of all components of the ESRWI Foundation shall comply with the size limit [29].

4.2.2.9 As a contingency, the ESRWI Foundation shall be recovered and reinstalled in a location as close as possible from the original one and approved by PETROBRAS. The contingency includes cases such as heading deviations, excessive tilting or settling during installation, severe damage during installation or if any object (or the SRWIFB) falls over the ESRWI Foundation prevents it from normal or safe operation.

4.2.2.10 ESRWI Foundation material, installation, structure, non-destructive testing and foundation shall fully comply with [41].

4.2.2.11 The SUPPLIER is responsible for defining the anchoring method (torpedo base, mud mat, etc.…) of each ESRWI Foundation and shall submit the selected method to PETROBRAS for approval with the corresponding analysis, according to [32] and [41].

4.2.2.12 The anchoring method shall be specified by SUPPLIER to prevent the Stations from moving in any direction when attached to flowlines.

4.2.2.13 The minimum soil information is in [70] and [71]. The SUPPLIER is responsible for any additional soil information needed.

4.2.2.14 The base case for installation and recovery of ESRWI Foundation considers that the structure shall be supported by a number of padeyes. The number of these devices shall be approved by PETROBRAS.

4.2.2.15 The ESRWI Foundation shall have positioning transponders — 4 (four) and one skid — according to [57]. This premise shall be confirmed during the Detail Design Stage.

4.2.2.16 The ESRWI Foundation shall have 2 ROV docking points for orientation during installation according to 4.3.2.2 of ref [6].

4.2.2.17 The ESRWI Foundation shall have at least four padeyes in opposing extremities of the equipment designed for connecting ESRWI Foundation to a secondary anchoring system (contingency). Those padeyes shall comply with [32] and [41].

4.2.2.17.1 This secondary anchoring system in 4.2.2.17 shall not be considered in ESRWI Foundation design required in 4.2.2.4 and the analysis to be submitted to PETROBRAS in 4.2.2.11.

4.2.2.17.2 SUPPLIER shall submit for PETROBRAS approval the analysis proving the resistance and strength of the secondary anchoring structure required in 4.2.2.17.

4.2.3 SUBSEA RAW WATER INJECTION FLOW BASE

4.2.3.1 All non-retrievable subsea piping and equipment in SUBSEA RAW WATER INJECTION SYSTEM is part of a SRWIFB.

4.2.3.2 Each SRWIFB shall be designed to minimize settlement and assure that the Station (Foundation + Flow Base + MBSRWI + RETRIVABLE MODULEs) complies with the maximum inclination angle towards the horizontal in [29] even after installation, retrieve and reinstallation of the Flown Base and all RETRIVABLE MODULEs during the whole SUBSEA RAW WATER INJECTION SYSTEM design life.

4.2.3.2.1 A report with manufacture and assemblies dimensions and tolerances shall be sent for PETROBRAS approval to guarantee that the maximum inclination is met by all Station points and RETRIVABLE MODULEs.

4.2.3.3 SRWIFBs shall be designed and manufactured to withstand all forces and stress involved in transportation, sea fastening and installation of itself and retrieval of all RETRIVABLE MODULEs and MBSRWI through the SUBSEA RAW WATER INJECTION SYSTEM design life.

4.2.3.4 The SRWIFBs shall be designed and manufactured in a way that all their components are protected against impacts in transportation, sea fastening, installation, removal or reinstallation of itself, MBSRWI and of all RETRIVABLE MODULEs.

4.2.3.5 Each SRWIFBs shall be designed and manufactured in a way that no transportation skid is used or needed.

4.2.3.6 The combined weight of all components of each SRWIFB shall comply with the size limit in [29].

4.2.3.7 The combined weight of all components of each SRWIFB shall comply with the weight limit [29].

4.2.3.8 As a contingency, each SRWIFB shall be recovered and reinstalled in a location as close as possible from the original one and approved by PETROBRAS. The contingency includes cases such as heading deviations, excessive tilting or settling during installation, severe damage during installation or if any object (or the SRWIFB) falls over the ESRWI Foundation prevents it from normal or safe operation.

4.2.3.9 SRWIFBs' material, installation, structure, non-destructive testing and foundation shall fully comply with [41].

4.2.3.10 The base case for installation and recovery of SRWIFB considers that the structure shall be supported by a number of padeyes. The number of these devices shall be approved by PETROBRAS.

4.2.3.11 SRWIFB shall have four positioning transponders and one skid according to [57]. This premise shall be confirmed during the Detail Design Stage.

4.2.3.12 The SRWIFB shall have 2 ROV docking points for orientation during installation according to 4.3.2.2 of [6]

4.2.3.13 Each SRWIFB shall have at least four tilt/inclination indicators of the "bull-eye" kind fixed with 90 degrees spacing in an easily identifiable by ROV position.

4.2.3.14 The SRWIFB shall be designed with the hubs for connection with the MBSRWI and ESRWI RETRIVABLE MODULEs according to [31].

4.2.3.15 SRWIFB shall have one service downline hub for MEG or Alcohol injection or depressurization.

4.2.3.16 SRWIFB shall be delivered to PETROBRAS filled with MEG or inhibited water (to be defined by PETROBRAS in Detail Design Stage).

4.2.3.17 SRWIFB Well Inlet Choke Valves shall be designed according to [40].

4.2.3.18 In base case ([31]), each SRWIFB shall have a CKM per well. All CKMs shall be similar and interchangeable.

4.2.3.19 Each CKM shall have a Multiphase Flowmeter. This requirement shall be confirmed by SUPPLIER with PETROBRAS during the clarification before bidding phase if not explicit in [29].

4.2.3.20 SRWI System's MCVs necessary for lines connections and respective spares are considered part of the SRWIFB and shall be delivered by supplier according to [29] and designed according to [42] and [47]

4.2.4 ESRWI RETRIEVABLE MODULEs

4.2.4.1 All RETRIEVABLE MODULEs shall comply with the RETRIEVABLE MODULEs weight and size limit in [29].

4.2.4.2 The base case of RETRIEVABLE MODULEs philosophy is shown in [31].

4.2.4.3 During the SUBSEA RAW WATER INJECTION SYSTEM design, the SUPPLIER shall propose optimization and changes in the RETRIEVABLE MODULEs quantity, position and philosophy in [31] as soon as they are conceived. Optimization and changes shall be submitted to PETROBRAS for approval together with calculations considering at least process safety, operational safety and production efficiency according to sections 5.1, 7, 8 and 11.

4.2.4.4 All RETRIEVABLE MODULEs shall be designed for safe installation by cable without heave compensation and according to [68].

4.2.4.5 All RETRIEVABLE MODULEs shall be designed with the same kind of guiding system for positioning, heading correcting and aligning RETRIEVABLE MODULEs with Station Base (connector and HUB).

4.2.4.5.1 This guiding system shall also align seals, sealing areas and sealing rings.

4.2.4.6 All RETRIEVABLE MODULEs shall be designed to be connected to the respective Station Base with a vertical hydraulic connector according to [42].

4.2.4.7 All RETRIEVABLE MODULEs shall be designed with ROV panel according to [42].

4.2.4.7.1 All RETRIEVABLE MODULEs connectors shall be designed to allow sealing and locking with at least 5 (five) degrees dealignment towards the hub when the guiding system begins acting.

4.2.4.7.2 The soft-landing system shall remain active and protect the sealing rings and areas until final controlled settling and locking even with 0.7 m/s maximum landing speed.

4.2.4.7.3 The soft-landing system shall be actuated during landing and retrieval and comply with the requirements of [42] and [68].

4.2.4.7.4 The hydraulic connectors shall be designed for at least 40 at least 40 locking and unlocking cycles.

4.2.4.7.5 The hydraulic connectors shall be designed to guide, support, lock and energize all seals and all fluids flow paths between hub and connector.

4.2.4.7.6 The hydraulic connectors pre-load shall be adequate and compatible with internal pressures, forces, shears, bending moments and other stresses during installation and production.

4.2.4.7.7 The connectors shall be designed with a secondary hydraulic independent unlocking system.

4.2.4.7.8 The connectors shall be designed with another hydraulic operated mechanic unlocking system that can replace the primary system if necessary.

4.2.4.7.9 The modules shall have in a place easily accessible by ROV one panel with the hydraulic connectors lock line that may be cut in case of emergency unlock necessity. This line shall be painted in red according to [42].

4.2.4.7.10 The connectors shall have two easily visible by ROV visual LOCKED/UNLOCKED indicators with 90 degrees between them.

4.2.4.7.11 The connectors shall have AX rings and shall have ports for AX rings Seal Tests.

4.2.4.7.12 The connectors shall have at least 3mm full clad in all metal x metal sealing areas.

4.2.4.8 All RETRIEVABLE MODULEs shall be installed by cable without a special installation tool and comply with the requirements of [41] and [42].

4.2.4.9 All RETRIEVABLE MODULEs shall have 2 ROV docking points for orientation during installation according to 4.3.2.2 of [6]

4.2.4.10 Chemical injection lines in the SRWIFB shall have BPV according to [78] located in a retrievable module according to [29] and [31]. SUPPLIER shall confirm this requirement with PETROBRAS during bidding phase.

4.2.5 SUBSEA SEAWATER PUMP MODULE

4.2.5.1 MBSRWI shall be delivered to PETROBRAS filled with MEG or inhibited water (to be defined by PETROBRAS in Detail Design Stage).

4.2.5.2 ESRWI motor and pump assembly (MBMS) shall be individually retrievable and follow [35], [37] and [39]. MBSRWI shall be installed in SRWIFB.

4.2.5.3 SUBSEA SEAWATER PUMP FINE-FILTRATION MODULE

4.2.5.3.1 The SUBSEA SEAWATER PUMP RETRIEVABLE MODULE shall have a SUBSEA SEAWATER PUMP FINE-FILTRATION MODULE with a continuously self-cleaned/ flushed filter that shall be individually retrievable without other components of the module.

4.2.5.3.1.1 An alternative with the PFFM as a separate subsea retrievable module connected to the SRWIFB may be submitted for PEROBRAS approval during the detailed design phase.

4.2.5.3.2 The maximum size of the particles allowed to reach the pump through the PFFM self-cleaning filter is 50 µm

4.2.5.3.3 Supplier shall propose for PETROBRAS approval material, shape, retrivability and the continuous self-cleaning/flushing technology, self-cleaning/flushing efficiency and maximum allowed differenctial pressure for the PFFM.

4.2.5.3.4 The PFFM self-cleaning/flushing technology shall be designed to allow full cleaning of the filter avoiding preferential flushing path.

4.2.5.3.5 The SRWI shall be designed for regular water injection during the PFFM self-cleaning/flsuhing

4.2.5.4 Each MBSRWI shall have at least four tilt/inclination indicators of the “bull-eye” kind fixed with 90 degrees spacing in an easily identifiable by ROV position.

4.2.6 SUBSEA ELECTRICAL POWER SYSTEM

4.2.6.1 ESRWI SEPS shall comply with the requirements of this technical specification, [35].

4.3 UMBILICAL TERMINATION ASSEMBLY

4.3.1 UTA mechanical design shall follow [36].

5 SUBSEA RAW WATER INJECTION SYSTEM STEADY-STATE AND DYNAMIC SIMULATIONS

5.1 This chapter defines the steady state and transient dynamic simulations scope for the RAW WATER INJECTION SYSTEM application, including the cases that shall be simulated. All the transient studies shall be performed using the Olga Simulator on the 7.3.3 or 7.3.2 version.

5.2 SUPPLIER shall submit to PETROBRAS all Technical Reports in PDF format file and the Olga files with pump models used during the pump performance evaluation (Olga Simulator on the 7.3.3 or 7.3.2 version).

5.3 SUPPLIER shall submit for PETROBRAS evaluation the Dynamic simulations schedule plan for all contracted RAW WATER INJECTION SYSTEMS, considering flow assurance issues and transients events involving:

5.3.1 Pump(s) startups with and without injection of lift gas on the producer wells;

5.3.2 Planned shutdowns;

5.3.3 Unplanned shutdowns (considering on the highest pump speed):

5.3.3.1 Closing of topside SDV, without closing valves on the Christmas Tree

5.3.3.2 Closing of the Christmas Tree valves, without closing topside SDV

5.3.3.3 Pump trip with Christmas Tree valves and with topside plant in normal operation

5.3.3.4 Barrier fluid response during the possible transient events

5.4 Report with all simulation files (reference item 5.3) shall be delivered, including control loops eventually used on the Olga simulation and the Raw Water Injection System models used on the simulation files. Also, all auxiliary spreadsheet files used to perform studies of the transients shall be delivered to PETROBRAS.

5.5 Technical meetings shall be scheduled by the SUPPLIER to present the partial and final simulations results of the dynamic simulations scope.

5.6 All the fluid models, reservoir model and required flow assurance information to the SUPPLIER to build the simulation files on the Olga simulator, from the

reservoir up to the platform, shall be requested to PETROBRAS by SUPPLIER during the executive phase of the project.

5.7 Dynamics in the electric and hydraulic systems shall be included as time-delays on the transient simulation studies.

5.8 The upstream and downstream pipelines of the Raw Water Injection System shall be represented by detailed models to reflect the accurate flow dependent pressure variations. Simplified models of the pipeline or any other simplification shall only be used if approved by PETROBRAS.

5.9 As base case, all control valves shall be simulated considering the Cv curve of a subsea control valve and actuation delays of an electrically actuated choke. Exceptions to this specification shall be identified and approved by PETROBRAS.

5.10 Erosional velocity study shall be performed to evaluation on the pipelines of the pump systems.

5.11 Evaluation of hydrate inhibitor shall be performed to define the number of lines required to inject monoethylene glycol (MEG) in the pump module and, eventually, in the dead legs points of the pump system.

5.12 Verify Barrier Fluid operation in transient conditions

5.12.1 BFHPU, subsea accumulators and valves set points adjustments.

5.12.2 Pressure and temperature variations during operational conditions – ramp up, normal operation, controlled rump down, cold and hot start ups as well as planned and emergency shutdown.

5.13 After all simulations in the scope of this chapter (5) are finished, one unified final simulation report for all systems in the project scope shall be sent for PETROBRAS approval in only one PDF file, including the final Olga files with the Raw Water Injection models, on the 7.3.3 or 7.3.2 version, and auxiliaries spreadsheets eventually used to perform the dynamic analysis.

5.14 Flow Assurance specific objectives

5.14.1 Verify if there is flow assurance issues such as hydrate formation and wax deposition events that could cause problems or reduce system efficiency or availability in any operational activity, including the operations below, but not limited to:

5.14.1.1 Cold and hot Start-ups.

5.14.1.2 Planned and emergency shutdowns

5.14.1.3 Production ramp-up

5.14.1.4 Production ramp-down

5.14.1.5 Unintended valve closure and opening

5.14.1.6 Pump trip

5.14.1.7 Transient operation

5.14.2 SUPPLIER shall verify if chemical injection points proposed in base case (dead legs, pumps and other points shown in [31] or added during Detail Design Stage) are sufficient or if more points need to be added in SUPPLIER design. The final position and number of injection points shall be submitted for PETROBRAS approval.

5.14.3 SUPPLIER shall do an overpressure protection assessment for subsea pump system. The elements that are to be considered and described are the following (not limited to):

5.14.3.1 Pressure and temperature sources

5.14.3.1.1 Wellhead shut-in pressure (WHSIP) of existing wells

5.14.3.1.2 Rotating equipment: Identify the most conservative maximum dead head pressure (control not accounted for)

5.14.3.1.3 Chemical injection (MEG, MeOH, barrier fluid…): provide maximum pressure supplied from the chemical system (PSV, setpoint, fluid density, elevations)

5.14.3.2 Overpressure causes

5.14.3.2.1 Well cleaning or start-up

5.14.3.2.2 Start-up after a longer shutdown

5.14.3.2.3 Chemical injection for pressure equalization or for preservation

5.14.3.2.4 Overpressure from barrier fluid

5.14.3.2.5 Blocked outlet (any relevant, such as valves closing, hydrate plugs etc)

5.14.3.2.6 Valves: inadvertent valve operation, leakage through check valves, choke valve failure

5.14.3.3 Typical anticipated overpressure scenarios and likelihood

5.14.3.3.1 Maximum WHSIP applied simultaneously with the maximum dead head

5.14.3.3.2 Maximum WHSIP and the booster running on 100% liquid against blocked outlet

5.14.3.3.3 Maximum pressure from the chemical system applied simultaneously with the maximum dead head

5.14.3.3.4 Maximum pressure from the chemical system and the booster running on 100% liquid against blocked outlet

5.14.3.4 Overpressure protection barriers

5.14.3.4.1 Interlocks

5.14.3.4.2 Pressure and temperature limiting devices

6 SUBSEA RAW WATER INJECTION SYSTEM RISK ASSESSMENT

6.1 SUPPLIER shall implement a RIM process to assess and prioritize efforts based on the level and source of technical risks and uncertainties of the proposed SUBSEA RAW WATER INJECTION SYSTEM configuration and manage them as part of the project activities.

6.1.1 In this phase, SUPPLIER shall also perform biweekly follow-up technical meetings with PETROBRAS´ representatives using a web-based on-line meeting, conferencing and videoconferencing tool.

6.1.1.1 These meetings shall continue through the other phases until ESRWI is commissioned and operating at maximum design capacity and the meeting frequencies shall be changed by PETRBRAS requests.

6.1.2 The first technical meeting shall be scheduled two weeks after SUBSEA RAW WATER INJECTION SYSTEM kickoff meeting. SUPPLIER shall present the whole project schedule focus on SUBSEA RAW WATER INJECTION SYSTEM mechanical and process related activities, ESRWI proposed configuration and equipment main data and the RIM process at this first technical meeting.

6.1.3 The supplier shall also present in the first technical meeting the qualification program for all equipment that need qualification activities within SUBSEA RAW WATER INJECTION SYSTEM detailed design. The qualification program shall be updated each Detail Design Stage considering at least TRC, TRL, TMA and FMECA according to process KP8 in Figure B.5 of ref. [11].

6.1.4 Each equipment that has qualification tests to be performed as part of SUBSEA RAW WATER INJECTION SYSTEM shall have its qualification program started immediately after RIM first meeting (6.1.2) and equipment manufacturing shall begin only after all equipment qualification program is completed and the equipment successfully qualified. Exceptions shall be submitted for PETROBRAS approval. A detailed qualification schedule for each equipment under these circumstances shall be presented in RIM first meeting.

6.1.5 The further technical meetings shall cover all technical activities related to and its equipment performed during the last two weeks prior to the meeting and the planned activities during the next six weeks.

6.2 The RIM process shall cover all stages of the SUBSEA RAW WATER INJECTION SYSTEM life cycle, from Detail Design to Operation, and related technical documents, analysis and activities.

6.3 Risk assessment engineering techniques shall be able to clearly identify the impact of technical risks and uncertainties in SUBSEA RAW WATER

INJECTION SYSTEM´s Process Safety, Operational Safety and Production Efficiency and treat them adequately.

6.4 SUBSEA RAW WATER INJECTION SYSTEM configuration proposed by SUPPLIER shall meet, at least, the following goals:

6.4.1 Process Safety – To design considering inherently safer design practices to prevent any event of loss of containment during commissioning, operation, intervention and decommissioning activities.

6.4.2 Operational Safety: To design equipment and elaborate procedures considering multifactor techniques to prevent any accident during manufacturing, testing, installation, commissioning, operation, intervention and maintenance activities.

6.4.3 Production Efficiency: To specify, manufacture and test components and establish maintenance strategies to minimize unplanned system unavailability, achieving estimated production availability for planned and unplanned events during the operating phase of SUBSEA RAW WATER INJECTION SYSTEM greater than 94,841% (average).

6.4.4 PETROBRAS may review this requirement based on updated RAM analysis as well as any other study or methodology, based on the detailed design of the SUBSEA RAW WATER INJECTION SYSTEM.

6.4.5 The RIM process shall consider the following strategies:

6.4.6 Integrity: (1) to consider Inherently Safer Design (ISD) principles, (2) to apply recognized Risk Assessments (RA) techniques and manage its recommendations, (3) to design adequate safeguards, (4) to evaluate predictive maintenance solutions, and (5) to define inspection, monitoring and test (IMT) plans based on identified failure modes and mechanisms identified during FMECA analysis as per 7.11;

6.4.7 Production: (1) to achieve availability goals prioritizing system reliability at the expense of reducing mean time to repair, (2) to impose additional qualification effort and greater Quality Control (QC) in manufacture of components with highly manual assembly, (3) to evaluate condition monitoring solutions for equipment or components with high TRC or high criticality for production efficiency.

6.5 The RIM DPIEF assurance loop shall have its focus adjusted at the beginning of each project stage in accordance to [11] and as per sections 7, 8 and 11 of this TS.

6.6 RIM process shall provide adequate evidence that goals and requirements stated in sections 4.1 and 6.4 of this TS were correctly addressed and treated during project development.

6.7 [11] shall be used as reference to RIM process.

6.8 RIM process shall be able to clearly identify the proposed Safety Critical Elements considering the Process Safety Risk Assessment results, and treat their related technical risks and uncertainties.

6.9 RIM process shall provide adequate evidence that goals stated in 6.4 and the requirements of this Technical Specification were correctly addressed and treated during project development.

6.10 SUPPLIER shall propose Safety Critical Elements that shall be identified considering [1]. PETROBRAS operational team shall give the final list based on SUPPLIER proposed Safety Critical Elements.

6.10.1 SUPPLIER shall generate a list with all identified Safety Critical Elements with element´s characteristics and function, i.e., Critical Equipment, System or Procedure of Operational Safety.

6.10.2 The list of Safety Critical Elements shall be addressed in full in all risk assessment activities performed during the project development.

6.10.3 Risk assessment procedures shall clearly identify the Safety Critical Elements in the scope of work to be analyzed.

6.10.4 The list of all Safety Critical Elements shall be reviewed and updated after risk assessment activities conclusion through all project life cycle stages.

6.11 A TRC shall be performed at the beginning and reviewed at the end of each project life cycle stage.

6.11.1 At least, the change risk factors for equipment and procedure in Annex A of [11] shall be considered.

6.11.2 A scorecard shall be generated for each equipment or procedure evaluated TRC A, TRC B or TRC C with information of all technical risks and uncertainties identified, the correspondent criticality to SUBSEA RAW WATER INJECTION SYSTEM Requirements, Operational Safety and Production Efficiency, and the strategy to reduce risk to adequate levels in accordance to the goals and requirements as per sections 2.1 and 6.4 of this TS.

6.12 SUPPLIER shall perform a FMECA of each equipment or procedure evaluated TRC A, TRC B or TRC C.

6.12.1 SUPPLIER shall develop/update an equipment hierarchy or taxonomy that is a realistic representation of the installed system in preparation for FMECA.

6.12.2 The focus and the scope of the FMECA shall be adjusted to the object under analysis and the stage and timing of FMECA application. SUPPLIER should comply with [18].

6.13 Risk analysis of the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration shall be performed through all project development to identify potential hazards and problems that may represent risks to personnel, equipment or environment.

6.13.1 Hazards and risks related to each SUBSEA RAW WATER INJECTION SYSTEM life cycle stage shall be identified.

6.13.2 The risk analysis procedure shall consider, at least:

6.13.2.1 Latest SUBSEA RAW WATER INJECTION SYSTEM design and process simulation, as per sections 2.1, 4.1 and 5 of this TS.

6.13.2.2 Latest equipment TS and datasheet.

6.13.2.3 Previously performed risk analysis reports

6.13.2.4 The updated list of Safety Critical Elements.

6.13.2.5 List of historical accidents in similar systems and with similar equipment.

6.13.2.6 FMECA results as per section 6.12 of this TS.

6.13.2.7 Failure modes stated in applicable industry codes, standards, rules, regulations and recommended practices.

6.13.2.8 System layout, interfaces, adjacent areas and external causes.

6.13.2.9 Procedures, equipment or other conditions that could contribute to human failure.

6.13.2.10 Management of changes performed since last risk analysis approval.

6.13.2.11 Identification of all related documents in its updated revision.

6.13.2.12 Identification of hazards and classification of risks.

6.13.2.13 Identification of existing safeguards and its suitability.

6.13.2.14 Identification of actions and safeguards that will eliminate, reduce, prevent or mitigate the risk or hazard.

6.13.3 The risk analysis shall be performed by a multidisciplinary team to ensure rigor and completeness. At least, appropriate technical specialists with adequate knowledge of the following areas shall participate in the risk analysis:

6.13.3.1 Detail Design.

6.13.3.2 Process Design.

6.13.3.3 Equipment Design

6.13.3.4 Flow Assurance

6.13.3.5 Topside and Subsea Operation and Intervention.

6.13.3.6 Topside and Subsea Maintenance and Inspection.

6.13.3.7 Instrumentation and Control.

6.13.3.8 Environment.

6.13.3.9 Human Factors.

6.13.3.10 Applicable industry codes, standards, rules, regulations and recommended practices.

6.14 SUPPLIER shall perform a RAM analysis of the normal operation mode of the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration.

6.14.1 The RAM analysis shall cover the complete SUBSEA RAW WATER INJECTION SYSTEM life cycle.

6.14.2 The scope and the battery limits of the analysis shall include all SUBSEA RAW WATER INJECTION SYSTEM ´s topside and subsea equipment needed for SUBSEA RAW WATER INJECTION SYSTEM normal operation and within the scope of supply of SUBSEA RAW WATER INJECTION SYSTEM proposed configuration.

6.14.3 FMECA results as per section 6.12 of this TS shall be used as input data in RAM analysis.

6.14.4 SUPPLIER shall present a list of each equipment modelled for RAM analysis, its functional requirements, failure modes and associated failure rates considered in the analysis. The list shall also clearly present the failure rates sources and if that was performed any data treatment and which it was.

6.14.5 SUPPLIER shall present a list of all resources considered in the RAM analysis, with indication of mobilization time and intervention time used in each type of intervention. Additionally, assumptions on spare parts availability and vessel availability considered in the mobilization and intervention times shall be clearly stated.

6.14.6 SUPPLIER shall clearly present all the assumptions considered in the RAM modeling.

6.14.7 SUPPLIER shall present the RBD in all modelling levels considered in the RAM analysis.

6.14.8 Simulation results shall give, at least, the mean average availability and the availability with the 90%, 50% and 10% probability of exceedance values.

6.14.9 SUPPLIER shall present a ranking list of equipment criticality per total system and per sub-system that impacts system total availability. The RAM analysis shall include a criticality assessment to identify the equipment and components that have high impact on production unplanned unavailability.

6.14.10 SUPPLIER shall provide a list with spare parts consumption, according to RAM analysis base case performed.

6.15 A TRAR shall be scheduled at the end of each project stage and before moving to the next project stage.

6.15.1 At least, considerations in Annex B, section B.6 of [11] shall be addressed.

6.16 SUPPLIER shall review and updated the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration RIAD at the end of each project life cycle stage.

6.16.1 At least, considerations in Annex B, section B.6 of [11] shall be addressed.

6.16.2 At least, the list of Safety Critical Elements and the scorecards of equipment and procedures TRC A and TRC B shall be in the scope of TRAR.

7 SUBSEA RAW WATER INJECTION SYSTEM DETAIL DESIGN

7.1 At the Kick-off meeting of the DETAIL DESIGN STAGE , the supplier shall present to PETROBRAS all professionals involved in the analysis required in items 7.2, 7.3, 7.4, 7.5 and other analysis required by ref. [29] and if these analysis will be done by the SUPPLIER or other companies of recognized knowledge.

7.2 Flowrate Analysis Report shall be presented before the end of the DETAIL DESIGN STAGE to PETROBRAS for approval according to [62] considering all data in [30] and [63].

7.3 Erosion Analysis Report shall be presented before the end of the DETAIL DESIGN STAGE to PETROBRAS for approval according to [62] considering all data in [30] and [63].

7.4 SUPPLIER shall present before the end of the DETAIL DESIGN STAGE for PETROBRAS approval a report with calculations and CFD analysis proving:

7.4.1 If sand or other solids flushing is needed in any part of SUBSEA RAW WATER INJECTION SYSTEM (see 5.12.8) considering data in [30] [63].

7.4.2 That the thermal insulation project complies with the requirements in [8] and [29] considering data in [30].

7.4.3 That the final 3D geometry of SUBSEA RAW WATER INJECTION SYSTEM has no dead legs without proper mitigation. (see items 4.1.2.27, 4.1.2.26.1 and 5.14.2). The CFD report shall present the chemical injection frequency and if it is needed.

7.4.4 All CFD analysis reports shall be submitted for PETROBRAS approval during DETAIL DESIGN PHASE, as part of the calculation report documents. Definitions about domain, mesh, physics modelling and convergence shall be presented and justified. The reports shall include, as a minimum, the following information:

7.4.4.1 Simulated cases description;

7.4.4.2 Premises and general simplifications;

7.4.4.3 Input data used in simulations: geometry, environmental conditions, flow data (e.g inlet temperature) and etc.;

7.4.4.4 Physics modelling information (e.g. steady/transient analysis, heat transfer modes, compressible/incompressible flow, wall treatment, turbulence models and etc.);

7.4.4.5 Table of fluid properties and source of information;

7.4.4.6 Mesh data (e.g. types and number of elements used, total number of mesh elements, mesh images to show relevant details);

7.4.4.7 Monitoring residuals plots (e.g continuity residuals, energy residuals, etc.);

7.4.4.8 Monitoring plots of relevant quantities (e.g mass flow rate, maximum outlet temperature, etc.);

7.4.4.9 Results analysis (including plots and images): e.g. flowrate analysis, heat transfer analysis and other relevant values;

7.4.4.10 Bibliography (References).

7.5 Before the end of the Detail Design Stage , the supplier shall present to PETROBRAS a report with videos of 3D model simulations of the SUBSEA RAW WATER INJECTION SYSTEM proving that all ROV interfaces and inspection points (as per 7.12and 7.13) are feasible and easily accessible.

7.6 Vibration and Modal Analysis Report (4.2.1.21) shall be presented before the end of the DETAIL DESIGN STAGE to PETROBRAS for approval according to [62] considering all data in [30] and [63].

7.7 At Detail Design Stage, SUPPLIER´S RIM process shall be tuned to component or subassembly level.

7.7.1 The Detail Design DPIEF assurance loop and risk assessment as per section 5.1 of this TS shall be completely executed at the end of Detail Design Stage.

7.7.2 The identification and implementation of risk assessment activities associated with procedures executed during MATIC stage shall be conducted. The Define step of MATIC DPIEF assurance loop shall be completely concluded at the end of Detail Design Stage and the Plan step shall start to be addressed.

7.7.3 Inspection, monitoring, testing and maintenance activities to be undertaken as part of the ITMM plan for integrity management in Operations stage shall be considered in the scope of risk assessments conducted during Detail Design Stage. The Define and Plan steps of Operations DPIEF assurance loop shall start to be addressed, sections 11.2 and 11.3.

7.7.4 SUPPLIER shall present goals and requirements for each package and demonstrate how they will be achieved.

7.7.4.1 Goals and requirements of components and sub-assemblies' part of a package shall not deteriorate the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration goals and requirements stated in sections 2.1 and 6.4 of this TS.

7.8 SUPPLIER shall perform a TRL of the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration for each equipment in the scope of supply, as stated in reference [12], with the identification of equipment actual TRL.

7.8.1 Lessons learned and best industry practices shall be included in TRL assessment;

7.8.2 For items with TRL<3, SUPPLIER shall perform a Q-FMECA and establish required qualification programs (SQP or TQP) to achieve TRL=4.

7.8.3 Equipment´s sub-supplier representatives shall participate in the Q-FMECA.

7.8.4 Evidence of TRL=3 completion and evidence of concluded activities in the scope of TRL=4, in accordance with [12], shall be available for the Q-FMECA.

7.8.5 SUPPLIER shall include each required SQP or TQP in the project schedule considering that SQP or TQP shall be successfully concluded before respective equipment start of manufacturing.

7.9 SUPPLIER shall generate the list of Safety Critical Elements as per section 6.10 of this TS.

7.10 SUPPLIER shall carry out a TRC assessment for each component of the package as per section 6.11 of this TS.

7.10.1 Lessons learned and best industry practices related to management of supply chain and operations shall be included in the TRC assessment.

7.10.2 Sub-supply participants may be needed, based on TRC approval

7.11 FMECA shall be performed, as per section 6.12 of this TS, to identify failure modes and correspondent possible consequences, to prioritize areas of improvement and to identify the need of further analysis or testing. Design shall always consider sensors to continuous monitor the condition to avoid the failure modes identified, as required in 7.12. At least, the following aspects shall be addressed by FMECA during Detail Design Stage :

7.11.1 A functional assessment to confirm all required functions expected to be performed by the element are fulfilled.

7.11.2 Hardware and design assessment to verify that system, packages and components specific technical and technological details do not impact on system goals and requirements.

7.11.3 Interface assessment to verify that packages and system interfaces details do not impact on system goals and requirements.

7.11.4 Process assessment to identify and preliminary address MATIC procedures and process deviations that may compromise system goals and requirements.

7.11.5 Integrity management assessment to preliminary identify and address inspection, monitoring, testing and maintenance activities to be part of ITMM plan.

7.11.6 Preparedness response scheme to preliminary identify potential repair strategies following a failure and the value of investing in spare equipment items.

7.12 For the failure modes identified during FMECA analysis as per 7.11, supplier shall design the installation of sensors for continuous monitoring of equipment condition whenever technically feasible and present the strategy to be adopted in order to be approved by PETROBRAS. Only the failure modes that are not technically feasible to be continuous monitored the Supplier shall present the inspection plan with the required tools to be operated by ROV and the required periodicity.

7.13 For the equipment inspection points that shal be defined, depending on the type of inspection, visual only or using tools, SUPPLIER shall consider in the design of the equipment how ROV operations will be performed to have effective access to perform the inspection during system production in normal operation.

7.14 SUPPLIER shall perform risk analysis of the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration, as per section 6.13 of this TS, and feedback Detail Design team with analysis results for review and implementation of inherent safer solutions wherever possible.

7.14.1 All hazards and risks to Process Safety and to Operational Safety shall be clearly identified.

7.14.2 Human factors that may compromise Process Safety and Operational Safety shall be clearly identified.

7.14.3 SUBSEA RAW WATER INJECTION SYSTEM Safety Envelope shall be identified and the permissible range of operation of operational variables shall be defined.

7.14.4 A control and monitoring system shall be designed to maintain the operational variables of SUBSEA RAW WATER INJECTION SYSTEM Safety Envelope inside its limits and identify alarms when human intervention is needed.

7.14.5 A protection system shall be designed to prevent or mitigate the consequences of failure modes present in the system.

7.15 A RAM analysis of the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration shall be performed, as per section 6.14 of

this TS, to evaluate the ability of the system to remain in the operational state and to validate the definition of the maintenance or intervention support strategy.

7.15.1 The RAM analysis shall consider the complete SUBSEA RAW WATER INJECTION SYSTEM in the scope of supply, integrating package and component details, to confirm that the overall production availability performance meets or exceeds expectations. As per section 6.4 of this TS;

7.15.2 The RAM analysis shall support the definition of package interfaces requirements.

7.15.3 The RAM analysis shall support the definition of installation, intervention and maintenance requirements (vessel and sparing) needed to support stated production availability goals and requirements.

7.15.4 Additional criteria should be included for the integrity management plan for proposed safety critical elements, components or equipment with high TRC or high impact on production unplanned unavailability as per RAM analysis.

7.16 SUPPLIER shall review and verify that the risk assessment results are consistent with goals stated in 6.4 and requirements of this TS.

7.16.1 If results demonstrate that the package delivers the required safety, availability and reliability, the component safety, reliability and maintainability input data shall be validated as the component requirements.

7.16.2 If results demonstrate that the package cannot meet the safety, availability and reliability specification, SUPPLIER shall state a plan to achieve the specifications, e.g., by stretching component reliabilities beyond that which has been historically achieved or by reconfiguring proposed package architecture.

7.16.3 A TRAR shall be schedule at the end of Detail Design Stage as per section 6.15 of this TS.

7.17 SUPPLIER shall generate the complete SUBSEA RAW WATER INJECTION SYSTEM proposed configuration RIAD at the end of Detail Design Stage as per section 6.16 of this TS.

7.18 SUPPLIER shall present to PETROBRAS before the end of Detail Design Stage the Qualification Assurance Report, as per [12], with description and evidence of TRL 4, as per [12], and TRC C, as per [11], achievement of all equipment listed in the qualification program presented in 6.1.3, 6.1.4 or any further updated list.

8 SUBSEA RAW WATER INJECTION SYSTEM MATIC STAGE

8.1 At MATIC stage, SUPPLIER´s RIM process shall be tuned to procedural level but shall also address equipment, handling, and tools needed in each procedure execution.

8.1.1 DPIEF assurance loop covering Manufacture, Assemble and Testing phases of MATIC stage shall be completely executed before the beginning of system Installation phase.

8.1.2 The Plan step of DPIEF assurance loop covering Installation phase of MATIC stage shall be concluded before system Installation phase start-up.

8.1.3 The MATIC DPIEF assurance loop and risk assessment as per section 5.1 of this TS shall be completely executed at the end of MATIC stage.

8.1.4 ITMM plan, started at Detail Design Stage, shall be concluded at the end of MATIC stage.

8.1.5 FAT Tests:

8.1.5.1 SUBSEA RAW WATER INJECTION SYSTEM FAT Tests shall comply with the requirements of ref. [42] and [72] and all tests in these references shall be performed for SUBSEA RAW WATER INJECTION SYSTEM equipment, sub equipment, subcomponents, systems and sub systems.

8.1.5.2 For any of the tests for components, subcomponents or equipment of SUBSEA RAW WATER INJECTION SYSTEM (subsea or topside) SUPPLIER shall notify PETROBRAS at least 60 days before each test.

8.1.5.3 Unless otherwise agreed, witnessed FATs and SITs require written confirmation of a successful preliminary test according to ref. [72].

8.1.6 For any of the tests for components, subcomponents or equipment of SUBSEA RAW WATER INJECTION SYSTEM (subsea or topside) SUPPLIER shall send the detailed test procedures for PETROBRAS approval at least 60 days before each test.

8.1.7 Connection Test shall be performed as part of each RETRIEVABLE MODULE FAT to guarantee that all modules comply with the installation requirements, orientation and stresses for the connection. SUPPLIER shall propose the procedure for PETROBRAS approval.

8.2 SUPPLIER shall develop detailed procedures for each MATIC phase considering, at least:

8.2.1 Verification that all integrity management activities can be performed as planned.

8.2.2 Confirmation that each equipment is manufactured, assembled, delivered, installed, and commissioned correctly.

8.2.3 Confirmation that all loads and environment conditions that each equipment is exposed to during each MATIC Stage, including storage and transport, are within equipment acceptable limits.

8.2.4 Human factors as sources of human errors and identification of possible effect of those errors on safety, reliability and integrity.

8.2.5 Adequate QC/QA procedures ensure that reliability and integrity goals and requirements are not compromised by MATIC activities.

8.2.6 System interfaces are reviewed and addressed before SIT start up.

8.3 SUPPLIER shall carry out a TRC assessment for each procedure and associated equipment and tooling as per section 6.11 of this TS.

8.4 SUPPLIER shall review the list of Safety Critical Elements as per section 6.10 of this TS.

8.4.1 Lessons learned and best industry practices for each MATIC procedure and associated equipment and tooling shall be included in the TRC assessment.

8.4.2 SUPPLIER shall identify the participants in each procedure TRC assessment and representatives from equipment supplier and sub-suppliers, project, installation and operation teams shall be included when needed.

8.4.3 SUPPLIER shall invite PETROBRAS to participate in each procedures TRC assessment.

8.5 SUPPLIER shall perform a P-FMECA or other similar technique of each detailed procedure, identify technical risks and hazards associated with each of them and verify they do not compromise reliability and integrity.

8.5.1 Manufacture and Assembly detailed procedures shall:

a. Avoid the introduction of defects or assembly errors.

b. Prevent damage, overloading, shock loading or degradation during activities execution and including during transit and storage between locations.

8.5.2 Testing detailed procedures shall:

a. Include all pertinent information, e.g., calibration, settings, acceptance criteria, results etc.

b. Avoid damage to or degradation of the equipment being tested.

c. Provide evidence to demonstrate equipment function, performance, reliability and integrity.

d. Reveal any latent defects or incorrect assembly.

e. Restore equipment to the required post-test configuration after test completion.

f. Provide baseline data.

9 SUBSEA RAW WATER INJECTION SYSTEM SIT

9.1.1 SIT shall be performed with the complete set of equipment to be installed topside at FPSO and subsea in SUBSEA RAW WATER INJECTION SYSTEM scope of supply. SIT procedures shall:

9.1.1.1 Verify all SUBSEA RAW WATER INJECTION SYSTEM operation modes from well start-up to commanded and emergency stop;

9.1.1.2 Verify all equipment interfaces;

9.1.1.3 Verify protection, control and monitoring systems;

9.1.1.4 Verify all auxiliaries' systems and interfaces.

10 SUBSEA RAW WATER INJECTION SYSTEM INSTALLATION AND COMMISSIONING

10.1 Installation and Commissioning detailed procedures shall:

10.2 Before Installation phase start-up, SUPPLIER shall review and verify that the Manufacturing and Assembly registers and Testing results are consistent with goals and requirements stated in 6.4 of this TS.

10.2.1 SUPPLIER shall review and update the risk analysis with update Manufacture, Assembly and Testing information, as per section 6.13 of this TS.

10.2.2 SUPPLIER shall review and update the Safety Envelope.

10.2.3 SUPPLIER shall review and update the RAM analysis.

10.2.4 SUPPLIER shall review and update RIAD with all reliability and integrity data generated and collected of each package during MATIC stages ahead of handover to operations.

10.2.5 Verify consistency between reference documents part of the detailed procedure and identify any unexpected changes to components, systems or procedures that impacts on safety, reliability and integrity performance during commissioning and operations.

10.2.6 Prevent damage, overloading and degradation including during transport and storage;

10.2.7 Prevent delays to field start-up;

10.2.8 Provide baseline data.

11 SUBSEA RAW WATER INJECTION SYSTEM OPERATIONS

11.1 At Operations stage, SUPPLIER´s RIM process shall be tuned to procedural level and consider, at least:

11.1.1 Define and Plan steps of Operations stage DPIEF loop assurance shall be completely concluded at the end of Installation Stage of MATIC stage. All operation and intervention procedures shall be available before system commissioning and handover to operations.

11.1.2 SUPPLIER shall implement an effective data management system to support information handover to operations including training of operation, maintenance and intervention teams.

11.1.3 Identification of any unexpected changes to components, systems, or procedures that impacts on safety, reliability and integrity performance during commissioning.

11.1.4 Development of plans to update safety, reliability and integrity assessment and models prior to, or early, during operation stage.

11.1.5 Identification of actions to address any new risks to safety, reliability, integrity and maintainability achievement arising from the changes.

11.1.6 Update the RIAD with all safety, reliability and integrity data generated during the SUBSEA RAW WATER INJECTION SYSTEM development project. RIAD shall be updated by the commissioning team ahead of handover to operations.

11.1.7 Any issues identified in any of the procedure reviews shall be considered in the context of the other procedures, to ensure that changes identified in one area are consistently addressed in all other related areas.

11.2 Define step of Operations DPIEF shall consider, at least:

11.2.1 Revision and update of system taxonomy and segmentation.

11.2.2 Revision and update of the TRC for each subassembly and component.

11.2.3 Revision and update of detailed risk assessment undertaken earlier.

11.2.4 Identification of key performance indicators for both the equipment and the integrity management activities.

11.2.5 Definition integrity management and maintenance strategy and response actions to be undertaken depending on failure consequences and risk.

11.2.6 Revision and update of ITMM plan. Any activities in the ITMM plan that involve human intervention shall be backed up by HAZID/HAZOP or other similar technique to ensure any risks to the safety of personnel are identified and managed appropriately.

11.3 Plan step of Operations DPIEF shall consider, at least:

11.3.1 A communication plan involving other disciplines, e.g., process, topside facilities, etc., to ensure all relevant parties understands the ITMM task scope, integrity limits and objectives and that any relevant scope can be added or interfaced.

11.3.2 Integrated planned activities, where appropriate, with maintenance work for other related systems, e.g., topsides, to ensure that there is alignment in relation to scheduling, personnel on board, etc.

11.3.3 Definition of work pack contents for each ITMM activity, including drawings and acceptance criteria.

11.3.4 Verification that all tasks have clearly defined QC requirements, data management requirements, reporting requirements, and anomaly limits.

11.3.5 Verification that competencies are available to perform activities specified in the ITMM plan.

11.3.6 Definition of criteria for defined anomaly reporting limits.

11.4 SUPPLIER shall develop detailed operation procedures considering, at least:

11.4.1 A detailed P-FMECA / HAZID / HAZOP or other similar technique shall be performed to identify potential failures that could occur during each step of the procedure and alter the procedure to remove each failure possibility. Whenever possible, each procedure step shall include a positive record that action was carried out correctly.

11.4.2 For all equipment items and associated operations procedures, detailed risk assessment shall be undertaken to support identification of the required RIM activities during operations. Where possible, the risk assessment shall be an update of design assessment undertaken earlier by the project team.

11.4.3 Trouble-shooting procedures shall be developed to effectively identify failures, e.g. solids, wax or hydrate clogging, pump trip, vessel levels high or low, SEPS failure, and indicate the ITMM procedures to be performed to restore system to an operable state.

12 INTEGRITY MANAGEMENT PROGRAM

12.1 RBI shall be used to determine required inspection frequencies based on the identified threats from the risk assessment.

12.2 At the end of each integrity management campaign, results arising from reports from the various integrity management activities (inspections, monitored data, tests, etc.) shall be collated, assessed, evaluated, and summarized in the RIAD to provide feedback to management and provide input to the next integrity management campaign.

12.3 INTEGRITY MANAGEMENT PROGRAM shall comply with [1].

12.4 SUPPLIER shall present the Integrity Management Program for SUBSEA RAW WATER INJECTION SYSTEM to manage an appropriate level of reliability and integrity through subsea system life cycle.

12.5 In general, the Integrity Management Program shall consider:

12.5.1 The trade-off between upfront reliability, integrity, and engineering effort vs. operational integrity management and maintenance effort.

12.5.2 Effective management and response to regulatory requirements or guidance related to or affecting subsea equipment reliability and integrity performance.

12.5.3 Provide assurance of future reliability and integrity performance of subsea systems.

12.5.4 Effective management of risks from using novel equipment (including standard equipment in novel applications) and standard equipment.

13 DECOMISSIONING

13.1 SUPPLIER shall submit a decommissioning plan for PETROBRAS approval.

13.2 Decommissioning plan shall comply with [1].

14 DOCUMENTS AND DERIVERABLES

14.1 SUBSEA RAW WATER INJECTION SYSTEM Documents shall comply with [51] and document lists [58], [59] e [60].

14.2 Additionally, the SUPPLIER shall provide equipment information list according to chapter 4 of [1].

14.3 Qualification documents shall comply [61].