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1 INTRODUCTION

1.1 Scope of the specification

The purpose of this specification is to define the minimum requirements for the engineering/ installation/ testof the flowlines and risers systems on the DALIA Field.

Spools, jumpers and export lines from FPSO to offloading buoy are also covered by this specification.

1.2 Definitions

Shall: verbal form used to indicate requirements strictly to be followed in order to conform to the standard and accepted by all involved parties.

Should: verbal form used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.

May: verbal form used to indicate a course of action permissible within the limits of the standard.

Can verbal form used for statements of possibility and capability, whether material, physical or casual.

Flowline Riser System included all part of flowline and riser equipment

1.3 Abbreviation

API American Petroleum Institute
CP Cathodic Protection
FAT Factory Acceptance Test
EFAT Extended FAT
SIT System Integration Test
IT Integration Test
EN European Norm
FPSO Floating Production Storage & Offloading unit
ISO International Standardisation Organisation
ROV Remote Operated Vehicle
SDU Subsea Distribution Unit
IPB Integrated production bundle (riser)
PIP Pipe in pipe
FLET Flow Line End Termination

1.4 Responsibility

Deviations from any of the requirements defined herein shall be treated as non-conformances in accordance with COMPANY procedures.

1.5 Applicable Documents

1.5.1 Choice of Reference Documents

Where national regulations exist, their provisions and those of the standards and codes to which they refer shall apply, supplementing or amending the provisions of this document.

If there are no national regulation covering all or part of the subject of this document, the reference documents shall be strictly applied, as supplemented by the provisions of this document according with Article 6.3 of contract.

1.5.2 Reference Documents

Only the main reference documents are mentioned; the CONTRACTOR shall be responsible for complying with all secondary reference documents dealing with the subject of this document.

Unless otherwise indicated in the detailed contractual conditions, all the reference documents to be used as well as their supplements shall be in their latest editions unless differently specified.

1.5.3 Technical Documents

1.5.3.1 Project Specific Documents

Reference	Title
AO32-1-010-000-00-00-QH-001	HSE Plan
AO32-1-018-000-00-00-GA-002	Main Process Data
AO32-1-018-000-00-00-QE-001	Flow Assurance
AO32-1-018-000-00-00-QE-002	Field Operation Philosophy
AO32-1-018-000-00-00-QE-005	Hydrate Management Plan
AO32-1-018-190-00-00-TA-165	Methanol Injection System
AO32-1-018-300-00-00-QA-164	Chemical Injection System

AO32-1-018-000-00-00-TE-004	Subsea Operating Pressure and Temperature Assessment
AO32-1-010-000-00-00-QO-001	Corrosion Prevention Method
AO32-4-013-820-00-00-SG-001	Underwater Diverless Tie-in Systems Engineering and Operation
AO32-2-011-000-LJ-00-SW-001	SPS specification for tie in
AO32-5-013-820-00-00-SE-001	FPSO and Offloading Buoy Mooring System Design, Engineering, Procurement and Installation
AO32-1-010-000-00-00-GC-001	Environmental Design Criteria
AO32-1-010-000-00-00-GC-002	Soil Data
DGEP/TDO/TEC/GEO 01-02RT	DALIA Development: 3D HR Analysis of Superficial Layers
AO32-4-013-000-00-00-DW-001	DALIA Preliminary Layout
AO32-1-010-000-00-00-GX-004	Design Philosophy – Scheme and Layout
AO32-1-013-000-00-00-QW-001	Design and Operational Philosophies – UFL Design
AO32-4-013-000-00-00-SG-001	Acceptance of an Offshore Construction Vessel
AO32-4-013-000-ME-00-SW-001	Engineering/Procurement/Installation of a Permanent Frame Array for Acoustic Positioning
AO32-5-014-000-00-00-SG-001	FPSO Hull, Mooring & Offloading Design Basis
AO32-4-013-000-00-00-QV-001	Flowlines, Risers and Umbilicals Testing Requirements
AO32-4-013-000-00-00-SE-001	Subsea Structure Loadout, Transportation and Installation
AO32-4-013-000-00-00-SE-002	Offloading Buoy Design and fabrication
AO32-1-017-000-00-00-SJ-001	Interfaces Identification and Battery Limits
AO32-1-018-560 00 00 DA 560	Gas injection X Tree
AO32-1-018-560 00 00 DA 561	Gas injection branch 561
AO32-1-018-560 00 00 DA 562	Gas injection branch 562
AO32-1-018-300 00 00 DA 305	Production Loop 301 NH case
AO32-1-018-300 00 00 DA 306	Production Loop 302 NH case
AO32-1-018-300 00 00 DA 307	Production Loop 303 NH case
AO32-1-018-300 00 00 DA 308	Production Loop 304 NH case

AO32-1-018-760 00 00 DA 760	Water injection X Tree
AO32-1-018-760 00 00 DA 761	Water injection branch 761
AO32-1-018-760 00 00 DA 762	Water injection branch 762
AO32-1-018-760 00 00 DA 763	Water injection branch 763
AO32-1-018-000-00-00-SX-003	Crude Off-loading
AO32-1-009-000-00-00-QH-006	Dalia Project Reliability Strategy
AO-32-2-011-300-LB-00-SL-001	Gate Valve Specification for Subsea Manifold Systems
AO-32-2-011-300-LB-00-SL-002	Ball Valve Specification for Subsea Manifold Systems
AO32-1-010-000-00-00-SX 851	Risk Management Specification for CONTRACTOR
AO32-1-018-000-00-00-SE-205	Maintenance preparation during project phase : Spare parts
AO32-8-018-000-00-00-SE-217	Maintenance preparation during project phase: Vendor obligation
AO32-4-013-800-00-00-PE-001	Weather stand-by application

1.5.3.2 COMPANY Specifications

Reference	Title
SG.TVX.006.P	Remotely Operated Vehicle
SG.TVX.010.P	Subsea Production Systems Integration Principles
SG.TVX.023.P	Work Status Methodology
SG.SUR.001.P	Offshore Geotechnical Soil Survey
SG.SUR.010.P	Geophysical Site Survey Prior to Installing Offshore Structures
SG.SUR.011.P	Subsea Line Installation Surveys

SG.SUR.020.P	Offshore Surface Positioning Works
SG.SUR.021.P	Subsea Positioning Works
SG.CNL.001.P	Steel Sea-line Design Requirements
SG.CNL.002.P	Steel Pipe for Pipelines
SG.CNL.003.P	Carbon steel Pipeline Induction Bends for Non-Sour Service
SG.CNL.004.P	Packaging and Transportation of Line Pipes
SG.CNL.006.P	Construction of Subsea Steel Pipelines
SG.CNL.007.P	Welding of Pipelines and Related Facilities
SG.CNL.022.P	Design of Cathodic Protection of Sealines by Sacrificial Anodes
SG.CNL.023.P	Supply of Monobloc Insulating Joints for Pipelines
SG.CNL.026.P	Installation of Anodes on Submerged Pipelines
SG.CNL.027.P	Control by Electrical Measurements of Cathodic Protection of Submerged Pipelines
SG.CNL.032.P	External 3-Layer Extruded PE Based Coating
SG.CNL.033.P	External 3-layer Extruded PP Based Coating
SG.CNL.036.P	Field Coating of Welded Joints on Coated Pipelines
SG.CNL.039.P	Carbon Steel Pipeline Flanges and Fittings for Non-Sour Service
SG.CNL.041.P	Design, Fabrication and Installation of Steel Risers for Floating Production Units
SG.CNL.042.P	Design, Fabrication and Testing of Submarine Flexible Pipe and Risers
SG.CNL.044.P	Load out of Submarine Cables, Umbilicals and Flexible Pipes
SG.CNL.045.P	Transportation of Submarine Cables, Umbilicals and Flexible Pipes
SG.CNL.046.P	Installation of Submarine Cables, Umbilicals and flexible Pipes
SG.STR.001.P	Design of offshore Jacket and subsea structures
SG.STR.003.P	Offshore Jacket and Subsea Structures Fabrication
SG.STR.005.P	Steel Materials for Offshore Structures

SG.STR.008.P	Offshore Structures Constructions standards
SG.STR.009.P	Load out and Sea-fastening of Petroleum Objects for Sea Transportation
SG.STR.00 10.P	Sea transportation for Petroleum Structure
SG STR 00 12 P	Weight monitoring and weighting off shore unit
SG.PRO.001.P	External Protection of Structures and Equipment by Painting
SG.PRO.009.P	Design of Cathodic Protection of Offshore Structures
SG.PRO.011.P	Supply of Sacrificial Anodes
SG.PRO.015.P	Control of Cathodic Protection of Submerged Fixed Structures
SG MAS 001 P	material for sour service (upstream applications) design
SG MAS 002 P	Material for H_2S service
GS PVV 614	Welding of duplex and Super duplex and stainless
SG.ING.006.P	Specification for the supply and exchange of documents and databases for a petroleum industry project
SG.ING.007.P	Standard charter for CAD word-processing and spreadsheet files
SG.ING.010.P	Criteria for the Choice and Design of Subsea Equipment
SG SHE 006 P	Guideline for the performance of production availability studies of oil & gas system
GS.GEO.701	Geotechnical data and foundation design considerations for subsea production systems and pipelines
GS.GEO.702	Requirements for design and installation of skirted foundations and suction anchors
GS EXP 101	Precommissioning and commissioning guideline
GS EXP 103	Precommissioning and commissioning technical preparation
GS EXP 105	precommissioning execution

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1.5.3.3 Industry Standards

Reference	Title
API RP 1111	Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines
API 17J / ISO 13628-2	Specification for Unbonded Flexible Pipe
API RP 2RD	Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
API RP 2A	Planning, Designing and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design
ASME B 31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
ASME B 31.8	Gas Transmission and Distribution Piping Systems
DNV OS F101 2000	Design Rules for Submarine Pipeline Systems
DNV OS F 201 2000	Dynamic riser
DNV	VMO – Rules for Planning an Execution of Marine Operations

1.6 Units

SI units shall be used in all documents. Nevertheless, standardised diameters for cables and pipes may be expressed in inches. When applied, the symbol for inches (“ or in.) shall be clearly mentioned. . Value expressed in inch shall be real value (ie 12 “ = 12x25.4mm and not 12” 75)

2 FUNCTIONAL REQUIREMENTS

2.1 General

All systems within the Flowline riser system shall be designed in accordance with the following overall design philosophy:

- Field proven equipment and techniques shall be preferred unless newly developed techniques providing improved performance without compromising safety can be documented.
- The equipment shall be designed for access by both work class and inspection ROVs when required for inspection and/or intervention.

- All tools for equipment valve operation, locking device or other shall be ROV deployable unless differently agreed with COMPANY.
- Design of equipment and interfaces shall be standardised wherever possible.
- At all stages of running and installation of subsea equipment, the sequence of operations must be reversible.
- As a general practise, the handling surface unit shall be moved off the vertical of the final location prior to handling of heavy equipment. The surface unit shall stay around this position until a safe distance above seabed is reached before moving over to the final location.
- The design shall be made to have no maintenance operation during field life.
- The system shall be designed in accordance with decommissioning policy
- Pressure and temperature data are detailed in: “Subsea Operating Pressure and Temperature Assessment” ref. AO32-1-018-000-00-00-TE-004.

2.2 General layout

A preliminary layout for the Dalia field is given in the following documents and drawing:

- “Scheme and Layout” ref. AO32-1-010-000-00-00-GX-004
- “Dalia Preliminary Layout ” ref. AO32-4-013-000-00-00-DW-001

CONTRACTOR shall refer to these documents as a basis for design of the layout of the production, water injection, gas injection lines and buoy.

All risers including spares will be run through I-tubes to FPSO deck level. Export lines will run outside the hull.

2.3 Production lines

Production lines are arranged in loops, connecting the subsea structures to the FPSO in a daisy chain configuration.

These loops shall be piggable with an instrumented pig.

Characteristics of the transported fluid and process requirements have led to the operating philosophies / procedures detailed in the following documents:

- “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001
- “Hydrate Management Plan” ref. AO32-1-018-000-00-00-QE-005
- “Field Operation Philosophy” ref. AO32-1-018-000-00-00-QE-002

These loops shall be insulated according to “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001

2.4 Water injection lines

The water injection lines are feeding the water injection wells and connected via tees (rigid). Tees extremities shall be equipped with SPS hubs and pressure caps.

Each line shall have its end fitted with an ROV-operated ball valve and a permanent pig receiver connected with a SPS connector**.**

Two spare tees (with SPS hubs, pressure caps, without valves) shall be fitted on the Southwest injection line for the future connections of wells 3GW08 and 1G02.

2.5 Gas injection lines and export gas line

The gas injection lines are feeding the gas injection wells and connected via tees (rigid). The North export gas line shall be piggable with an instrumented pig. Tees extremities shall be equipped with SPS hubs and pressure caps and tees shall be fitted with an ROV operated gate valve.

North export gas line and south gas injection line shall be fitted at their ends with an ROV-operated full bore ball valve and a permanent pig receiver connected with a SPS connector..

The North gas injection line shall be fitted with 3 tees (with SPS hubs, pressure caps and with ROV-operated gate valves) for the connection of well 1G01, plus the future connection of wells D3W01 and 1W02.

The South gas injection line shall be fitted with 2 tees (with SPS hubs, pressure caps and with ROV-operated gate valves) for the connection of wells 3WG08 and 1G02.

2.6 Oil export lines

The export lines (2) will link the FPSO to the offloading buoy. They shall be piggable with an instrumented pig

The export lines shall be floating in mid water. Configuration of lines shall be defined in order to avoid collision risk with vessel (receptacles at FPSO side below the sea water level), cope with stuctural design and thermal condition for flow assurance, prevent any clashing with other lines (mooring lines, flowline) or between export lines, whatever the configuration (filled with oil or water).

➢

The export lines will consist of two flexible lines, min ID 18.5 “, with attached buoyancies, in camel waves configuration.

The export lines shall be designed for all condition of filling (oil or water).

The export lines shall be designed so as to meet all the pressure and flowrate requirements stated in “Crude Off-loading” ref. AO32-1-018-000-00-00-SX-003 specification

2.7 Protection corrosion and material

Refer to specification “Corrosion Prevention Method” ref. AO32-1-010-000-00-00-QO-001. “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001

For IPB , as base case material for Gas lift line shall be Inconel

2.8 Riser heating system

Refer to specification “Riser heating system ” ref. AO32-4-013-300-00-LQ- SW -001 “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001 , “Hydrate management plan ” ref. AO32-1-010-000-00-00-QE-005

3 DETAILED ENGINEERING REQUIREMENT AND STUDIES

3.1 General requirements

All systems shall be designed in accordance with the following overall design requirements:

- All designs of the flowlines, risers, export lines and ancillary equipment shall be performed in every respect on the basis of 20 year design life, with no plan for repair or replacement.
- All lines (risers, flowline, spool) shall be designed for overpressure due to blocked outlet, hammer effect (in particular for water injection and oil export line).
- All lines shall be designed for installation in dry and flooded condition.
- All Units shall be designed and qualified for potential service conditions expected during, manufacture, transport, installation their design life and decommissioning if applicable.
- The equipment shall be designed with due consideration to ease and speed of installation, operation and where possible use of standard tools.
- The number of seals made up under water shall be minimised. All seals made up under water shall be new, i.e. not previously energised. Seal areas on equipment installed under water and temporally not in use, shall be protected against mechanical damage and corrosion. It shall be possible to clean all seal areas using either standard industry tools/equipment or dedicated.
- All connectors including flanges shall have test ports for verification of seal integrity. Connectors and flanged connections incorporating a dual seal arrangement shall include facilities for testing between the seals.
- Any equipment, which requires personnel to climb onto individual Units or Units stacked up on each other, shall be furnished with temporary foot steps and hand holds, ladders, protection and floor grating as required by common practice.
- All mechanical components which are subject to relative motion between metal faces during make-up of e.g. a preloaded seal or a connection (high contact stress), shall be designed with adequate differential hardness to

establish correct contact load without causing any form of galling or other mechanical damage due to friction between the components.

- Components of a Unit which are electrically isolated from the Cathodic Protection (CP) system of the Unit, shall either be electrically connected to the Unit by cables, or shall be made of a material which does not require cathodic protection.

- The design phase shall include the main procedures for installation, inspection, repair, monitoring excursion, maintenance, operations, retrieval if applicable and abandonment.

- All equipment shall be designed with the objective of achieving safe handling and operation through all stages of assembly and testing, transportation, installation, commissioning, operation and removal. All handling and operational procedures shall be reviewed, with particular attention to methods and support facilities.

- All safety factors used in calculation shall be identified and justified with respect of standards in use and pertinence of use.

- All lines shall be fitted with buckle arrestors, the number of which will be justified.

- All lines shall include water stops, the number of which will be justified.

- As far as relevant, results from both qualification program results (see section 4) and detailed engineering studies shall be thoroughly reconciliated, in order to ascertain the design parameters and their related accuracy levels.Therefore, the detailed design and qualification processes shall commence with a detailed method statement showing clearly how the design and qualification phases will interact and culminate with the fully established design parameters.

3.2 Particular requirements

3.2.1 Particular general Risers requirements

Design shall be done with SN curve in flooded condition and worth environmental conditions (PH CO_2 ..) in annulus

No weld are allowed in fatigue sensitive area.

Risers shall be designed for installation empty or flooded.

The risers shall be designed to sustain an impact of 5kJ applied on 100mm diameter surface.

3.2.2 Particular production riser requirements

Bundle annulus (gas lift, electrical cable and insulation layer) shall be flooded with fresh water or liquid fit for purpose(seawater excluded). . The specific gravity of the liquid will be adjusted to be as close as possible from the specific gravity of sea water

Riser will included heating system according to specification Flow Assurance AO32-1-018-000-00-00-QE-001

Both production riser end fitting shall be internally cladded with inconel 625.

Electrical pigtail shall be minimum 1.5 m long.

Annulus of core flexible from IPB shall remain dry during the field life

Gas lift line shall be manifolded in several off at the top . Manifolding shall be done at manufacture

3.2.3 Injection riser requirement

Each riser section shall have a bend stifffener.

Intermediate connector shall be mechanically protected, as minimum, for installation operation.

The pig receivers at extremities shall be left in place after hydrotest operations to enable further commissioning operations to be performed by Company.

The pig receivers shall be designed to accommodate a train of three foam pigs to be used for commissioning operations. The pig receivers shall be designed as “permanent” equipment for field life in accordance with the requirements of flowlines/risers Tender specifications and cathodic protection Tender specification.

3.2.4 Flowlines requirements

Production flowline and production spool will be in PIP.

Subsea valves shall be provided according to requirements described in the following specifications :

- AO32-2-011-300-LB-00-SL-001 Gate Valve Specification for Subsea Manifold Systems
- AO32-2-011-300-LB-00-SL-002 Ball Valve Specification for Subsea Manifold Systems

One extra anode shall be installed at each end of flowline

3.3 Line Length

CONTRACTOR shall propose for COMPANY review the calculations of lines length for the production, water injection and gas injection networks and export lines. CONTRACTOR shall link these calculations to the layout requirements (locations of subsea structures and wells), the flow assurance requirements (avoidance of downhill slopes, for instance).

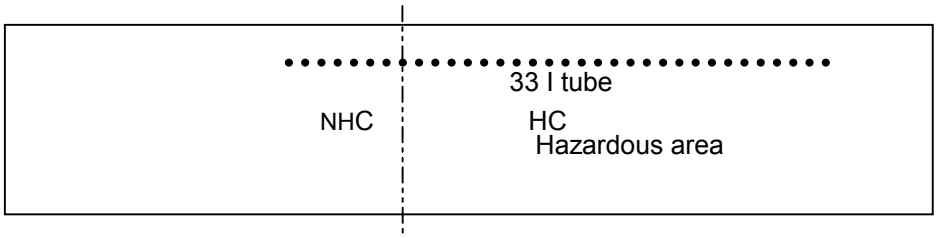
CONTRACTOR shall propose for COMPANY reviews the calculations of “procured line length” considering installation tolerances and spare length required for possible repair during installation.

Spare length shall be clearly stated and documented

3.4 Risers arrangement on FPSO

3.4.1 Lay out on deck

I-tube arrangement is one row on portside, with a spacing of 2.4 m with a dedicated area in the north of maximum 33 I-tubes for HC risers or other. Internal diameter is 40'' I-tubes on FPSO shall be vertical



HC hazardous area mandatory : 18 I-tubes

- 8 production system IPB
- 8 production spares (4 production lines and 4 gas lift lines)
- 2 gas injection lines

HC hazardous area not mandatory : 19 I-tubes

- 9 umbilicals (5 production and 4 water injection)
- 4 spare umbilicals (2 production and 2 water injection)
- 4 water injection lines
- 2 water injection spares

Risers shall be grouped by function as far as possible. **I Tube Top and FPSO hull**

Refer to '' Interfaces Identification and Battery Limits'' specification ref AO32-1-017-000-00-00-SJ-001

Top level

Hang off shall seal the top of I tube. A gas drain at HC flexible termination shall be provided at hang off system.

Flanges at top of I-tubes shall be provided by UFL Contractor.

CONTRACTOR shall design the hang-off system of the risers and the export lines receptacles on the FPSO.

Type of end extremity is "graylock". A identical "graylock" hub shall be supplied by UFL Contractor to FPSO shipyard for mounting on all riser spool-pieces.

Maximum vertical load applied on hang off shall not exceed :[KN] : 4100 (offshore test)

FPSO hull

A flange "graylock" hub supplied by UFL CONTRACTOR will be mounted on the I tube so that the base of the hub protrudes by 0.5m. This termination will be the base for installation of elbow or/and necessary guiding device.

Maximum load applied on flange bottom for each I tube shall not exceed:

Maximum bending moment at lower I-tube support [kNm	2056
Horizontal shear force [kN]	744

.

CONTRACTOR shall design hang-off, receptacle for export lines and guiding systems at the entrance of the riser I-tubes below sea level and alongside the FPSO hull.

Export lines receptacles will be located at the starboard side of the FPSO with an offset from the North mooring lines

and toward the FPSO stern to avoid any crossing with riser catenaries. Spacing between export lines axis with be a multiple of hull frames spacing of 2.4 m.

Installation of guiding systems, receptacles, flanges…. will be done as a base case on shipyard or in a shelter area next to yard . Nevertheless possibility shall be kept and design shall allow to install these devices offshore, in case it is needed.Riser pull in

FPSO will provide two beams on topside upper deck to skid pull in device. CONTRACTOR shall study and provide all temporary devices and permanent devices (Frame, trolley winch , including independent power supply unit, skidding system) to perform pull in.(ref to "interface specification " table).
The pull-in winch and/or pulley trolley guiding system will be located above the FPSO deck with a few meters offset from the I-tube axis.

The pull-in system may not be kept on board the FPSO after installation, therefore the trolley winch and associated pull-in equipment must be removable and reinstallable using the FPSO crane (maximum acceptable weight per element: 15 ton).Guiding devices will be incorporated in system substructures to ease reinstallation.

CONTRACTOR shall take into account that a zone of 5 m height above I tube is left free by FPSO.

3.5 Pipe Sizing

3.5.1 Internal Pressure

CONTRACTOR shall define the wall thickness of all pipes as per COMPANY General Specifications and the related Codes and Standards.

In the course of the calculations, the following definitions shall apply:

- **Pressure control system**: In relation to pipelines, this is the system for control of the pressure in pipelines, comprising the pressure regulating system, pressure safety system and associated instrument and alarm systems.

- **Pressure regulating system**: in relation to pipelines, this is the system which ensures that, irrespective of the upstream pressure, a set pressure is maintained (at a given reference point) for the pipeline.

- **Pressure safety system**: The system which, independent of the pressure regulating system, ensures that the allowable incidental pressure is not exceeded.

- **Pressure, design**: In relation to pipelines, this is the maximum internal pressure during normal operation, referred to a specified reference height, to which the pipeline section shall be designed. The design pressure must take account of steady flow conditions over the full range of flow rates, as well as possible packing and shut-in conditions, over the whole length of the pipeline or pipeline section which has a constant design pressure. In addition, overpressure due to blocked outlet, hammer effect (in particular for water injection and oil export line) shall be assessed and taken into account.

- **Pressure, maximum incidental**: In relation to pipelines, this is the maximum internal pressure the pipeline or pipeline section is designed to withstand during any incidental operating situation, referred to the same reference height as the design pressure.

- **Pressure, Maximum Allowable Incidental (MAIP)**: In relation to pipelines, this is the maximum pressure at which the pipeline system shall be operated during incidental (i.e. transient) operation. The maximum allowable incidental pressure is defined as the maximum incidental pressure less the positive tolerance of the pressure safety system.

- **Pressure, Maximum Allowable Operating (MAOP)**: In relation to pipelines, this is the maximum pressure at which the pipeline system shall be operated during normal operation. The maximum allowable operating pressure is defined as the design pressure less the positive tolerance of the pressure regulating system.

Pressure values or design are given in:

- "Subsea Operating Pressure and Temperature Assessment" ref. AO32-1-018-000-00-00-TE-004.

3.5.2 External Pressure

External pressure shall be computed for the related water depth.

3.6 Flow Assurance and Thermal Requirements

3.6.1 Oil line

Production flowlines and risers shall be designed to meet, as a minimum, the requirements set in:

- "Flow Assurance" ref. AO32-1-018-000-00-00-QE-001.

CONTRACTOR shall justify that his system meets the requirements by performing a detailed analysis, for COMPANY review and approval. Software's to be used are mentioned in the "Flow Assurance" document.

All result shall be obtained by using recognised industry standards or software. If such standards or software are not available, the results shall be confirmed by laboratory test or full scale test.

3.6.2 Water line

Water line will be insulated., they will be designed so as to achieve a U value of 10 W/K.m2.

3.6.3 Full scale test

CONTRACTOR shall perform a full scale test to verify thermal performance for each part of production flowline and riser subsystem (current section of riser and flowline, spool, connector, end fitting , other singular point).

Refer to section 6.7 for detail.

3.7 Thermal test after installation

A thermal performance test will be done after installation of each production loop, in order to verify the behaviour of the System in flowing, in warm up and in shut-down conditions.

Refer to section 6.9 for detail.

3.8 Design Studies

3.8.1 General

Equipment shall be designed to withstand the most unfavourable combination of the following load conditions:

- Operational and environmental loads acting simultaneously
- Test loads and environmental loads acting simultaneously
- Transportation loads
- Handling loads
- Installation loads
- Fatigue loads
- Operational load (pigging ,severe slugging…)
- Other

For each of the above load conditions, and for each component or cross section to be considered, the most unfavourable combination, position and force direction which may act simultaneously shall be used in the design analysis.

Design loads and conditions not provided by COMPANY shall be assessed and specified by CONTRACTOR and presented in the relevant design documentation for COMPANY review and acceptance.

Calculation methods and design/safety factors shall be selected in accordance with SG STR 001 rev 0A Design of Offshore Jackets and Subsea Structures, SG CNL 001 Steel Sea-line Design Requirements and other standards referenced therein.

All results shall be obtained by using recognised industry standards or software. If such standards or software are not available, the results shall be confirmed by laboratory test, full scale test, basin test.

All assumption shall be detailed and documented. For this, CONTRACTOR shall establish a design basis and premises document before calculation.

CONTRACTOR shall define and document for each type of line the maximum acceptable free span, in various configurations (line filled with air / water / operations fluid).

Software used for design shall be certificated or calibrated by test program. This shall be fully documented

Riser Analysis

CONTRACTOR shall perform a full detailed analysis of the riser system including export lines and umbilicals. The analysis shall be coupled with the mooring analysis (see “FPSO and Offloading Buoy Mooring System Design, Engineering, Procurement and Installation” ref. AO32-5-013-820-00-00-SE-001). These calculations shall cover each stage of riser life, manufacture, fabrication, loadout, transportation (towing or other), installation, testing and operation. Decommissioning feasibility shall be demonstrated.

Simplified modelling is not accepted.

Dedicated studies shall be performed for each singular point (bottom and top connection, , hang off point, end fitting , FLET , gas lift injection …).**Quasi-static Analysis**

CONTRACTOR shall perform a detailed analysis of the riser system connected to the FPSO. Environmental loads, FPSO motions and changes in transported fluids density shall be taken into account.

All stresses shall be calculated, and the suitability of the system to the different load cases shall be fully documented.

Singular elements (top of the risers, end fitting, gas lift injection points, etc.) shall be properly designed, using Finite Elements software.

3.8.1.2 Dynamic Analyses

All dynamic analyses are to be based on a precise methodology, stating the configuration studied, the load cases applied and the assumptions made according to design basis and premises.

Special operations (such as pigging), and special regimes (severe slugging, surge) shall be taken into account in the analyses.

Coupled analyses of riser system with mooring shall be performed. DEEPLINES and other software (choices to be documented by CONTRACTOR and approved by COMPANY) shall be used.

3.8.1.3 VIV

VIV analysis shall be performed using state of art numerical simulation program, such as SHEAR7 or other software (choices to be documented by UFL CONTRACTOR and approved by COMPANY) to demonstrate that no VIV devices will be needed for the dynamic parts of all riser

3.8.1.4 Fatigue

CONTRACTOR shall make a complete fatigue analysis of the riser system and the export lines. CONTRACTOR shall demonstrate that damage accumulated during manufacture fabrication, loadout, transportation installation and operation does not exceed the acceptable level for a 20-year service life.

All fatigue loading shall be considered in each stage of riser life. Response to wave frequency, low frequency dynamic response of the system Vortex Induced Vibrations shall be considered. Calculation shall be done for the worst cases of combinaison loadings.

Thorough modelling shall be performed. Dedicated studies shall be performed for each singular point.

CONTRACTOR shall design the riser components plus any required appurtenances to limit fatigue, if deemed necessary.

For each riser, fatigue shall be calculated for dry and flooded annulus condition.

Contractor shall clearly assess VIV impact on fatigue analyses and designed VI V devices if needed

3.8.1.5 Clashing Analysis

CONTRACTOR shall present for COMPANY review a detailed methodology for the assessment of the clearance between all risers, umbilicals, export lines and mooring lines, for all environmental loading and in the various configurations of the FPSO (ballasted to fully loaded, and with one mooring line damaged, during tanker offloading).

Based on this methodology, CONTRACTOR shall calculate the minimum clearance between all lines.

No interference at any time between the export lines and mooring lines, and between export lines is allowed. Any possibility of clashing shall be thoroughly studied (energy of impact, location, probability of occurrence), and shall be submitted to COMPANY for final approval.

As a general rule, a minimum vertical clearance of 150 m between flowlines and mooring lines shall be respected in all situations, plus a 200 m horizontal clearance between anchors and flowlines. Spacing on FPSO deck is mentioned in section 3.1.4.

Crossing between two catenary lines (fluid, mooring or umbilical) is not allowed.

3.8.1.6 Particular studies

As a minimum, the following particular issues shall be studied :

- Interaction assessment between riser and flowline due to thermal load , dynamic load ,pressure variation.

- Determination on the maximum allowable number of broken welds per pitch (based on a redistribution of loads on the remaining wires).
- VIV assessment
- Touch down point behaviour (soil disturbance , wearing of external sheath, mechanical and displacement studies)
- Riser behaviour with inner annulus flooded
- Flooding of bundle annulus (flooding system, monitoring system, flooding dynamic)
- Lateral bucking effect / end cap effect
- Liquid and gas diffusion, from the bore and from the intermediate sheath
- Bundle elements behaviour (gas lift line, electrical cable, insulation filler)
- Field life in case of accidental flooded of core flexible annulus
- Natural bend radius determination
- Cyclic slug effect assessment

3.8.2 Export Lines Analysis

CONTRACTOR shall perform a detailed export lines motion, stress and interference analysis and shall supply full details of all calculations performed. The export lines analysis shall be coupled with the mooring analysis of the FPSO and the buoy (see “FPSO and Offloading Buoy Mooring System Design, Engineering, Procurement and Installation” ref. AO32-5-013-820-00-00-SE-001).

If add-on floats are used, the attachment devices of float carriers shall allow to adjust the configuration of the export lines by moving the floats.

Float fastenings shall be carefully designed to eliminate any risk of loss of floats by corrosion or breakage of the fastenings, and the solution proposed by CONTRACTOR shall be submitted to COMPANY for APPROVAL.

The configuration, buoyancy and length of the export lines shall be carefully studied to prevent the export lines chafing against the anchor lines, against each other, whilst allowing full excursion of the buoy without undue stress on the export lines. Various configurations shall be investigated (filled with oil, water….).

Export lines ends connected to rigid piping shall have built-in reinforcement.

Singular (points) shall be properly designed, using Finite Elements software (connection to the buoy, connection to the FPSO, connection buoyancy line).

3.8.2.1 Quasi-static analysis

CONTRACTOR shall perform a detailed analysis of the export line system connected to the FPSO and the buoy. Environmental loads, FPSO/buoy motions and changes in transported fluids density shall be taken into account.

All stresses shall be calculated, and the suitability of the system to the different load cases shall be fully documented.

3.8.2.2 Dynamic Analyses

All dynamic analyses are to be based on a precise methodology, stating the configuration studied, the load cases applied and the assumptions made.

Special operations (such as pigging) shall be taken into account in the analyses.

Coupled analyses of riser system with mooring shall be performed. DEEPLINES and other software's (choices to be documented by CONTRACTOR and approved by COMPANY) shall be used.

A detailed description of the methodology and numerical tools used for the export lines analysis and motion simulation shall be provided. A design load case matrix shall be determined similar to the mooring analysis and given to COMPANY for APPROVAL.

The final export line (lines) configuration and corresponding calculations shall at least take into account the following:

- Minimum (Near) and maximum (far) excursions of the BUOY with respect to the FPSO under the operating conditions with a tanker moored and under survival conditions without a moored vessel, for both intact and damaged line cases.
- Motions of the components of the export line system.
- External forces on the export line system.
- Range of specific gravity of the content envisaged in the export line system.

For each case, the following criteria shall be demonstrated:

- Maximum tension, compression, minimum bend radius, twisting of export lines are within acceptable values.
- Forces on FPSO and buoy piping connections are within acceptable values

The allowable characteristics of the export lines shall be in accordance with supplier's specifications, latest issue of BS 1435.

3.8.2.3 VIV

VIV analysis shall be performed using state of art numerical simulation program, such as SHEAR7 or other software (choices to be documented by UFL CONTRACTOR and approved by COMPANY) to demonstrate that no VIV devices will be needed for the dynamic parts of all export line.

3.8.2.4 Fatigue analysis

CONTRACTOR shall make a complete fatigue analysis of the export line system (export lines and export line end connections). CONTRACTOR shall demonstrate that damage accumulated during manufacture fabrication, loadout, transportation, installation and operation does not exceed the acceptable level for a 20-year service life.

All fatigue loading shall be considered in each stage of export line life. Response to wave frequency, low frequency dynamic response of the system, Vortex Induced Vibrations shall be considered.

Thorough modelling shall be performed. Dedicated studies shall be performed for each singular point.

3.8.2.5 Clashing analysis

Refer to section 3.8 1 4

3.8.3 Flowline Analysis

CONTRACTOR shall perform a fully detailed analysis of the flowline system. These calculations shall cover each stage of Flowline life, manufacture, fabrication, loadout, transportation (towing or other), installation and operation.

3.8.3.1 Static / dynamic analysis

Following calculations as a minimum shall be performed:

- Design
- Fabrication
-
- Laying
- On bottom static analysis (stability, free-span, crossings…)

Thermal expansion loads shall be defined

Load transferred on extremity

Load at bulk head due to thermal gradient between inner and carrier pipe

3.8.3.2 Fatigue analysis

Construction, installation fatigue analysis shall be performed**)**

3.8.4 Spool Analysis

CONTRACTOR shall perform a fully detailed analysis of the spool system. These calculation shall cover each stage of spool life, manufacture, fabrication, loadout, transportation, installation , testing and operation.

3.8.4.1 Static / dynamic analysis

Following calculations as a minimum shall be performed:

- Design
- Fabrication

- Installation
- Operation (thermal expansion load, environmental load)
- Relative movement due to supporting structure settlement (and soil reaction if necessary).

Maximum horizontal load on manifold per connector shall be limited to 25 000 daN for axial load.

3.8.4.2 Fatigue analysis

Construction, installation and operation fatigue analysis shall be performed.

3.9 Structure and Subsea Structures

3.9.1 General

All types of Subsea Structures shall be designed for the following general requirements:

- The Subsea Structures shall be designed for field specific soil conditions.
- The foundation method will be field specific. The selection of foundation method shall be recommended by CONTRACTOR and decided by COMPANY based on an evaluation of geotechnical conditions, margin and loads as well as fabrication and installation costs.
- The foundation system shall allow for :
  - ± 20% variation in the soil characteristics
  - +/- 0.5° uncertainty on measured/estimated seabed slope
- All structures shall allow for the actual local seabed slope. CONTRACTOR shall demonstrate through appropriate design studies that the overall design is compatible with local slope conditions and installation /retrieval operations for each type of structure considered.
- CONTRACTOR shall assess and document the robustness of the overall system to variation of major parameters above assumed tolerances, like soil condition data, seabed slope, conductor pipe inclination, loads etc.
- The foundation system shall be designed in order to reduce the consequences of potential scouring.
- CONTRACTOR shall assess the requirement for a levelling system on the basis on the above studies and perform studies on this.
- In general closed profiles (rectangular hollow sections and tubular) shall be flooded. Free circulation of seawater shall be avoided. Oxygen scavenger shall be inserted in the profile internals. During installation, the flooding of the closed profiles shall be sufficient to avoid hydrostatic collapse of the profiles without restricting the lowering speed of the structure through the water.
- The Subsea Structures shall include permanent subsea marking as per section 5.2.2. The orientation of the subsea marking shall be according to the planned ROV intervention position. The numbering system for subsea marking of all equipment shall be agreed with COMPANY during detail engineering.

- The Subsea Structures shall incorporate test plates (100 mm x 100 mm) blasted and varnished accessible by ROV for cathodic protection measurement.
- Electrical continuity between units shall be ensured.
- Production pipe dead legs shall be avoided as much as possible.
- A ROV access study shall be carried out using a 3 D model comprising Structures, ROV and Units/Components to be accessed. ROV intervention shall be checked for each and every Unit or Component potentially requiring ROV access.
- The result of the geotechnical survey as performed by Contractor shall be used in the design of the anchor points. Soil design conditions shall be submitted to COMPANY for approval.
- The buried parts of suction anchors shall not be painted, while the part exposed to seawater shall be painted with an epoxy coating system, 450 µm DFT.
- Side openings shall be made near the bottom of the caisson structures to minimise horizontal displacements during lowering close to sea-bottom.
- The foundation cover shall be equipped with a device to balance the pressures inside and outside the anchor at the end of the suction operation in order to ease the removal of the suction pump if the suction pump doesn't allow to perform these operations..

3.9.2 Design requirements

Design of the Structures shall be based on SG STR 001 P rev 0A" Design of Offshore Jacket and Subsea Structures".

All applicable loads affecting the Subsea Structures shall be identified and evaluated. Loads acting on the Subsea System can be categorised as follows (non-exhaustive list):

- Permanent loads
  - Equipment weight
  - Buoyancy
  - Pre-stressing
- Environmental loads
  - Wave, wind, current
  - Water temperature
  - Hydrostatic pressure
- Variable loads
  - Installation loads
  - Transportation loads
  - Vessel motion induced loads
  - Mechanical testing loads
  - Accidental loads

Structural analysis shall be carried out for several load combinations. A matrix of load combinations shall be developed and selection of worst cases shall be justified and documented.

For seabed structure, a full finite element model shall be developed including:

- Soil model based on specific soil data

- The appropriate Foundation system

Foundation behaviour and performance shall be studied and checked as minimum for:

- All various installation sequences
- Flowlines and Riser connection operations
- Flowlines thermal expansion aspects

Design documentation shall include as a minimum:

- Modelling of the overall system with actual seabed characteristics: bottom slope and soil characteristics with associated uncertainties and variations.
- Structures and foundation vertical and orientation tolerances
- Operational loads : thermal expansion

3.10 Mechanical Protection requirements

. The permanent equipment shall incorporate means of protection capable of withstanding impact energy of 10 kJ from a dropped object of 100-mm diameter (except for risers which withstand 5 KJ from a dropped object of 100-mm diameter). The design shall ensure that the impact energy is fully absorbed by the protection and riser system, without damage to the Unit affecting its functionality or pressure integrity.

Subsea Structures shall include local protection of electrical cables and connectors, valves, small bore piping and other sensitive equipment in order to prevent impact from dropped objects, ROV, running tools, local guide wire snag and sling arrangements. Small-bore piping shall be routed in pipe racks and equipment shall be as little exposed as possible

Protection shall allow IMR operation with a ROV

Fragile equipment such as piping, valves, cables, sensors etc. shall be protected against ROV collision or ROV umbilical snagging.

Critical components exposed to dropped objects and/or ROV impact during intervention, such as sensors, and non-ROV replaceable cables, small bore valves, etc., shall have specific local protection.

3.11 Tie in system

Refer to specification ‘’Underwater Diverless tie systems engineering and operation’’ ref. AO32-4-013-000-LA-00-SE-001 and “SPS specification for tie in “ ref AO32-011-000-LJ-00-SW-001.

3.12 Pigging

Production lines, North gas injection line, export lines including spool pieces shall be fully piggable by instrumented pigs. Their design shall therefore accommodate a 5D minimum bend radius.

CONTRACTOR shall ensure a constant internal diameter throughout ~~all~~ each single type of line. CONTRACTOR shall therefore ensure compatibility with subsea production systems piping and all fittings.

CONTRACTOR shall perform an assessment of pig behaviour with various type of pigs (intrumented pig, foam pig, bi-directionnal pig), in all fluid conditions taking into account the production of solid deposit possibility and the risks associated. Studies shall demonstrate that adequate profile of flowline copes with all conditions.

3.13 Heating system

Refer to specification “Riser heating system ” ref. AO32-1-010-000-00-00- - “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001 , “Hydrate management plan ” ref. AO32-1-010-000-00-00-QE-005

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3.14 Corrosion Protection

3.14.1 General

CONTRACTOR shall design the internal and external corrosion protection of the flowlines, risers system and export lines according to the documents:

- “Corrosion Prevention Method” ref. AO32-1-010-000-00-00-QO-001
- “Flow Assurance” ref. AO32-1-018-000-00-00-QE-001.

CONTRACTOR shall take care of the possible interactions between the flowlines, risers and export lines corrosion protection system and the FPSO, SPS and offloading buoy corrosion protection systems.

The system design shall include a corrosion protection system based on a combination of cathodic protection and surface coating, in accordance with the principles for corrosion protection defined in

- SG PRO 001 P rev 02 External protection of structures and equipment by painting
- SG PRO 009 P rev 01 Design of Cathodic protection of offshore structures

3.14.2 Surface protection

Coating system selection, surface preparation and protective coating shall be in accordance with SG PRO 001 “External protection and equipment of structures by painting“.

The coating shall be a 450 µm DFT epoxy system for equipment and structures.

3.14.3 Cathodic Protection

Cathodic protection design and manufacturing of sacrificial anodes shall be in accordance with SG PRO 009 rev 01“Design of Cathodic protection of marine structure”.

The Cathodic protection system shall be sized for the design life of the structure.

The design shall provide reliable electrical continuity to each individual element within the System. Electrical continuity checks shall be performed to verify adequate protection.

CONTRACTOR shall study interference between FPSO Cathodic Protection system based on impressed current and UFL Cathodic Protection system with regard to this study.

3.14.4 Monitoring

The structure and equipment of the system will be monitored by cathodic protection measurements on the structural parts. A specific unpainted steel plate shall be welded to the structure for easy measurement by ROV.

3.15 Sensitivity

CONTRACTOR shall perform all other necessary sensitivity study required during the engineering.

For riser, as minimum , following sensitivity studies shall be performed

- main FPSO RAO data versus mechanical behaviour,
- environmental data (waves direction, meteocean, current …) versus mechanical behaviour
- mooring offset versus mechanical behaviour
- potential marine growth versus mechanical behaviour
- accidental flooding of inner annulus (IPB) versus mechanical behaviour
- accidental flooding for bundle annulus (IPB) versus mechanical behaviour
- gas diffusion versus corrosion/mechanical behaviour

For flow assurance, sensitivity studies shall be performed according to Flow Assurance specification " AO32-1-018-000-00-00-QE-001".

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3.16 Riser Temperature Monitoring

As an option all production risers shall be monitored by fiber optic . Refer to ANNEX 5 .

3.17 RAM

CONTRACTOR shall develop and implement a Reliability, Availability and Maintainability program. This document shall describe and formalise the Reliability, Availability and Maintainability policy in accordance with Operator's requirements, organisation, and resources. This program shall be applied from conceptual phase to delivery of equipment.

Reliability, Availability and Maintainability targets shall be checked against design at each stage of project and be used as a decision aid tool as well as for developing a qualification / verification program.

Input data to the RAM analysis shall be fully documented either by experience feed back or specific studies or testing.

As a minimum, the following RAM studies shall be done :

- Production riser heating system (including surface equipment)
- IPB alone dealing with each specific component
- Production subsea system
- Water injection subsea system
- Gas injection subsea system
- Export line system

Refer to specification “Dalia Project Reliability Strategy” AO32-1-009-000-00-00-QH-006 and COMPANY specification “Guideline for the performance of production availability studies of oil & gas system” SG SHE 006 P.

In particular FMECA studies shall be performed for each equipment.

3.18 Inspection, Maintenance, Repair

Philosophy, inspection studies and procedure (means, planning) shall be established.

The design shall be made to have no maintenance operation during field life.

Repair studies and procedure (means, planning) shall be established.

Contractor shall indicate the lead time for replacement of each line and riser,especially for risers and export lines.

These shall include, but not be limited to, the following

- IRM Philosophy for all system
- Local permanent monitoring system
- Cathodic Protection Measurement
- Leak Detection
- Inspection
- Maintenance
- Access
- Tools
- Spares

3.19 Risk analysis

3.19.1 Project risk analysis

CONTRACTOR shall put a risk management plan with regards to the technical, schedule and cost risk to the project.

The risk studies shall be based on design competition risk studies and with accordance with AO32-1-010-000-00-00-SX-851 “Risk Management Specification for CONTRACTOR”.

3.19.2 Hazid / Hazop

Contractor shall implement during the project life an Hazid and Hazop process for the whole system.

3.19.3 Qualitative and quantitative risk assessment

Contractor shall perform qualitative and quantitative risk assessment studies for the whole system.

3.20 HSE Studies

Refer to “HSE Plan document ref. AO32-1-010-000-00-00-QH-001.

3.21 Decommissioning

CONTRACTOR shall develop a decommissioning plan with corresponding operational procedures for the flowline riser System. According to “HSE Plan document” ref. AO32-1-010-000-00-00-QH-001.

3.22 Interfaces

Refer to document “Interfaces Identification and battery Limits” ref. AO32-1-017-000-00-00-SJ-001.

CONTRACTOR shall provide all necessary data and document to other interfacing CONTRACTOR

Specific Interface document shall be established and provided.

CONTRACTOR shall implement interface specifications, sketches and drawing produced by others within its own design documents and fabrication.

CONTRACTOR shall clarify with other CONTRACTOR all interfacing parameters.

3.23 Documentation

The engineering file system shall comprise all engineering produced documents and as minimum:

- Basic design book
- Design premises
- Conclusions and recommendations (design, qualification, fabrication, installation, interventions, field operations,…)
- Consistency review of the applicable normative references
- Summary data sheets
- Supplier's documentation for any component of the system
- Manufacture reports
- Drawing
- Operation and maintenance manual
- All calculation notes

In particular, CONTRACTOR shall establish and update as a minimum the following general documents which cover several packages:

- PFD from FPSO to SPS for all loops and from FPSO to buoy
- I tubes arrangements
- Pull in arrangements
- Field lay-out
- 3D overview
- Clashing movies simulations

In addition during the course of the studies a design report covering all main data shall be updated each month . This report shall be initiated two month after contract award

4 QUALIFICATION

4.1 Definition

4.1.1 Field proven equipment

Field proven equipment shall satisfy the following conditions:

- The equipment is already in use and assuring the same function(s) in conditions similar to the Dalia ones.
- It has acceptable performance and an acceptable level of in-situ repairs.
- Essential design and operations parameters have been reviewed and analysed. No API scaling or modifications have been made to its design.

- Documentation from suppliers and wherever possible from users are available, have been submitted and reviewed by the Project Group to its satisfaction.

4.1.2 Qualified equipment

Qualified equipment satisfies the following conditions:

- Equipment has satisfied a qualification process, either for DALIA or for other projects, in order to demonstrate it is fit for purpose.
- Qualification process has been approved by DALIA project Group.
- In case of qualification performed for other projects :
  - Essential parameters shall be reviewed and analysed, no API scaling or modification being acceptable.
  - Relevant documentation shall be issued to DALIA project group for review and acceptance.

4.2 General

All new and non field proven Units and parts thereof, shall be qualified in accordance with the qualification program established by the CONTRACTOR and approved by COMPANY and requirements of relevant ISO standards, API specifications, and COMPANY specifications.

CONTRACTOR shall implement a verification-qualification programme. This document shall identify down to the component level the design review, manufacture control, qualification and testing activities required and carried out in order to reach the dependability objectives.

CONTRACTOR shall develop and implement a methodical complete review on **all** of the flowline riser system and installation tools and devices. Aim is to identify all new unit and non field proven component, subsystem, system.

This review shall encompass as a minimum:

- Level of development conceptual / studied / built
- Status field proven / qualified / non qualified
- Criticality low / medium / high based on failure consequences
- Back up description if any
- Reference for field proven equipment

Equipment lacking the necessary track record and hence requiring full qualification for the application shall be clearly identified at an early stage during the preparation phase. CONTRACTOR shall develop a realistic qualification program and schedule for submission to COMPANY.

Field proven equipment but requiring minor modification or upgrading shall be subject to a specific qualification programme unless otherwise agreed by COMPANY.

Equipment used for qualification purposes shall not be reused for the Project unless agreed by COMPANY.

New design of flowline, riser or export lines without previous field history for similar environmental and service conditions, or a verification record, shall be verified by testing. A development and qualification program with planning shall be submitted to COMPANY approval in such a case.

New Systems, comprising qualified Units in combinations or configurations without previous field history, or a verification record, shall be verified by testing as above.

Modifications on a previously qualified product, which in COMPANY's opinion affects the performance of the product in the specified service conditions, shall undergo a new qualification test.

Equipment / tools without sufficient track record in conditions similar to the Project shall undergo a qualification program. This includes non permanent equipment to be used as installation aids like for example buoyancies…etc which shall be tested at maximum expected water depth plus contingency.

The qualification program will be integrated in the overall Project planning in order to identify the critical path.

A design based on scaling principle, i.e. design similarity of an existing component regarding fit, form and function, will not be accepted. For all new designs, including new sizes and ratings of an existing design, completion of a successful qualification test program is required unless agreed by COMPANY.

All such test procedures and programs shall be subjected to COMPANY approval prior to commencing the tests. Program shall include clear acceptance criteria.

For each riser component material, especially for steel carcass material, material compatibility with production fluid shall be established (documented or tested by qualification test)

4.3 Field proven component/equipment :

For Field proven component/equipment, following information shall be given as a minimum:

- Detail of equipment and documentation to prove that equipment is identical to DALIA one, variation with Dalia equipment if any.
- Field name and operator contact if possible.
- Detail operation condition (water depth, pressure, environmental data) extrapolation explanation if any for Dalia use**.**
- Time on operation and extrapolation explanation if any for Dalia use.
- Traceability of event, explanation, remediation and improvement.
- Qualification report if available.

4.4 Qualified equipment

For qualified equipment following information shall be given as a minimum:

- Detail of equipment and documentation to prove that equipment is identical, variation with Dalia equipment if any and extrapolation explanation for Dalia use.
- Detail qualification process and data (water depth, pressure, environmental data, measured data, comparison of results with acceptance criteria) extrapolation explanation for Dalia use.
- Traceability of event, explanation, remediation and improvement.
- Qualification report.

4.5 Non Qualified equipment

For Non Qualified equipment a detailed qualification program shall be provided before beginning of test.

This program shall comprise as a minimum:

- Definition analysis of essential parameters with respect to Fabrication, working condition (i.e. water depth, pressure, temperature and flow rate, electrical data, etc…), HSE issues
- Description of test and methodology (theoretical evaluation, test protocol, small scale test, full scale test, other)
- Acceptance criteria of test. This shall be issued to COMPANY review before the beginning of test. These criteria shall be quantifiable. Value and curve shall be given.
- Means
- Schedule necessary to complete qualification, in relation with the project overall schedule.
- Report

CONTRACTOR shall perform all necessary qualification tests. CONTRACTOR shall provide all equipment and facilities to carry out all the tests. COMPANY shall have access to CONTRACTOR's premises during tests. CONTRACTOR shall provide to COMPANY in each test site one fully equipped lockable office and PC and access to telefax ,E mail and photocopying machines.

If some test fail, or result are not accepted by COMPANY, the CONTRACTOR either will redo the test or use back-up solution if applicable.

As a minimum all qualification test listed and described in Appendix 2 shall be performed .

fabrication should be launched after complete qualification

4.6 fall back solution

In case of failure or delay of the following test at the expected date defined in exhibit C, Contractor shall mobilise a parallel team to develop the back up solution

The back up solution development shall be launched in parallel if following qualifications have failed or are delayed at date defined in exhibit C.

Test number	Product	object
1	IPB	Full scale bending and pulling tests on end fitting
2	IPB	Full scale crushing test
4	IPB	Full scale thermal test on a hand made sample
9	IPB	End cap effect
11	Gas injection	End cap effect

The back up solution shall be selected and developed if following qualifications have failed or are delayed at the date defined in exhibit C.

Test number	Product	object

1	IPB	Full scale bending and pulling tests on end fitting
2	IPB	Full scale crushing test
3	IPB	Full scale fatigue test
4	IPB	Full scale thermal test on a hand made sample
7	IPB	mechanical & fatigue test of electrical cables
8	IPB	Carazite qualification
9	IPB	End cap effect
10	Gas Injection.	Full scale fatigue test
11	Gas injection	End cap effect

The back up solution shall be developed according to the planning in exhibit C

Back up concept could be in house concepts such as SLOR/ COR with associated adjustment for umbilical. All requirement mentioned in the contract remains applicable for

5 PROCUREMENT and FABRICATION

5.1 General

CONTRACTOR shall supply all equipment and material including spare parts, temporary items for installation or temporary work, all consumables necessary during each phase of the work.

All equipment shall be field proven or qualified. Refer to section 4.

A Quality Plan shall be in effect and agreed upon prior to any phase of manufacture. This overall plan shall require, as a minimum, individual plans for purchasing, manufacturing, testing, maintaining material traceability, inspection, inspection documentation, calibration of test instruments, identification and non-conformances.

Precommissioning of pull-in equipment on FPSO shall be performed according to OPERCOM/ ICAP methodology in accordance with specifications GS EXP 101 Precommissioning and commissioning guideline, GS EXP 103 Precommissioning and commissioning technical preparation and GS EXP 105 precommissioning execution

5.2 Procurement and fabrication requirement

5.2.1 Material Requirements

5.2.1.1 Material selection

Material philosophy and requirement are stated in:

- “Corrosion Prevention Method” ref. AO32-1-010-000-00-00-QO-001

- "Flow Assurance" ref. AO32-1-018-000-00-00-QE-001

Material selection and corrosion protection shall be performed in accordance with the principles defined in:

- **Structure**
  - SG STR 001 rev 0A Design of offshore jackets and subsea structures
  - SG STR 005 rev 04 Steel materials for offshore structures
- **Piping**
  - SG MAS 001 P rev 0A material for sour service (upstream applications) design
  - SG MAS 002 rev 0A Material for H 2 S service
  - SG CNL 001 P rev 01 Steel Sealines design requirement
  - SG CNL 002 P rev 01 Supply of steel pipelines and flowlines
  - SG CNL 003 P rev 01 Supply of steel induction bends for pipelines and flowlines
  - SG CNL 040 P rev 01 Supply of steel for pipelines and flowlines
  - GS PVV 614 rev XX Welding of duplex and Super duplex and stainless
- **Flexible pipe**
  - SG.CNL.042.P Design, Fabrication and Testing of Submarine Flexible Pipe and Risers
  - GS PVV 614 rev XX Welding of duplex and Super duplex and stainless

Manufacturers of components in special materials such as 22 Cr, Duplex or 6 Mo Stainless Steels and other high austenitic alloy stainless steels, Nickel alloys and Titanium castings shall be chosen from the COMPANY's list of qualified suppliers. The list of suppliers will be provided by COMPANY.

The risk of hydrogen induced cracking due to cathodic protection shall be evaluated as part of the material selection.

The material selection shall be documented in a Material Selection Report.

5.2.1.2 Valve and Components

Valve components such as gates, spheres, seats, stems etc., which are exposed to high contact loads in dynamic situations, shall be made of materials with appropriate mechanical strength, surface finish and hardness to avoid loss of functionality and/or sealing capability. If hard facing material is applied (such as e.g. Tungsten Carbide), fully qualified application processes such as High Velocity Oxygen Fuel (HVOF) or D-gun process shall be used.

Valve units used for qualification shall not be used for application.

5.2.1.3 Metallic Seals and Seal Surfaces

All carbon steel seal surfaces permanently installed subsea, including areas not permanently used, shall be overlaid with corrosion resistant alloy, typically UNS N06625.

Seal materials shall be galvanically compatible with the seal areas and satisfy all requirements of API 6A.

The seal area shall be of a harder material than the seal element, with a difference in hardness of minimum 50 Brinell units.

5.2.1.4 Non metallic seal materials

Non metallic seal materials shall be selected on the basis of service condition and lifetime required. The seal materials shall be compatible with all chemicals and fluids the seals may be exposed to, as well as interfacing metallic components.

5.2.1.5 Material Certificates

All carbon steel materials shall be certified in accordance with EN 10-204 -31 b.

All stainless steel materials shall be certified in accordance with EN 10-204 –3 1 c.

The mechanical testing shall be carried out in a laboratory, which meets the requirements of ISO Guide 25 or equivalent

5.2.1.6 Inspection

As a minimum, all following material shall be controlled according to ISO 9002 level 3.1 C :

- Steel wire
- Armour wire
- Carcass material
- Gas lift line
- IPB insulation material
- IPB electrical cable
- Forged pieces

5.2.2 Identification and marking requirements

5.2.2.1 Name Plates

All equipment, shall be marked with the following information as a minimum:

- Description (name) of the component
- Part no.
- Serial no.
- CONTRACTOR s name
- Year/month of fabrication
- Client
- Client Contract no.
- Tag/Item no.
- Weight in air and in water
- CE certification data

The information shall be clearly legible on a nameplate of corrosion resistant material, mechanically attached to the Unit, or hard stamped if necessary, in a position, which is easily accessible. In addition, tag or item number shall be painted on the Unit for omnidirectional identification.

All Units and lifting equipment shall be marked in accordance with European Community regulations with data/information/certificate relevant for lifting of the equipment.

5.2.2.2 ROV Marking

Marking of Subsea Stations shall be in accordance with ISO 13628-1, and the following requirements:

- Marking of submerged Units and functions shall be by means of “Aquasign” or similar marking system. Letter size shall be 50 mm.
- ROV operable functions shall be marked with function identification and status O/S (open/shut - lock/unlock etc.).
- Visual position indicators shall be legible using ROV deployed cameras.
- All ROV marking, shall be with black painted characters. If required, white colour may be used to ensure contrast and achieve proper identification.
- Transportation devices, lifting points and sea fastening points shall be clearly marked with function and rating to prevent incorrect use.
- Subsea Aquasign shall be protected with sunproof covers during storage.
- Orientation marking shall be done only on horizontal surface.

5.2.2.3 Export Line, IPB, flexible risers Marking

On each export line, IPB and flexible riser, two indelible lines shall be marked 180 degrees apart, which shall be positioned identically with respect to the flanges.

5.3 Procurement and fabrication engineering

CONTRACTOR shall perform all engineering and issue all documents required for the fabrication of all items of the contract including ancillary equipment.

Document shall be developed to cover the different sequences of each fabrication process, and inspection to be performed.

CONTRACTOR shall establish and produce following items as a minimum:

- Requisition, material take off specifications, workshop drawing necessary to supply component / equipment
- List of commissioning and start up spare part for COMPANY approval
- List of spare part for repair

CONTRACTOR shall perform detailed fabrication engineering in accordance with selected yard.

CONTRACTOR shall study environmental issues on the yard especially on the waste elimination issues.

Specific inspection plan shall be developed according with fabrication process.

5.4 Manufacturing / fabrication

CONTRACTOR shall carry out all the construction works.

CONTRACTOR shall carry out all necessary shop drawing, welding procedure, and perform fabrication qualification tests, assembly works, inspection, testing, weighing.

Applicator qualification shall be done

CONTRACTOR shall provide the following services but not limited to

- Mobilisation and preparation of construction works site
- Complete construction and assembly of Flowline ,base , ancillary, sled , tee, others
- Engineering, procurement fabrication and installation of temporary equipment required for all lifting operation such as lifting device ,pulling device etc
-
- Weighing
- Dimensional test
- On shore testing

- Preservation for transportation shall be assessed (i.e.line filled with suitable inhibitor, nitrogen...)
- Guarding (safety and security) on yard
- Demobilisation
- Others

6 TEST AND ACCEPTANCE

6.1 General

All Units and Systems shall be subject to a verification and acceptance testing programme in order to demonstrate that the design of the equipment, whether it is field proven or not, will satisfy all specified requirements and will perform satisfactorily in service, and that all Units and Systems have been completed in accordance with the specifications prior to delivery.

A global comprehensive test program, covering the whole range from component and Unit integrity testing through functional and performance verification of all Units and Systems, shall be implemented and detailed. The test program shall be structured in such a manner that field installation and commissioning operations are simulated. The programme shall as a minimum include the following types of tests:

- Unit Factory Acceptance Test (FAT)
- System FAT, Extended Factory Acceptance Test (EFAT)
- System Tests
- Integration Tests (IT)
- Shallow Water
- Deep water Test (if applicable)
- Full scale test

All the results from all the qualification, inspection and acceptance tests for individual components as well as the complete systems shall be supported and controlled by the CONTRACTOR's Quality assurance plan, maintained as part of its records and presented to COMPANY.

Testing shall be carried out by the flowlines, risers and export lines manufacturer at all stages of manufacture to ensure the finished products are fit for purpose.

The benefit of specific shallow water tests or deepwater test (if applicable) should be assessed for unproven subsea installation techniques and procedures, or for techniques which cannot be fully tested in air (e.g. acoustic based, buoyancy elements, ROV held tools ….). CONTRACTOR shall document need or non need for shallow water testing or deepwater test activities.

The number of System FAT/EFAT, System Tests and Integration Tests is to be defined in conjunction with delivery contractual schedule.

CONTRACTOR shall develop and implement a complete and comprehensive plan to state test type applied to each component /subsystem /system. This plan must follow the complete review performed to identified equipment “to be qualified “(refer to section 4) and should be established in the same document.

The tests shall be performed by use of the appropriate test facilities and test media required to demonstrate all functions and performance of the system, including interfaces to other equipment.

All equipment shall be tested for the current operation during field life.

The test program shall include the necessary system interface and stack-up tests to verify all the internal and external interfaces involved in the overall subsea system. All tool interfaces shall be tested by use of the appropriate tool.

The procedures shall reflect all the functional and performance requirements specified for the different Systems and Units. The tests shall be performed with the relevant equipment and medium such as the correct hydraulic fluid, metal to metal seals etc.

Care shall be taken to ensure that the testing does not cause deterioration or wear of the equipment, at the point of delivery of the Units. Actual design life (number of cycles) shall not be reduced due to extensive operation of the System during fabrication and testing.

Repeated stroking of valves to achieve sealing capability is not permitted. In the case where a valve does not seal during a test, the test shall be recorded as a failure, with identification of the reason for failure, and the corrective action required.

Test and acceptance shall take into consideration SPS interfacing CONTRACTOR witnessing / assistance and respectively UFL CONTRACTOR shall define and witness or assist to some of the SPS CONTRACTOR tests.

6.2 Test Facilities

For all type of tests, CONTRACTOR shall provide all equipment, power supply, consumable, lifting devices and facilities.

COMPANY shall have access to CONTRACTOR' s premises during test.

CONTRACTOR shall provide to COMPANY in each test site three fully equipped lockable offices and PC and access to telefax, E mail and photocopying machines unless other COMPANY agreement.

6.3 Unit Factory Acceptance Test (FAT)

A factory acceptance test (FAT) of a Unit is the set of tests required to prove that the components of a Unit and the Unit itself, satisfy all specified functional and performance requirements. All factory acceptance tests for Units shall be performed in accordance with the requirements defined in relevant specifications.

The Unit FAT shall be performed for each manufactured Unit.

Unit FAT shall be performed at the Unit manufacturing site.

6.4 System FAT/Extended Factory Acceptance Test (EFAT)

A System FAT or Extended FAT shall include interface, pressure and functional tests of all Units within a System to prove that the System will perform satisfactorily in service and meet all specified system and detailed requirements.

CONTRACTOR shall prepare relevant procedures and undertake a comprehensive system FAT programme at the fabrication site to demonstrate that the materials, subsystems or complete assembly at each level of testing meets or exceeds the specified requirements. All assemblies shall be mechanically complete prior to start of system FAT.

Single Unit FAT shall be performed on all components and assemblies produced to demonstrate that manufacture is according to shop drawings and manufacturing specifications. The same set of tests shall be repeated for each assembly produced.

The EFAT program shall demonstrate and document that the specified requirements are met with respect to:

- Functional and operational capabilities.
- Interface configuration.
- Operational envelopes
- Interfaces between Units and loose items
- Pressure integrity
- Fluid and system cleanliness
- Thermal performance
- Mechanical resistance due to the dynamic fluid instabilities
- ROV access where applicable

EFAT shall be applied, as a minimum, to following parts:

-
- IPB / PIP connection , if applicable
- Connexion and cover of intermediate connection on flexible risers.

6.5 System Test

The System Test shall verify and demonstrate the capability of the Systems to be installed, operated, inspected and repaired during field life.

The System Test shall verify equipment installation and operation by simulating actual conditions and by following the operational procedures.

All equipment shall have undergone FAT and System FAT/EFAT prior to System Testing.

The detailed System Test Program and test procedures shall be established and agreed with COMPANY in due time before start of testing.

Integration tests shall be performed before the beginning of the installation campaign to check that the different elements fit together according to plan.

CONTRACTOR shall, upon COMPANY's request perform the modifications and corrections of the Units in order to close out findings and punch list items from the System Test. The revised design shall be approved by COMPANY prior to implementation. All modifications and corrections shall be documented and registered.

The system test programme shall as a minimum comprise the following main activities:

- Inspection of equipment received on site
- Equipment hook-up

- Photo and video recording of testing
- Pressure test of connections
- Verification of all override functions
- FAT of valves at valve supplier site
- Operation of valves after installation in the piping system
- Function testing of hydraulic operated equipment
- Barrier verification of isolation valves
- Pigging (pushing by water)
- Locking mechanisms
- Operation of hatches and protection covers

As a minimum, the following parts shall be covered by System Test **:** Spools connections to Manifold / FLET, injection jumpers connections to Xmas tree/ tee , production jumpers connections to Manifold/ Xmas tree.

- Spool / jumper / connection tool / lifting trigging assembly
- Particular insulation system deployment
- Deployment of manifold/ FLET
- Deployment of spool / jumpers
- Deployment of baskets
-
-
-
-
- FPSO risers I-tubes guiding systems connection
- Hang off systems / pull-in system.
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- Connection taken into account relevant deformation (twisting) of the structures from uneven seabedconditions
- Pigging launcher/ receiver recovery and installation
- Thermal insulation system of connector

Tie-in tests requirements are detailed in specification ''Underwater Diverless tie systems engineering and operation'' ref. AO32-4-013-000-LA-00-SE-001.

6.6 Integration Tests

The objective of the Integration Tests (IT) is to verify all external interfaces between Systems and units supplied by CONTRACTOR and systems supplied by other CONTRACTORs, such as interfaces with, manifold, X MAS tree, FPSO hull.

Some Integration tests shall be performed at other CONTRACTOR premises. Refer to specification “Interfaces Identification and Battery Limits” ref. AO32-1-017-000-00-00-SJ-001.

The Integration Test programme shall : verify:

- The ROV accessibility check , using a dummy ROV and all relevant tools
- The interface between riser (IPB) termination head and FLET
- The interface between flow line termination head and production spool
- The interface between production spool and manifold
- The interface between flow line tee and jumper
- The interface between jumper and Xmas-tree
- The interface between jumper and manifold
-
-
- The interface between dog house and relevant connections.
- Any other activity to ensure proper fit, function and integrity between the flowline / riser system and external interfaces (equipment and services) as required

Conditions , operations such as pull-in and connection of flowline with actual stiffness and back tension, ROV functions using a full scale model to demonstrate accessibility to all worksites , capability to observe indicator positions and also camera zooming functions shall be simulated.

CONTRACTOR shall organise photo and video recording of testing activities.

Integration tests shall be performed before the beginning of the installation campaign to check that the different elements fit together according to plan.

These integration tests could be performed together with the shallow or deep water tests (if applicable).

In addition to the test listed above, Contractor shall perform Site integration test according to Contractor document n° 310011736 “ Dalia testing and acceptance “ in the latest revision and appendix n° 3 (Site integration test summary sheet)

6.7 Full scale test

A full scale test of the riser / flowline system especially for thermal characteristic verification, spool and connection system is required. CONTRACTOR shall propose for COMPANY review all necessary full scale test.

Full scale test shall also forecast the thermal performance verification tests of the subsea system once assembled in order to prove that the component assemblies of the subsystem satisfy all specified thermal requirements.

As a minimum, CONTRACTOR shall perform a full scale test to verify thermal performance for each part of flowline and riser subsystem

- Current section of riser .and flowline

- spool
- connector, dog house
- flowline section/ connector/ spool section
- riser section/ connector/ flowline section
- other singular point

CONTRACTOR shall submit to COMPANY a detailed program of test. This shall include criteria of acceptance.

6.8 Shallow /Deep Water Tests

The objective of the shallow water test or deep water test (if applicable) is to:

- Verify design
- Verify operability of ROV tool and specific tool
- Verify the actual ROV access capability and readability of equipment markings by ROV
- Verify Full operability of connecting tools: each tool shall be able to perform a full connection /disconnection operation.
- Verify the efficiency of buoyancy elements and check that subsea equipment is properly balanced
- Test, validate and optimise the offshore installation procedures
- Familiarise offshore personnel with handling of equipment to promote efficiency and safety in installation and operation of subsea system
- Verify ROV free access and fly around and above the subsea structures
- Verify vessel adequacy

CONTRACTOR shall organise photo and video recording of the shallow water test activities.

The shallow water tests shall be organised in facilities reproducing the subsea environment. Upon request, UFL Contractor will have a one week free access to SPS facilities , after SPS SWT, to perform UFL SWT.

Shallow programs shall include as a minimum:

- Deployment of spool and connection between Flet/ manifold and production spool
- The connection between riser (IPB) end termination and flow line Flet
- The Flet overboarding operation
- The taut wire or acoustic metrology of a spool and / or jumper
- The removal and recovery of temporary pig receiver
- Subsea pigging unit (if applicable)
- Acoustic shackles tests (if applicable)

- Demonstrate accessibility to worksite suitability and functionality of the ROV , for all installation tasks

- Test back up system such as manual overrides
- Verify lifting operation (in air and in water)
-
- ROV tools and instrumentation test
-
- Rigging assembly:

  levelling of package, Rigging disconnection/connection

  by ROV (shackle operated by ROV,…)

In addition to the test listed above, Contractor shall perform Shallow water test according to Contractor document n° 347911736 " UFL shallow water test program for Dalia " in the latest revision and appendix n° 4 (shallow water test summary sheets).

- Tie-in (refer to "Underwater diverless tie systems engineering and operation'' ref. AO32-4-013-000-LA-00-SE-001)
- SPS tie-in test (Refer to specification " Interfaces Identification and Battery Limits" AO32-1-017-000-00-00-SJ-001)

Deep water test shall include) as a minimum:

-

- Specific test of lifting equipment / winch including active heave compensation system
- Acoustic metrology system (if applicable)
- Test required for an acceptance of vessel ((Refer to specification " Acceptance of an offshore construction vessel" ref. AO32-4-013-800-00-00-SE-001)

6.9 Thermal test after installation

The objective of this test is to verify the thermal performance of each loop, each part of the system in particular, riser bottom, spools, connectors, current section will be tested in all conditions: flowing, warm up and cool down.

CONTRACTOR shall establish and submit to COMPANY for approval a detailed test procedure concerning all parts of the loop even item installed by others (manifold headers for example). This Test procedure shall be done in close collaboration with Company start Up Team.

This procedure shall clearly indicate the acceptance criteria.

Test procedure shall be based on existing installation devices on FPSO and SPS system. Additional devices (if needed) shall be studied, procured, installed and operated by Contractor.

Tests will be performed by Company Start Up Team.

Contractor shall nominate a representative to witness all the tests.

This test is an acceptance test

7 HANDLING, STORAGE, TRANSPORTATION

7.1 General Requirements

This section defines general requirements for handling, storage and transportation of Systems and Units. The following general requirements apply:

- All Units shall be provided with the necessary bumper bars and/or transportation skids/boxes/frames and protective covers required for safe handling and transportation onshore and offshore
- All Units shall be provided with lifting points and attachment points with the necessary equipment to lift and secure Units during land and sea transportation, transfer between offshore vessels and onboard handling and storage
- Lifting devices for all Units shall be provided. This shall include but not be limited to lifting subs, spreader bar arrangement, etc., all suitable for lifting in onshore and offshore conditions, both in air and submerged as required
- Lifting points, load bearing structures and associated lifting devices shall be designed and certified in accordance with the appropriate industry standards
- All Units subjected to sea transportation shall have designated facilities (pad eyes or similar) for sea fastening, clearly marked with "Sea Fastening Only". All other equipment or modules which are not suitable for transportation in baskets or containers, shall be furnished with facilities for sea fastening as appropriate
- All components which are handled and/or deployed as individual Units shall be balanced, both in air and submerged to provide safe lifting and handling conditions
- Skids shall be furnished with fork lift pockets in accordance with lifting rules
- Minor equipment (above 20 kg) shall be furnished with dedicated lift points for maintenance purposes, such as threaded eye bolts or safe sling attachment points as appropriate
- Rotating lifting points such as threaded lift caps, swivels etc. shall not be used on Units with weight above 50 kg. Welded pad eyes are required where possible
- Test skids shall have fully grated bases for safe operation offshore

Specifications Load out and Sea-fastening of Petroleum Objects for Sea Transportation SG.STR.009.P and Sea transportation for Petroleum Structure SG.STR.00 10.P shall be appliedContractor shall establish for all item storage and preservation condition and maximum duration of storage

7.2 Design and Certification Requirements

Unless otherwise agreed, all assemblies shall be lifted in the workshop, from shore to vessel, between vessels or platforms or into the sea with use of one of the following methods in combination with a wire sling arrangement and/or purpose built spread to ensure a stable lift

- Unit with purpose built integrated frame (such as pad eyes on the Unit)
- Purpose built lifting and transportation frame/box/container
- Standard Basket
- Standard Container

Prior to any design, fabrication, testing or documentation of any type of equipment to be lifted and appliances to be used during the lift, it is CONTRACTOR's responsibility to clearly define the intended use, frequency and lifting conditions for such equipment and identify applicable rules and regulations.

Before any lifting can take place, a certificate of compliance and Certificate for usage shall be issued.

8 INSTALLATION

8.1 Installation engineering

8.1.1 General

Engineering shall be performed for all the different phases of the installation campaign, including load out, transportation, mobilisation, survey, installation, connection and testing activities, and interface works, in order to achieve operational efficiency and an adequate level of safety during offshore work.

The installation of the riser, flowline and export lines system on the DALIA field shall be documented by a complete study, including but not limited to the following:

- Construction vessel description and certificates
- Load out, Seafastening and transportation Manual
- Handling/lifting equipment certificates
- Vessel Mobilisation/Demobilisation Manual
- Towing manual (if any) including contingency manual
- Calculation notes for laying, towing, upending, lifting operations, as applicable
- Field layout
- Riser clashing studies
- Detailed installation procedures, including contingency procedures.

- Installation planning including aleas/risks
- Risk Analysis Studies, HAZID, HAZOP
- Field repair procedures – IMR recommendations
- Authority Consents and Licences Register
- Check lists
- Control Plans
- Marine Management Manual.
- Emergency Response Procedure
- Bridging document.

These documents will be submitted to COMPANY for approval. Some of them will be transmitted to COMPANY warranty surveyor for approval.

Supporting documentation, calculations, drawings, sketches and other back-up information shall be incorporated in the above documents.

The clashing studies should cover all intermediate configurations happening during installation, and until all risers are connected to the FPSO, which are not covered by the operational configuration clashing study.

8.1.2 Pre-engineering Survey

Soil information provided by COMPANY (soil data, ref. A032-1-010-000-00-00-GC-002) shall be verified by performance of a pre-engineering geotechnical and geophysical survey as per Contract preliminary scope of work. This survey shall be performed according to COMPANY Specification ‘’Offshore Geotechnical Soil Survey‘’ ref. SG.SUR.020.P and “Geophysical Site Survey Prior to Installing Offshore Structures “ ref. SG.SUR.010.P. The location of the survey, tests and samplings shall be adjusted to CONTRACTOR field layout. It shall cover as a minimum the corridors of the flowlines and umbilicals, the FPSO/buoy anchors location and underwater structure locations (manifolds….). Accurate bathymetry, seabed slope measurements… shall be performed at location of underwater structures installation.

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8.1.2.1 Laying Analysis (

For flowline laid in J-lay or reeled, the laying analysis shall include:

- Top and bottom of catenary tension calculation for normal laying and in case of emergency (wet buckle…)

- Flowlines stresses during laying/abandonment operations and in case of emergency
- Minimum acceptable bending radius for reeling operations
- Minimum, optimum and maximum catenary
- Laying tensioner parameters and configuration (laying tower angle, tensioner pads design, clamping force …)

For catenary riser, the riser configuration during transfer from the construction vessel to the FPSO shall be checked against the line installation minimum bending radius.

For flexible lines, the configuration during reeling operations shall also be checked against the line installation minimum bending radius.

8.1.2.2 Preparatory Works

In case of towing, the following works shall be performed during the engineering

- Survey of the coastal area off the construction yard
- Towing route /launching areas environmental analysis
- Sea water density data collection on different locations (wet storage area, along the route, near the cost, DALIA field)

8.1.2.3 Testing

Refer to COMPANY document “Flowlines, Risers, Export Lines and Umbilicals Testing Requirements” ref. AO32-4-013-000-00-00-QV-001. A testing manual shall be developed by CONTRACTOR, based on the requirements as defined in this specification.

8.1.3 Mobilisation Manual

Mobilisation manual shall contain as a minimum, the following:

- Organisations, Responsibilities and Communications
- Scope of Work to be performed
- Overall Execution Plan for the activity
- Deck lay out
- Equipment list
- Mobilisation schedule
- Seafastening calculations

- Lift analysis
- Check lists
- Control Plans
- Equipment calibration and testing certificates
- Positioning check
- Contingency procedures, covering scenarios resulting from any parameter variation or equipment failure.
- Activity Risk Assessment
- Sketches and drawings

One mobilisation manual shall be developed for each main mobilisation. For intermediate mobilisations, a quick descriptions of the tasks to perform, with reference to the main mobilisation manual, shall be enough. All the lifts shall be analysed independently.

8.1.4 Installation Procedures

Installation procedures shall contain, but not be limited to, the following information:

- General Project Information
- Scope of Work to be performed
- Overall Execution Plan for the activity
- Schedule
- Responsibilities and Organisation
- Lines of Communications
- Limiting weather criteria for each step
- Lists of equipment, with spare levels
- List of permanent works
- Check lists
- Control Plan
- Field lay out with positions of equipment to install
- Equipment calibration and testing certificates
- Back up equipment list for critical equipment (vessel, ROVs,…).

- Contingency procedures, covering scenarios resulting from any parameter variation or equipment failure.
- Survey procedure
- Field repair procedure
- Detailed activity and method plan
- Activity Risk Assessment
- Sketches and drawings
- Pertinent design criteria and specifications
- Testing procedure

One procedure shall be developed for each line to be installed.

Specific procedures shall be developed for specific steps, where justified by complexity of criticality (e.g. connection, external leak test, …).

Contingency procedures shall include as a minimum, the following, as applicable:

- Response to increase of weather
- Wet buckle
- Dry buckle
- Coating repair
- Pipe repair
- Abandonment/recovery Procedure
- Construction vessel loss of position
- Interruption / re-start of the towing (if applicable), considering the worst soil conditions found en route
- Emergency stop of towing (if applicable)
- Tug failure.
- Recovery/repair of broken towing rigging (if applicable)
- Flooding of an air can, a riser line (if applicable)
- Instrumentation failure during towing/upending operations (if applicable)
- Mechanical damage
- Poor visibility

8.1.5 Controlling Documents

8.1.5.1 Check Lists

Check lists shall be developed as a way to control the initiation of the main steps of the installation campaign. As a minimum, independent check lists shall be developed for the following steps:

Equipment Hand over from SUBCONTRACTOR or from another COMPANY or CONTRACTOR

- Load out
- Mobilisation
- Towing / Transportation
- Survey prior to installation
- Installation
- Connection
- Survey
- Testing

The check lists shall contain as a minimum the following:

- Procedure approved
- Safe Job Analysis performed
- Operational people familiarisation performed
- Communication checked
- Weather conditions checked
- Installation rigging and equipment
- Seafastening
- Lifting rigging and equipment
- Positioning and survey equipment
- Instrumentation equipment
- Hand over certificates
- COMPANY/warranty Surveyor approval

8.1.5.2 Control Plans

Control Plans shall be developed, based on the detailed procedures and manuals, to control the operations, from mobilisation to demobilisation. They shall be developed according to model in appendix 1. Each step shall be signed off by the CONTRACTOR, the COMPANY and the Warranty Surveyor Representatives (if required). Any data produced during the installation operation shall be noted or referenced on the Control Plan.

8.2 Installation operations

8.2.1 General

8.2.1.1 Safety

Refer to document ref. AO32-1-010-000-00-00-QH-001 “HSE Plan”.

Communications onboard vessels and between vessels shall be by UHF or VHF using dedicated channels.

A safety meeting will take place once a week onboard the vessels involved in the operation.

A weekly safety report will be produced by CONTRACTOR Installation Manager. The form of this report will be submitted to COMPANY before starting the operations.

A pre-job safety meeting will be organised before each critical operation and especially heavy lifting operations if any.

All transponder frequencies to be used by each vessel entering the field will be submitted to COMPANY for approval.

8.2.1.2 Vessel Acceptance

Any vessel working on the DALIA Field shall be accepted by COMPANY. Please refer to COMPANY Specification “Acceptance of an Offshore Construction Vessel” ref. AO32-4-013-800-00-SE-001

8.2.1.3 Positioning

Refer to COMPANY specifications ‘’ Offshore Surface Positioning Works’’ ref. SG.SUR.020.P and “ Subsea Positioning Works” ref. SG.SUR.021.P

Surface primary positioning system shall be dual frequency DGPS. A back-up positioning system different from DGPS shall be provided

Underwater positioning will be done using a LBL array that will have been deployed by CONTRACTOR. Refer to COMPANY project specification “ Engineering/ Procurement/ Installation of a Permanent Frame Array for Acoustic Positioning” ref. AO32-4-013-000-ME-00-SW-001.

8.2.1.4 Communications

Lines of communication onboard a vessel shall be identified and described in the operational procedure.

Communication between vessels shall be described in the bridging document. Regular communications shall be organised to ensure a good co-ordination amongst the vessels.

8.2.1.5 Weather Forecast

A weather forecasting, approved by COMPANY, shall be supplied for the entire duration of the installation operation. Weather forecasts shall be received every 12 hours onshore in LUANDA and on main vessels, and provide a detailed forecast for the following 24 hours, and a three day lookout. Additional weather reports shall be provided on a as needed basis in case of an unexpected event not notified in the latest report.

An installation step will start only if the weather conditions and weather forecast are in compliance with the installation step defined limiting criteria, and thus for the whole duration of the installation step.

For installation purpose, A DATAWELL buoy including telemetry equipment, monitors on main vessels, data storage……shall be procured, installed and used by CONTRACTOR to update and improve reliability of weather forecasts.

A spare DATAWELL buoy will also be provided by CONTRACTOR for storage in LUANDA.

8.2.1.6 On Board Facilities for COMPANY Representatives

CONTRACTOR shall provide on board the installation vessel, accommodation, catering, safety equipment, medical and office facilities as defined in specification AO32-4-013-000-00-0-SG-001 “Acceptance of an offshore Construction Vessel”.

All such facilities shall be provided from time of COMPANY approval of the mobilisation of the relevant vessel until the completion of the offshore WORKS.

8.2.1.7 Reporting

A daily progress report shall be sent to the COMPANY every day from start of mobilisation till end of demobilisation.

A field report shall be issued at the end of the operations, including as a minimum all main data on the as-left status of the risers, flowlines, export lines and non-conformances or discrepancies, if any.

An operation report shall be transmitted to COMPANY, no later than one month after the end of the operations, including but not limited to the following information:

- Introduction
- Operational summary
- HSE report
- Major events

- Survey Report
- Daily reports including weather forecasts and actual weather measured on site during operations
- Signed off Check Lists
- Signed off Control plans
- Video tapes of installation main steps
- Flowline alignment sheets
- Testing certificates

8.2.2 Mobilisation

A mobilisation notification schedule shall be agreed between COMPANY and CONTRACTOR.

Mobilisation shall include a familiarisation of all offshore personnel to the project specifics.

The mobilisation shall follow a mobilisation plan.

8.2.3 Load Out and Seafastening

Load out and seafastening of the pipe lines and equipment shall be done according to COMPANY specification ''Load out and Sea-fastening of Petroleum Objects for Sea Transportation'' ref. SG.STR.009.P

8.2.4 Access to Site

Access to GIRASSOL-DALIA site will be given to clearly identified vessels involved in operation. These operations will be covered by procedures, which will have been previously reviewed and approved by COMPANY.

The task of any vessel on the site will be performed according to the approved procedures. If any change occurs in the procedure, the vessel will be allowed to access the site after COMPANY approval of the work change.

Access to site by vessels and equipment shall be authorised beforehand by COMPANY. Authorisation shall be requested 72 hours before arrival on site.

Drilling units and other vessels could be operating on the field. In that respect access to site for new coming vessel is subject to interfaces analysis and risk assessments, all priorities will be decided by COMPANY, the program of operations will be amended after consulting the involved parties.

For DP vessels, transponder frequencies shall be transmitted to COMPANY sufficient time in advance for approval in order to avoid interference with other vessel's system.

8.2.5 Survey

All surveys shall be performed according to the COMPANY specification Ref. SG.SUR.011.P " Subsea Line Installation Surveys".

Underwater positioning shall use the LBL array frames deployed on the field to position transponders on the seabed.

8.2.5.1 Pre Installation Survey

A pre installation survey shall be performed prior to starting pipe line installation operation. Its purpose is to verify:

1. The presence of obstacle or debris or dropped objects on or near the laying corridor
2. The position of subsea structures already installed in the vicinity of the laying corridor.

It shall consist of a ROV/side scan sonar survey. It shall cover all the laying corridors identified in CONTRACTOR layout, including riser bases area.

Targets on or near the corridor shall be investigated visually.

The position of already installed structures shall be measured and compared with the as-installed position for discrepancy. In particular, if the FPSO mooring system has already been installed and the mooring lines pre-deployed on the bottom , it shall be surveyed.

8.2.5.2 Interim Survey

During laying of the pipe, the position of its touch down point shall be continuously monitored by ROV and recorded onboard. On-line monitoring of the position shall ensure that the pipe is laid within tolerance inside the laying corridor.

8.2.5.3 As laid Survey

In addition to the data mentioned in SG.SUR.011.P, the as laid survey shall incorporate positioning of other subsea structures relatively to the pipe. Any free span/ crossing shall be measured for analysis .

8.2.5.4 Final Survey

Final survey will take place at the end of the installation campaign, after completion of the installation, connection and pressure test/leak test of the pipe line surveyed. It shall include position recording and video recording, including connectors, spools, hubs, etc, ...

For straight pipes sections without singular points (tees, FLET…), upon prior agreement with Company, interim survey can replace final survey insofar as no subsea structure has been installed in the vicinity of this straight section in the meantime.

This survey shall also show that no installation aid, debris or dropped object are left in the water.

8.2.6 Flowline Installation

Installation of flowlines shall be done according to COMPANY Specification ref. SG.CNL.006.P ''Construction of Subsea Steel Pipelines'' where applicable.

Project specification "Subsea Structure Installation Specification" ref. AO32-4-013-000-00-00-SE-001 shall apply for the installation of foundation/sled/gravity base etc… if any.

The extremities of the flowlines shall be positioned with precision in order to minimise the size of the connecting spools. Typically, these spools should be of a size allowing installation in one lift.

Because of soft soil conditions, extremities of flowlines (FLET) /tees where connections will be performed shall be equipped with supporting sleds. This also apply to extremities of water/ gas injection lines where connections could be performed in the future.

In case of crossing between lines (and with umbilicals), these crossing locations shall be prepared in order to maintain a 20cm gap minimum between the two pipes (or umbilical).

Any free span identified during the as-laid survey and found to be unacceptable shall be corrected.

All subsea connection shall be done according to COMPANY specification "Underwater Diverless Tie-in Systems Engineering and Operation" ref. AO32-4-013-000-LA-00-SE-001.

8.2.6.1 J-Lay and Reeled Rigid Installation)

The touch down point of the flowline shall be continuously monitored by ROV.

The installation corridor shall be +/-15m from design route

On injection lines, the tolerances on the Tee pieces positions are:

Tee position: +/- 5m laterally

+/-5m longitudinally

On production lines, the tolerances on the FLET positions are:

FLET position: +/- 5m laterally

+/-5m longitudinally

Maximum allowed tee-piece angle with vertical shall be function of tie-in method / type of connector selected.

8.2.7 Riser Installation

Riser installation sequences shall be developed to optimise potential clashing problem with production / service umbilical during installation.

Project specification “Subsea Structure Installation Specification” ref. AO32-4-013-000-00-00-SE-001 shall apply for the installation of foundation, if any.

8.2.8 Export Lines Installation

A sequence of installation shall be developed to optimise the problems of clashing between export lines during installation.

Diving works during this installation shall be according to COMPANY Specification ref. GS STR 461 ‘’ General Diving Specification’’ and Project specification AO32-4-013-800-00-00-SE-001 “Acceptance of an offshore Construction Vessel”. Diving will NOT be allowed from the FPSO / buoy or from a Vessel moored to the FPSO or the buoy.

Equipment, installation aids and personnel required onboard the FPSO for the operation of pulling and hang-off of export lines shall be provided by CONTRACTOR. FPSO crane will NOT be available for assistance.

8.2.9 Testing

During and at completion of the installation campaign, the lines shall be filled with inhibited fluid, gauged, pressure/leak tested and left in the status required by field operations. This shall be done according to the testing manual following the requirements of specification ref. AO32-4-013-000-00-00-QV-001 ” Flowlines, Risers, Export Lines and Umbilicals Testing Requirements ”.

CONTRACTOR shall provide onboard the FPSO as a base case all the equipment (Compressor, generator etc..) required for supporting all above testing operations.

9 APPENDIX

Appendix 1 Control Plan Model

CONTROL PLAN

Date: Control Plan reference: Warranty surveyor :

Vessel: COMPANY Representative :

Operation: CONTRACTOR Superintendent :

Weather: Wave: Wind: Current :

Step #	Step Description	Responsible person	Reference Document	Produced Document	Acceptance Criteria	Signature						Time	Comments, Data, Documents
						Superintendent		COMPANY Rep		Warranty Survey.			
						Action	Signature	Action	Signature	Action	Signature		

Note Status: H(old), R(eview), M(onitor), W(itness

Appendix 2

Qualification test list and summary sheet

Qualification Tests list

N°	Prod	Test	Objective	Status
1	IPB	Full scale bending and pulling tests on end fitting	Verify integrity of the whole structure at the end-fitting interface under bending, and then under maximum operating tension	Base case
2	IPB	Full scale crushing test	Verify the integrity of the S-Z bundle under installation operation: crushing and tension	Base case
3	IPB	Full scale fatigue test	Verify the long term integrity of the IPB under dynamic loading	Option
4	IPB	Full scale thermal test on a hand made sample	Measure the overall thermal performances of a hand made IPB in a vertical set-up (U-Value, cool down time, electrical heating) in order to validate design tools	Base case
5	IPB	Full scale thermal test on a manufactured sample	Confirm the overall thermal performances of a manufactured IPB in a vertical set-up (U-Value, cool down time, electrical heating) with respect to the predicted values	Base case
6	IPB	Cool down test on bottom end-fitting	Verify the cool down time of the bottom insulated end-fitting	Base case
7	IPB	mechanical & fatigue test of electrical cables	Confirm the mechanical and fatigue performances of the IPB heating electrical cables	Base case
8	IPB	Carazite qualification	Material qualification program at high operating temperature	Base case
9	IPB	End cap effect	Deep water test	Option
10	Gas Inj.	Full scale fatigue test	Confirm the fatigue performance of the riser under pressure and dynamic loading: combined tension and bending cycles	Option
11	Gas inj	End cap effect	Deep water test	Option
12	WI	Full scale fatigue test	Confirm the fatigue performance of the riser under pressure and dynamic loading: combined tension and bending cycles	Option
13	WI	End cap effect	Deep water test	Option
14	PiP	Reeling test	Check the reel ability of the insulation layer	Base case
15	PiP	Thermal test	Measure the U-Value and the Cool Down Time Evaluate the impact of the centraliser on the overall thermal performance	Base case
16	PIP	Areogel material	Ageing test	Base case

TEST SUMMARY SHEET N° 1

IPB/End fitting full scale bending & pull-in test

Title	IPB Dalia – Full scale bending & pulling test
Location	Coflexip – Le Trait
Purpose	• Verify behaviour of IPB components anchoring into the end-fitting when submitted to bending and tension • Pulling test with pressure to check end-fitting design up to failure, within the limits of existing test bench.
Objectives	• Verify structure integrity under bending & pulling • Verify the good bundle crimping within the end fitting while bending • Test crimping and anchoring of layers within the end-fitting under tension • Pulling load until end-fitting failure (if possible). Will take place after the test N°2: Crushing Test, which will be carried out with the same test sample.
Test duration	3 weeks
Project equipment required	Around 10 m long IPB core structure from specific manufacturing. Bundle is hand made. End fittings
Support & Test Equipment	Pulling bench Instrumentation (load, deformation sensors) Rig test / sample adaptation pieces
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 2

IPB full scale crushing test

Title	**IPB Dalia – Full scale crushing test**
Location	Coflexip – Le Trait
Purpose	• Verify good behaviour of IPB under laying tension and tensioner crushing loads
Objectives	• Verify structure integrity under crushing & pull-in • Verify that no slippage will occur under crushing pads • Test crimping of layers within the end-fitting under tension load. (Torsion loading is considered negligible because $\theta < \pm 0.03°/m$). Torsion due to load application will be measured
Test duration	1 week
Project equipment required	Same sample from Test 1 will be used on the same test bench. It will be carried out before the final pulling test under pressure, which could lead to sample failure.
Support & Test Equipment	Pull-in bench Instrumentation (load, slippage, deformation sensors) Rig test / sample adaptation pieces
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 3:

Full scale IPB fatigue test

Title	**IPB Dalia – Full scale IPB fatigue test**
Location	Coflexip – Le Trait
Purpose	• Verify integrity of IPB after a service life time when submitted to bending loading, tension, pressure and temperature loading.
Objectives	• Verify structure integrity of the structure in the stiffener area after a service life time (Pressure test acceptance criteria) • Verify integrity of sample layers through dissection • Possibility to perform a test extension (until sample damage) • Test will include heating and pressure cycling
Test duration	4 month itself + test preparation
Project equipment required	Around 10 m long IPB core structure from specific manufacturing. Bundle is hand made. 2 welds will be located on the armour layer. No weld on the Zeta dynamic section. Test end fittings
Support & Test Equipment	Fatigue test rig Instrumentation (load, pressure, temperature sensors) Rig test / sample adaptation pieces
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 4

Full scale thermal test with hand made IPB sample

Title	**IPB Dalia – Full scale thermal test with hand made IPB sample**
Location	Coflexip – Le Trait
Purpose	• Thermal characterization of the IPB
Objectives	• Verify thermal performances of the anticipated design of IPB under 3 different tests conditions : flowing conditions (internal heating), cooldown and electrical heating conditions with dry and wet armour annulus • Validation/control of modelisation 2D and 3D ~~To allow to finalize the design following interpretation of the results. 3D interpretation where possible~~. • Validate free flooding mechanism inside insulated annulus • Verify gas lift expansion&behaviour
Test duration	3 weeks
Procedure summary	IPB sample vertical inside a caisson and equipped with simplified end fittings. Measurements : internal temperatures in layers, external temperature and electrical power by means of thermocouples and fibre optic. Insulation annulus has to be flooded. Monitoring of flooding during sample installation into the caisson. Core structure annulus has to remain dry for first test serial and wet for second test serial Water in caisson will be regulated
Project equipment required	IPB core sample from specific manufacturing. Bundle is hand made. Simplified thermal tests end fittings
Support & Test Equipment	Thermal vertical test bench (water tank) Electrical power generator Instrumentation equipment (fiber optic, Thermocouples, Electrical voltage and amperage recorder) External water regulation system
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test report

TEST SUMMARY SHEET N° 5

Full scale thermal test with final product IPB sample

Title	**IPB Dalia – Full scale thermal test with final product IPB sample**
Location	Coflexip – Le Trait
Purpose	• Thermal characterization of the IPB
Objectives	• Verify the as built thermal performances of the IPB under 3 different tests conditions : flowing conditions, cool down and electrical heating conditions with dry and wet armour annulus • Control free flooding mechanism inside insulated annulus • Verify Gas Lift tubes expansion & behaviour
Test duration	3 weeks
Procedure summary	IPB sample vertical and equipped with simplified end fittings. Measurements : internal temperatures in layers, external temperature and electrical power by means of thermocouples and fiber optic. Insulation annulus has to be flooded. Monitoring of flooding during sample installation into the caisson. Core structure annulus has to remain dry for first test serial and wet for second test serial Water in caisson will be regulated
Project equipment required	Around 15 m of the final product IPB Simplified thermal tests end fittings
Support & Test Equipment	Thermal vertical test bench (water tank) Electrical power generator Instrumentation equipment (Fiber optic, Thermocouples, Electrical voltage and amperage recorder) External water regulation system
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test report

TEST SUMMARY SHEET N° 6

Cool Down Time of IPB Bottom End-Fitting

Title	**IPB Dalia – Cool Down Time of IPB Bottom End-Fitting**
Location	Coflexip – Le Trait
Purpose	• Thermal test set-up to simulate a real shut down after a steady operating conditions at the most critical place for the riser, i.e. at the subsea intermediate connection.
Objectives	• Measure the real cool down time performance of the insulated bottom end-fitting, ~~where the injection of the gas lift takes place~~.
Test duration	3 weeks
Procedure summary	Full scale bottom end fitting with length of IPB for one side and PIP on other side on water tank Water tank will be regulated
Project equipment required	Bottom end-fitting fully insulated with 5 m of IPB sample in one side, and 5 m of PIP ~~dummy insulated connector assembly~~ on the other side. .
Support & Test Equipment	Specific horizontal tank set up + flange of adaptation. Measurement means Heating means External water regulation system
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 7 :

IPB electrical cables: mechanical & fatigue test

Title	**IPB Dalia – Electrical cables mechanical & fatigue test**
Location	Coflexip – Le Trait
Purpose	• Reliability of electrical cables in project conditions
Objectives	• Verify mechanical and electrical performance • Verify aging property of material • Verify fatigue performance
Test duration	4 month itself + test preparation
Procedure	For fatigue Submit electrical cables to heating and fatigue conditions and verify their behaviour: electrical, mechanical performance and aging performance of thermoplastic.
Project equipment required	Contractor shall define project equipment required
Support & Test Equipment	Contractor shall provide all test equipment
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 8:

Thermal Insulation Profile

Title	IPB Dalia – MO-03 test
Location	Coflexip – Le Trait
Purpose	The purpose is to realise a full qualification program test as described bellow
Objectives	The objective is to qualify in following area the thermal insulation profil.
Test duration	Total test duration 1 year, but with intermediate results.
Project equipment required	Three MO-03 material samples.
Procedure Summary	See below
Personnel Requirements	CSO test engineer
Deliverables	Test procedure Qualification report

THERMAL TEST	**Comments**
Thermal conductivity	Measurements to be done on the proposed product at several temperatures above and under the Tg of the matrix PP. Sensitivity study on the impact of intact microspheres on the thermal conductivity shall be done
Specific heat	Measurements to be done on the proposed product at several temperatures above and under the Tg of the matrix PP.
Thermal test in pressure	To be done in several condition and especially at high temperatures with water absorption
Coefficient of linear thermal expansion	Measurements to be done if necessary for design
Coefficient of thermal expansion in volume	Measurements to be done if necessary for design
Thermal stability	
MECHANICAL TEST	**Comments**
Density	To be measured
DMA	To be done
Bulk modulus	To be defined
Tensile test	To be done f at several temperatures above and under the Tg of the matrix PP.
Compression test	To be done at crushing condition
Creep test	To be done measure of absorption
FABRICATION	**Comments**
Manufacture	To be done at full scale.
AGEING TEST	**Comments**
Ageing	the test is to verify material properties integrity versus time, when exposed to high temperature (90°C) Ageing study will be conducted at 3 accelerated ageing temperatures on samples immersed in water. Water uptake versus time will be determined at various thicknesses until saturation of the material, so as to be able to predict water absorption in service conditions. -Thermal conductivity versus water content will be determined -Mechanical and chemical properties on saturated material will be checked to verify material integrity

TEST SUMMARY SHEET N° 9:

Deep Water Test for IPB

Title	Deep Water Test for IPB (DIP test)
Location	Offshore site with 1350 m minimum water depth with clear water at sea bed
Purpose	The purpose of the offshore test is to simulate the bending cycle experienced by the riser (core structure) at touch down point in 1350 m water depth.
Objectives	The objective is to verify that the armour layers are capable to resist to lateral buckling and to reverse end-cap effect in the following conditions: - riser empty - 2 x 4 hours cycle bending of the riser at its minimum operating radius - riser annulus dry (exclusively) It may be also possible to resume the test until buckling of the armour occurs. This will allow to determine the minimum acceptable operating bend radius.
Test duration	½ day test sample preparation 1 day of offshore test. The test may be combined with other deep tests for the GI and WI risers;
Project equipment required	The test sample is 60/90 m long and is equipped with end-fittings. Only the core pipe structure is considered. IPB (base case) is considered to operate with dry annulus.
Support & Test Equipment	DP vessel is required to run the test. Sufficient desk space is required to store the pipe sample ROV with 1350 m capability equipped with shortbase transponder, gyroscope, and sonar. Numerical video to monitor the curvature of the pipe at touch down point
Personnel Requirements	TO test engineers Offshore vessel personal
Deliverables	Test procedure Progress reports Data log Photos Test and inspection reports

TEST SUMMARY SHEET N° 10 :

Full scale Gas Injection fatigue test

Title	**IPB Dalia – Full scale Gas Injection fatigue test**
Location	Coflexip – Le Trait
Purpose	• Verify integrity of GI after a service life time
Objectives	• Verify structure integrity of the structure in the stiffener area after a service life time (Pressure test acceptance criteria) when submitted to bending cycling with internal pressure and axial tension. • Verify integrity of sample layers through dissection • Possibility to perform a test extension (until sample damage)
Test duration	4 month itself + test preparation
Project equipment required	Around 10 m long flexible pipe sample from specific manufacturing. Test end fittings
Support & Test Equipment	Fatigue test rig Instrumentation (load, pressure, temperature sensors) Rig test / sample adaptation pieces
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 11:

Deep Water Test for GAS INJECTION Riser

Title	Deep Water Test for Gas Injection riser (DIP test)
Location	Offshore site with 1350 m minimum water depth with clear water at sea bed
Purpose	The purpose of the offshore test is to simulate the bending cycle experienced by the riser at touch down point in 1350 m water depth.
Objectives	The objective is to verify that the armour layers are capable to resist to lateral buckling and to reverse end-cap effect in the following conditions: - riser empty - 2 x 4 hours cycle bending of the riser at its minimum operating radius - riser annulus wet (exclusively) It may be also possible to resume the test until buckling of the armour occurs. This will allow to determine the minimum acceptable operating bend radius.
Test duration	½ day of test preparation 1 day of offshore test. The test may be combined with IPB Deep Test and possibly with the WI Deep test too.
Project equipment required	The test sample is 60/90 m long corresponds to the bottom section of the riser and is equipped with end-fittings.
Support & Test Equipment	DP vessel is required to run the test. Sufficient desk space is required to store the pipe sample ROV with 1350 m capability equipped with shortbase transponder, gyroscope, and sonar. Numerical video to monitor the curvature of the pipe at touch down point
Personnel Requirements	TO test engineers Offshore vessel personal
Deliverables	Test procedure Progress reports Data log Photos Test and inspection reports

TEST SUMMARY SHEET N° 12 :

Full scale Water Injection fatigue test

Title	**IPB Dalia – Full scale Water Injection fatigue test**
Location	Coflexip – Le Trait
Purpose	• Verify integrity of WI after a service life time
Objectives	• Verify structure integrity of the structure in the stiffener area after a service life time (Pressure test acceptance criteria) when submitted to bending cycling with internal pressure and axial tension. • Verify integrity of sample layers through dissection • Possibility to perform a test extension (until sample damage)
Test duration	4 month itself + test preparation
Project equipment required	Around 10 m long flexible pipe sample from specific manufacturing. Test end fittings
Support & Test Equipment	Fatigue test rig Instrumentation (load, pressure, temperature sensors) Rig test / sample adaptation pieces
Personnel Requirements	CSO test engineer CSO test operators (workers + instrumentation) CSO test designer (test implementation and end fittings drawings)
Deliverables	Test procedure Progress reports Data log Photos Test and dissection reports

TEST SUMMARY SHEET N° 13:

Deep Water Test for WATER INJECTION Riser

Title	Deep Water Test for Water Injection riser (DIP test)
Location	Offshore site with 1350 m mimimum water depth with clear water at sea bed
Purpose	The purpose of the offshore test is to simulate the bending cycle experienced by the riser at touch down point in 1350 m water depth.
Objectives	The objective is to verify that the armour layers are capable to resist to lateral buckling and to reverse end-cap effect in the following conditions: - riser pressurised with 80 bar (to simulate the riser always partially full) - 2 x 4 hours cycle bending of the riser at its minimum operating radius - riser annulus dry and wet. It may be also possible to resume the test until buckling of the armour occurs. This will allow to determine the minimum acceptable operating bend radius.
Test duration	½ day for test sample preparation 1 day of offshore test. Vessel “mob” and “demob” not included The test may be combined with IPB Deep Test and possibly with the GI Deep test too.
Project equipment required	The test sample is 60/90 m long. It corresponds to the bottom section of the riser and is equipped with end-fittings.
Support & Test Equipment	DP vessel is required to run the test. ROV with 1350 m capability equipped with shortbase transponder, gyroscope, sonar, and manipulator arm to remove the “T” plug on the end-fitting to allow flooding of the riser annulus. Numerical video to monitor the curvature of the pipe at touch down point
Personnel Requirements	TO test engineers Offshore vessel personal
Deliverables	Test procedure Progress reports Data log Photos Test and inspection reports

TEST SUMMARY SHEET N° 14:

PiP Reeling Trial

Title	PiP Dalia – PiP Reeling Trial
Location	Heriot Watt University – UK
Purpose	The purpose of this test is to carry out two complete bending cycles in order to simulate the reeling and un-reeling operation on the DeepBlue. One cycle consists of bending the test pipe onto the reel former and then onto the straightening former. For the proposed PIP, the radius of the reel former will be the radius of the sheave aligner (10.75m). Test should be done at 9.75 m (deep blue radius)
Objectives	Verify the good behaviour of the Aerogel foam layer wrapped around the flowline within the PiP annulus and check it has not seen major compression. Another objective of this test is to make sure that we don't have any slippage or damage of the centralizers, and also to ensure that the centralizers pitch is well defined
Test duration	1 week
Project equipment required	The test sample is roughly 12m long.
Support & Test Equipment	To simulate this loading (reeling and unreeling) a trial will be performed using the bending rig facility at Heriot Watt University, Scotland.
Personnel Requirements	CSO test engineer Herriot Watt personnel
Deliverables	Test procedure Progress reports Data log Photos Test and inspection reports

TEST SUMMARY SHEET N° 15:

PiP Thermal Test

Title	**PiP Dalia – PiP Thermal Test**
Location	Heriot Watt University – UK
Purpose	To run a thermal test which requires two phases of measurements. Firstly, the heat transfer through the insulation material alone is determined to establish if there has been material damage during reeling. The second test is to assess the actual U-value through the combination of insulation and centralizers.
Objectives	To assess the U-value and the cool down time of the proposed PiP using Aerogel insulated foam To validate calculation model
Procedure summary	The sample is a piece of the previous one (received from bending trial test) and has the length of approximately 12 m. The U-value is measured for the full scale PIP system and compared with the calculation and the project requirement. After stabilization of the temperature profile and measurement of the U-value, a shut-down of the heating core is done and the cool down time of the PIP system is measured. External water temperature shall be regulated
Test duration	3 weeks
Project equipment required	The test sample is roughly 12 m long (to be adjusted with detailed procedure).
Support & Test Equipment	Specific set-up tanks filled with water. Temperature water regulation system
Personnel Requirements	CSO test engineers Herriot Watt personnel
Deliverables	Test procedure Progress reports Data log Photos Test and inspection reports

TEST SUMMARY SHEET N° 16:

Aerogel Spaceloft Ageing Test

Title	Aerogel Spaceloft Ageing Test
Location	Aspen Aerogels Inc.
Purpose of the Test	The purpose is to perform a aging test on insulation material
Objectives	The objective is to demonstrate the long term insulating performance of aerogel exposed to high temperature.
Procedure summary	The purpose of this test is to expose aerogel blanket samples to temperatures in the range 160 °C to 170 °C for a period of 8 weeks (may be adjusted)to represent the field life of the system. The weight and thermal conductivity of the samples will be measured at the beginning of the test. The same measurements will be carried out at regular time intervals during the testing period in order to define the level of integrity of the test piece. These measurements will be carried out at the end of the 8 weeks period. A comparison of the weight and thermal conductivity of the sample pre and post testing will demonstrate the integrity of the aerogel spaceloft material after long time exposure to high temperature
Test duration	8 weeks
Project equipment required	One square Spaceloft Aerogel
Support & Test Equipment	The samples will be placed in a oven at temperatures in the range 160 °C to 170 °C. The thermal conductivity will be measured at regular time intervals using a Fox 200 instrument, capable of measuring the conductivity of flat samples in accordance to ASTM C518x and ISO 8301 standards.
Personnel Requirements	Test Carried out at Aspen Aerogels Inc.
Deliverables	Progress reports Data log Photos Test and inspection reports

Appendix 3

Site integration test summary sheet

TEST SUMMARY SHEET 01

PRODUCTION FLOWLINE Well Jumper / Tree / Manifold Tests

Title	**Production Flowline Well Jumper/ Subsea Tree/ Manifold Integration**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 01** **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify interfaces among Production Well Jumpers, Subsea Tree, and Manifold
Objectives	• Demonstrate measurement for a Well Jumper with taut wire or Acoustic systems • Confirm accessibility for ROV and taut wire measuring equipment • Accumulate experience fabricating a jumper with Kvaerner connection system • Demonstrate landing a jumper between the Subsea Tree and Manifold • Confirm clearance among Manifold, Subsea Tree, and Well Jumper • Confirm access for any Control Tooling at Subsea Tree and Manifold with Well Jumper in place • Confirm pressure integrity of installed Well Jumper • Obtain video record for training purposes
Procedure Summary	• Measure for Well Jumper with taut wire and Acoustic systems • Place fabrication jigs • Fabricate jumper • Pressure test the jumper and connectors • Remove jumper from jigs • Install Well Jumper at maximum misalignment / offset • Assess ROV access to critical points on Manifold, Subsea Tree, and Well Jumper • Assess clearance and impact on ROV accessibility to critical points • Place any Control Tooling and assess clearance and impact on ROV accessibility to critical points • Remove Well Jumper
Test Duration	7 days
Project Equipment Required	• Subsea Tree (1) • 12” Kvaerner Multibore Clamp Connectors (2), Kvaerner Tooling and Insulated Multibore Pipe Bundle • Tilted Manifold (1) • 12” Kvaerner Multibore Gaskets • Taut wire and Acoustic Systems • Spares
Support & Test Equipment	• Crane • Cherry Picker • Scaffolding or Man Lift • Pressure Test Equipment

	• Mock ROV • ROV Tools and Hot Stab • Inclinometer • Jumper fabrication / test stands • Spreader bar and rigging • Test HPU • Interconnect Hoses

Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Team including Project ROV Superintendent, Project Tie-in Tool Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Rigging Crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST SUMMARY SHEET 02

WATER INJECTION Flowline Jumper / IN-LINE TEE / FLET Tests

Title	**Water Injection Flowline Jumper / Subsea Tree / In-line Tee/Flet Integration**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 02** **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify interfaces among Water Injection Flowline Jumpers, In-line Tee, Subsea Tree and Water Injection FLET
Objectives	• Demonstrate measurement for a Flowline Jumper with taut wire and Acoustic systems • Confirm accessibility for ROV and taut wire measuring equipment • Accumulate experience fabricating a Water Injection Flowline Jumper with Kvaerner connection system • Demonstrate landing a jumper between a subsea Tree, In-line Tee and Jumper • Confirm clearance among Subsea Tree and In-line Tee • Confirm access for any Control Tooling at Subsea Tree. Tee with Water Injection Flowline Jumper in place • Confirm pressure integrity of Flowline Jumper • Obtain video record for training purposes
Procedure Summary	• Measure for Flowline Jumper with taut wire and Acoustic systems • Place fabrication jigs and fabricate jumper • Pressure test the jumper and connectors • Remove jumper from jigs • Install Flowline Jumper at maximum misalignment / offset • Assess ROV access to critical points on Subsea Tree, In-line Tee and Flowline Jumper • Remove Well Jumper
Test Duration	5 days
Project Equipment Required	• Subsea Tree • Water Injection In-line Tee • Flowline Jumper complete with (2) 6” Kvaerner clamp connectors, Kvaerner tools and Insulation • Flowline Jumper Rigging • Taut Wire and Acoustic systems
Support & Test Equipment	• Crane • Cherry Picker • Man Lift or Scaffolding • Pressure Test Equipment • Mock ROV • ROV Tools and Hot Stab • Inclinometer

	• Jumper fabrication / tests stands • Spreader bar and rigging • Test HPU • Interconnect Hoses

Personnel Requirements	• Crane Operator & Riggers (2) • CSO Installation Engineer • CSO Project ROV Superintendent • CSO RSU Team including Project Tie-in Tool Superintendent, Senior ROV Operators, Senior Tie-in Tools Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST SUMMARY SHEET 03

GAS INJECTION Flowline Jumper / IN-LINE TEE Tests

Title	**Gas Injection Flowline Jumper / Subsea Tree / In-line Tee**
Location	**Angola**
Test	Dalia SIT Workscope Test 03 **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify interfaces among Gas Injection Flowline Jumper, In-line Tee, Subsea Tree, and Tee Piece
Objectives	• Demonstrate measurement for a Flowline Jumper with taut wire and Acoustic systems • Confirm accessibility for ROV and taut wire measuring equipment • Accumulate experience fabricating a Gas Injection Flowline Jumper • Demonstrate landing a jumper between the Subsea Tree and In-line Tee and Gas Injection • Confirm clearance among Subsea Tree, In-line Tee and Well Jumper • Confirm access for any Control Tooling at Subsea Tree, Tee with Gas Injection Flowline Jumper in place • Confirm pressure integrity of installed Flowline Jumper • Obtain video record for training purposes
Procedure Summary	• Measure for Flowline Jumper with taut wire and Acoustic systems • Place fabrication jigs • Fabricate jumper • Pressure test the jumper and connectors • Remove jumper from jigs • Install Flowline Jumper • Assess ROV access to critical points on Kvaerner tools, Subsea Tree, Tee Piece and Flowline Jumper • Remove Well Jumper
Test Duration	5 days
Project Equipment Required	• Subsea Tree • Gas Injection In-Line Tee • Flowline Jumper complete with (2) 6” Kvaerner clamp connectors & Kvaerner tools • Flowline Jumper Rigging • Taut wire and Acoustic systems
Support & Test Equipment	• Crane • Cherry Picker • Scaffolding or Man Lift • Pressure Test Equipment • Mock ROV • ROV Tools and Hot Stab • Inclinometer

	• Jumper fabrication / test stands • Spreader bar and rigging • Test HPU • Interconnect Hoses

Personnel Requirements	• Service Equipment Operators • CSO Installation Engineer • CSO Project RSU Team including Project ROV Superintendent, Project Tie-in Tool Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Crane Operator and Riggers • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST SUMMARY SHEET 04

PRODUCTION (SPOOL) / MANIFOLD TESTS

Title	**Production Flowline Jumper (Spool) / Manifold Integration**
Location	**Angola**
Test	**Dalia SIT Workscope Test 4**
Purpose	• Verify interfaces among Spool, FLET and Manifold
Objectives	• Demonstrate measurement for a spool with taut wire or Acoustic systems • Confirm accessibility for ROV and taut wire measuring equipment • Accumulate experience fabricating a spool with Kvaerner connection system • Demonstrate landing a spool between the FLET and Manifold • Confirm clearance among FLET, Manifold and spool • Confirm access for any Control Tooling at Manifold with spool in place • Confirm pressure integrity of installed spool • Obtain video record for training purposes
Procedure Summary	• Measure for spool with taut wire or Acoustic systems • Place fabrication jigs • Fabricate spool • Pressure test the spool and connectors • Remove spool from jigs • Install spool • Assess ROV access to critical points on Manifold, FLET and spool • Assess clearance and impact on ROV accessibility to critical points • Remove spool
Test Duration	7 days
Project Equipment Required	• FLET (1) • Spool Connectors (2), Kvaerner Tools and Insulated Pipe • Tilted Manifold • Kvaerner 6” Gaskets • Taut wire or Acoustic Systems • Spares
Support & Test Equipment	• Crane • Cherry Picker • Scaffolding or Man Lift • Pressure Test Equipment • ROV Tools and Hot Stab • Inclinometer • Spool fabrication / test stands • Spreader bar and rigging • Test HPU • Interconnect Hoses

Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Team including Project ROV Superintendent, Project Tie-in Tool Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Crane Operator and Rigging crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log (weight CG) • Video / Photo Record

TEST Summary Sheet 5

Pig / Manifold / Jumper System Tests

Title	**Pig / Manifold / Jumper System Tests**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 5**
Purpose	To determine that the manifold is suitable for pigging operations via pig loop.
Objectives	• Pass each type of pig through the manifold in each direction • Verify functionality of pig detector
Procedure Summary	• Pig from FPSO side at manifold through the manifold and pigging loop and back through the manifold again • Repeat for each type of pig • Repeat in each direction
Test Duration	2 days
Project Equipment Required	• Manifold • Pigging Loop Jumper
Support & Test Equipment	• Pig Launcher / Receiver / Pigs • Pumping Equipment • Scaffolding • Crane • Inclinometer
Personnel Requirements	• CSO Installation Engineer • Pump Operators • Crane Operator and Rigging crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST SUMMARY Sheet 6

ROV / Jumper / Manifold / Tree System Tests

Title	**ROV / Integration Test**
Location	**Angola and SPS Construction Site**
Test	**Dalia SIT and SPS SWT Workscope** **Test 6**
Purpose	• Verify interfaces among ROV, Well Jumpers & Flowline Jumpers
Objectives	• Confirm ROV accessibility to critical points on the FLETs • Confirm ROV accessibility to critical points on the Manifolds • Confirm ROV accessibility to critical points on the Subsea Tree • Confirm ROV accessibility to critical points on the Flowline Jumper • Confirm ROV accessibility to critical points on the Well Jumper • Confirm functionality and accessibility for any other relevant ROV tools/ intervention (debris cap removal; jumper rigging release). • ROV access and tool functionality for Seal Replacement • Verify placement for optional jumper guideline latch points
Procedure Summary	• Verify ROV access to critical points on FLETs and verify functionality of tooling • Verify ROV access to critical points on Manifolds and verify functionality of tooling • Verify ROV access to critical points on Subsea Trees and verify functionality of tooling • Verify ROV access to critical points on Kvaerner tools, Flowline Jumpers and verify functionality of tooling • Verify ROV access to critical points on Kvaerner tools, Well Jumper and verify functionality of tooling, including release of rigging • Raise Well Jumper and verify operability and functionality of seal replacement tooling and hub cleaning tools
Test Duration	5 days
Project Equipment Required	• Manifold • Subsea Tree • ROV Tools • Well Jumper • Flowline Jumper • Gaskets • Debris cap
Support & Test Equipment	• Crane • Mock ROV • HPU • Hub cleaning tools • Gasket change-out tool
Personnel Requirements	• CSO Installation Engineer • CSO Senior Tie-in Tool Operators • CSO Project RSU Team including Project ROV Superintendent • Kvaerner Engineering & Service Equipment Operators • Film / Video crew

Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 7

Jumper Misalignment / FLET Movement Tests

Title	**Jumper Misalignment Test**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 7**
Purpose	• Verify integrity of jumper when subjected to tree/manifold movement
Objectives	• Apply representative displacements to fabrication jigs while connected to a jumper • Confirm pressure integrity of jumper before, during, and after displacements are applied
Procedure Summary	• Place jigs to replicate relative position of subsea equipment • Apply displacement to jigs representing measurement and fabrication inaccuracies • Latch jumper to jigs • Fill jumper and pressure test • Apply displacements to jigs while applying pressure and monitor for leakage and damage. • Reduce displacements of jigs while applying pressure and monitor for leakage • Rig down from test
Test Duration	2 days
Project Equipment Required	• Well Jumper • Well Jumper Rigging • Crane • Flowline Jumper • Flowline Jumper Rigging • Jumper Fabrication Stands
Support & Test Equipment	• Test HPU • Interconnect Hoses • Load Indicator • Inclinometer
Personnel Requirements	• CSO Installation Engineer • Crane Operator and Riggers • Kvaerner Service Equipment Operators • CSO Project RSU Team including Project ROV Superintendent and ROV Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log (weight CG) • Video / Photo Record

TEST Summary Sheet 8

Flying Lead / UTA / Manifold / Tree System Test Procedure

Title	**Flying Lead Installation and Removal**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 8** **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify Interfaces Among Flying Leads, Manifold, Trees, SDU's, UTA's and composite jumpers
Objectives	• Confirm fit of Flying Leads at relevant SDU position • Confirm pressure integrity of Hydraulic Flying Lead and pressure integrity with UTA. • Confirm fit of Electrical Flying Leads at UTA and SDU positions • Confirm electrical integrity of Electrical Flying Leads and connection to UTA/SDU
Procedure Summary	• Fit Hydraulic Flying Leads to UTA and SDU • Fit Hydraulic Flying Leads to Subsea Trees • Fit Hydraulic Flying Lead to Manifolds • Pressure test connections to Hydraulic Flying Leads • Fit Electrical Flying Leads to UTA and SDU • Fit Electrical Flying Leads to Subsea Trees • Fit Electrical Flying Lead to Manifold • Electrical test of connections to Electrical Flying Leads
Test Duration	5 days
Project Equipment Required	• Manifold • Subsea Tree • UTA/SDU • Hydraulic and Electric Flying Leads • Mock ROV • FLIS • ROV Tools (FLOT)
Support & Test Equipment	• Test HPU • Umbilical Simulator • Interconnect Hoses and Wiring
Personnel Requirements	• Kvaerner Controls and Service Equipment Operators • CSO Installation Engineer • CSO Project RSU Team including Project ROV Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log (weight CG) • Video / Photo Record

TEST Summary Sheet 9

ROV / UTA/SDU / Manifold / Tree System Test Procedure

Title	**ROV / UTA System Test**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 9** **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify ROV Interfaces at UTA/SDU • Verify access to, and functionality of, all ROV interfaces on the Subsea Tree and Manifold
Objectives	• Confirm ROV accessibility to Hydraulic Flying Leads on the UTA/SDU & tree • Confirm ROV accessibility to Electrical Flying Leads on the UTA/SDU & tree • Confirm functionality and accessibility for any relevant ROV tools. Log pertinent operational information (torque values, number of turns, linear force, etc). • Verify functionality of each ROV tool at each applicable interface • Demonstrate appropriate visual access to critical points on the Subsea Tree
Procedure Summary	• Rig Mock ROV with Hydraulic Flying Lead tooling. • Remove and Replace Hydraulic Flying Leads • Rig Mock ROV with Electrical Flying Lead tooling. • Remove and Replace Electrical Flying Leads • Confirm ROV accessibility to and functionality of UTA/SDU installation aids • Perform ROV access tests with Mock ROV at all relevant Subsea Tree interface points. • Operate all relevant Subsea Tree valves with Mock ROV and override tools. Log pertinent operational information (torque values, number of turns, linear force, etc). • Verify pressure integrity of all relevant ROV Hot Stab Receptacles on Subsea Tree and operate related functions as applicable • Verify visual access to all significant points on the Subsea Tree • Verify placement and access to Transponder Receptacles
Test Duration	2 days
Project Equipment Required	• Manifold • Subsea Tree • UTA/SDU • Hydraulic Flying Leads • Electrical Flying Leads • Mock ROV • ROV Tools • FLIS
Support & Test Equipment	• Test HPU • Interconnect Hoses

Personnel Requirements	• Kvaerner Service Equipment Operators • CSO Installation Engineer • CSO RSU Team including Project ROV Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 10

ROV / Manifold / Tree System Test Procedure

Title	**Manifold ROV Operations**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 10** **Note: Part of the test described in this data sheet could be done by SPS Contractor during SPS SWT.**
Purpose	• Verify accessibility and operability of all ROV interfaces on Manifold Note: ROV operations associated with the Manifold / Suction Pile Top, Well Jumper, Flowline Jumpers, Hydraulic Flying Leads, and Electrical Flying Leads are addressed elsewhere.
Objectives	• Verify installability of Pigging Loop • Verify ROV access to all ROV / Manifold interface points • Verify operability of all ROV operable Kvaerner and Manifold functions • Verify pressure integrity of Pigging Loop ROV hot stab
Procedure Summary	• Perform ROV access tests with Mock ROV at all Manifold and Pigging Loop interface points • Operate all Manifold and Pigging Loop valves with Mock ROV and override tools. Log pertinent operational information (torque values, number of turns, linear force, etc) • Simulate recovery and replacement of Pigging Loop • Verify pressure integrity of ROV Hot Stab Receptacle on Pigging Loop • Verify visual access to all significant points on the Manifold and Pigging Loop
Test Duration	2 days
Project Equipment Required	• Manifold • ROV Tools • Well Jumper • Flowline Jumper
Support & Test Equipment	• Crane • Man Lift • Mock ROV • Surface HPU
Personnel Requirements	• Kvaerner Service Equipment Operators • Crane Operator and Rigging crew • CSO Installation Engineer • CSO RSU Team including Project ROV Superintendent, Senior ROV Operators, Senior Tie-in Tool Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 11

FLET INITIATION

Title	**FLET Initiation**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 11**
Purpose	• Simulate overboarding and initiation of FLETs
Objectives	• Verify deck handling and rigging is suitable for deployment • Verify weight of the structure • Verify any hinging mechanisms work correctly and do not clash with any other part of the structure • Confirm COG • Verify initiation wire release or cut mechanism • Obtain video record for training
Procedure Summary	• Lift FLET horizontally and measure weight (CG) • Lift FLET vertically • Function hinge mechanism if so fitted • Access any cutting equipment to be used
Test Duration	1 day
Project Equipment Required	• 1 FLET • Initiation rigging • ROV cutting equipment
Support & Test Equipment	• Crane • Man Lift • Inclinometer • HPU
Personnel Requirements	• CSO Installation Engineer • CSO RSU Team including Project ROV Superintendent, Senior ROV Operators • Crane Operator and Rigging crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 12

DOG HOUSE INTERFACE

Title	**Trial of Dog House Installation**
Location	**Angola**
Test	**Dalia SIT Workscope** **Test 12**
Purpose	• Determine proper fit of dog house on subsea connections
Objectives	• To determine interface of dog house on flowline / spool / connections • Obtain video record
Procedure Summary	• Fit dog house onto flanged assembly complete with insulation collars
Test Duration	1 day
Project Equipment Required	• (1) Flowline connector • (1) Spool connector • (1) Gasket • Bolts and hardware • Dog house assembly
Support & Test Equipment	• Cherry picker crane • Bolt tension equipment
Personnel Requirements	• CSO Installation Engineer • Rigging Crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 13

FPSO INTERFACE CHECKS / TOP SIDE

Title	**FPSO Interface Checks – Top Side**
Location	**FPSO Shipyard Facility**
Test	**Dalia SIT Workscope** **Test 13**
Purpose	• Confirm all FPSO interfaces at the topside location
Objectives	• Confirm pig launcher and receiver interface and access of FPSO risers • Confirm interface of hang-off assemblies with tops of I-tubes • Confirm interface of pull-in spreads and rigging routing • Obtain video record
Procedure Summary	• Fit pig launchers and receivers on top of risers & verify access for pigging hoses, etc. and interfaces • Install hang-off assemblies and end fittings on tops of I-tubes • Mark out winch bases and rigging routes and all other rigging ancillary equipment • Mark out pre-commissioning equipment and hose routings
Test Duration	1 day
Project Equipment Required	• Pig launchers and receivers • Hang-off assemblies and fasteners • End fitting or mock-up
Support & Test Equipment	• Cranes / Winches
Personnel Requirements	• CSO Installation Engineer • CSO Pre-Commissioning Contractor Representative • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 14

FPSO INTERFACE CHECKS / SUBSEA

Title	**FPSO Interface Checks / Subsea**
Location	**FPSO Shipyard Facility**
Test	**Dalia SIT Workscope** **Test 14**
Purpose	• Confirm all FPSO interfaces at the subsea location
Objectives	• Confirm the interfaces of pulling heads and rigging assemblies through the bottom of the I-tubes • Confirm the interfaces of the I-tube deflectors to the I-tubes • Confirm the interface of the riser bend stiffeners • Obtain video record
Procedure Summary	• Pull the pulling head sections complete with rigging aids through the I-tubes • Installation and removal of the I-tube deflectors on the I-tubes • Install and lock the riser bend stiffeners at the bottom of the I-tubes
Test Duration	2 days
Project Equipment Required	• Pulling heads with short section of riser attached • Pull-in rigging arrangement sections • I-tube deflector • Bend stiffeners
Support & Test Equipment	• Crane / Winches • Man Lift
Personnel Requirements	• CSO Installation Engineer • CSO Diving Subcontractor Representative • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log (weight CG) • Video / Photo Record

TEST SUMMARY SHEET 15
FPSO PULL-IN SYSTEM FUNCTIONAL AND LOAD TEST

Title	**FPSO pull-in system functional and load test**
Location	**FPSO Shipyard Facility**
Test	**Dalia SIT Workscope** **Test 15**
Purpose	• Confirm functionality and perform load test of pull-in system
Objectives	• Confirm pull-in winch and auxiliary equipment functionality • Confirm clearance between topside and pull-in system during translation. • Confirm alignment between I-tubes and pull-in system. • Load test pull-in system
Procedure Summary	• Function test the pull-in winch and auxiliary equipment. • Translate the pull-in skid along topside rails. • Position pull-in skid above I-tubes and verify pull-in rigging route. • Load test pull-in system.
Test Duration	1 day (to be performed in conjunction with Dalia SIT Worscope Test 18)
Project Equipment Required	• Pull-in rigging arrangement
Support & Test Equipment	• Load cell • Dead Weights or Pad eye
Personnel Requirements	• CSO Installation Engineer • Winch operators • Third party inspector • Pull-in System Subcontractor Representative • Riggers
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Load test certificate • Photo Record

TEST SUMMARY SHEET 16

PIP / IPB INSULATION COLLAR

Title	**PIP / IPB insulation collar installation test**
Location	**IPB Manufacturing Site**
Test	**Dalia SIT Workscope** **Test 16**
Purpose	• Confirm physical feasibility of insulation collar on IPB/PIP connection.
Objectives	• Determine interface between insulation collar and IPB/PIP connection • Obtain video record
Procedure Summary	• Fit insulation collar to flange connection
Test Duration	0.5 day
Project Equipment Required	• (2) Flange connectors / end fittings • (1) gasket • Bolts and hardware • Insulation collar
Support & Test Equipment	• Cherry picker crane • Bolt tension equipment
Personnel Requirements	• CSO Installation Engineer • Rigging Crew • Film / Video Crew
Deliverables	• Test procedure signed off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo record

TEST SUMMARY SHEET 17

I-TUBE BOTTOM GUIDES / BSF

Title	**I-tube bottom guides and BSF test**
Location	**BSF Manufacturing Site**
Test	**Dalia SIT Workscope** **Test 17**
Purpose	• Confirm physical interface between I-tube bottom guides and BSF.
Objectives	• Determine interface between BSF and I-tube bottom guides • Obtain video record
Procedure Summary	• Fit BSF to I-tube bottom guides
Test Duration	0.5 day
Project Equipment Required	• I-tube bottom guide • BSF • Bolts and hardware
Support & Test Equipment	• Cherry picker crane • Bolt tension equipment
Personnel Requirements	• CSO Installation Engineer • Rigging Crew • Film / Video Crew
Deliverables	• Test procedure signed off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo record

APPENDIX 4

Shallow water Test

summary sheets

TEST SUMMARY SHEET 01

Spool Integration between Manifold and FLET Test

Title	**Spool Integration between Manifold and FLET**
Location	**SPS SWT Facilities**
Test	**Dalia SWT Workscope** **Test 01**
Purpose	• Verify interfaces among spool, FLET and manifold.
Objectives	• Demonstrate landing a spool between FLET and manifold • Confirm clearance between spool, FLET and manifold • Confirm access for any control tooling at manifold with spool in place • Obtain video record for training purposes
Procedure Summary	• Install spool between FLET and manifold • Connect spool to manifold and FLET using tie-in tool and ROV
Test Duration	3 days
Project Equipment Required	• Mock-up FLET + PIP • ROV • Mock-up spool assembly
Support & Test Equipment	• Crane • Cherry picker • Tie-in tool, equipment and personnel • 2 off 12”connectors • 2 off outboard hubs with 2 m long welded PIP • One off insulated dog house
Personnel Requirements	• CSO Installation Engineer • Crane Operator and Rigger (2) • Service Equipment Operators • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log (weight CG) • Video / Photo Record

TEST SUMMARY SHEET 02

Temporary Pig Receiver Integration Test

Title	**Temporary Pig Receiver Integration Test**
Location	**SPS SWT facilities**
Test	**Dalia SWT Workscope** **Test 02**
Purpose	• Verify interfaces between temporary pig receiver and FLET
Objectives	• Test physical interface between ROV tie-in tool and FLET • Confirm interface between temporary pig receiver and FLET • Obtain video recording for training purposes
Procedure Summary	• Install / Recover temporary pig receiver on FLET using tie-in tool
Test Duration	0.5 day
Project Equipment Required	• ROV • Mock up FLET • Pig receiver • Tie-in tool • 12” connector • 12” inboard hub with 2m welded PIP and second end porch
Support & Test Equipment	• Crane
Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Superintendent • Senior ROV Operator • Rigging Crew • Support Equipment Operators and Helpers • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action list • Data log • Video / Photo Record

TEST Summary Sheet 03

Acoustic Shackle Test

Title	**Acoustic Shackle Test**
Location	**SPS SWT facilities**
Test	**Dalia SWT Workscope** **Test 03**
Purpose	• Verify fitting and usability of acoustic shackle for rigging
Objectives	• Confirm suitability of acoustic shackle in rigging set-up • Confirm operability of acoustic shackle in rigging set-up
Procedure Summary	• Rig and lower to manifold/pile to seabed using acoustic shackles in the rigging • Activate acoustic shackles and remove lift rigging
Test Duration	0.5 day
Project Equipment Required	• Manifold and or suction pile • ROV • Acoustic shackles • Lift rigging
Support & Test Equipment	• Crane
Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Superintendent • Senior ROV Operator • Rigging Crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 04

Acoustic Metrology

Title	**Acoustic Metrology**
Location	**SPS SWT facilities**
Test	**Dalia SWT Workscope** **Test 04**
Purpose	• Verify interface between ROV, acoustic metrology, FLET and manifold
Objectives	• Demonstrate measurement for a spool with acoustic metrology system • Confirm accessibility for ROV and acoustic metrology measuring equipment • Obtain video recording for training purposes
Procedure Summary	• Measure for spool with acoustic metrology system • Assess ROV access to critical points on manifold and FLET.
Test Duration	1 day
Project Equipment Required	• (1) 12” inboard hub • Production manifold • Acoustic metrology system • ROV
Support & Test Equipment	• None
Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Superintendent • Senior ROV Operator • Rigging Crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

TEST Summary Sheet 05

Taut Wire Metrology

Title	**Taut Wire Metrology**
Location	**Europe**
Test	**Dalia SWT Workscope** **Test 05**
Purpose	• Verify interface between ROV, taut wire metrology, FLET and manifold
Objectives	• Demonstrate measurement for a spool with taut wire metrology system • Confirm accessibility for ROV and taut wire metrology measuring equipment • Obtain video recording for training purposes
Procedure Summary	• Measure for spool with taut wire metrology system • Assess ROV access to critical points on manifold and FLET.
Test Duration	1 day
Project Equipment Required	• (1) 12” inboard hub • Production manifold • Taut wire metrology system • ROV
Support & Test Equipment	• None
Personnel Requirements	• CSO Installation Engineer • CSO Project RSU Superintendent • Senior ROV Operator • Rigging Crew • Film / Video crew
Deliverables	• Test procedure signed-off, step-by-step • Punch list • Non-conformance log / corrective action reports • Data log • Video / Photo Record

APPENDIX 5

TEMPERATURE MONITORING TEMPERATURE REQUIREMENTS

Summary

1. INTRODUCTION
2. TEMPERATURE MONITORING PHILOSOPHY
3. SCOPE OF WORK
4. SCOPE OF SUPPLY
5. REQUIREMENTS
6. QUALIFICATION
7. TESTING

1 INTRODUTION

1 1 Purpose

The purpose of this annex is to define the specific requirements for the engineering, procurement and installation of a permanent temperature monitoring system on DALIA's production risers, located in Angola, approximate location 7°40'N, 11°45'E (1400 m water depth). All requirements described in Specification Flow line Riser export line is applicable.

1.2 Objectives

The DTS shall be able to detect regions of lower thermal resistance, i.e. cold spot, along the bottom end of the riser to prevent against formation of hydrates and provide the ICSS with a real time complete temperature monitoring control. Both temperature and location of the measurement point shall be delivered.

1.3 Definitions and Abbreviations

FPSO Floating Production Storage and Offloading Unit

DTS Distributed temperature system

ICSS Integrated Control and Safety System

1.4 Reference Documents

According section 1.5 of

in addition

Company General Specifications

GS INS101 Instrumentation engineering, procurement and construction general requirements

2 TEMPERATURE MONITORING PHILOSOPHY

Monitoring temperature shall be performed by fiber optic

Sensors shall be installed along each production riser (8 off) to monitor the production fluid temperature.

The monitoring systems shall be fully redundant on each riser and possibly retrievable, i.e. they shall be installed in independent conduits in the case of fibre optic monitoring or shall use independent cables, for discreet monitoring.

Monitoring systems shall be pre-installed during the production riser manufacturing or after the FPSO hook-up.

The entire system shall be ready for use, i.e. calibrated, during the thermal test.

Where possible, an additional conduit shall be pre-installed in case of use of optical fibre to provide further back up solution when the main conduit is damaged

3 SCOPE OF WORK

The scope of work for the monitoring system shall comprise as a minimum:

Engineering of system including integration with the ICSS

Assistance to the UFL contractor for the pre-installation of the housing and banding to the outer sheath of the inner pipe

Calibration of the system during thermal tests

Replacement of the damaged sensors

4 SCOPE OF SUPPLY

The scope of supply for the temperature monitoring shall be as minimum:

Temperature sensors and termination device (where needed)

Adequate length of cable/fibre optic depending on the data medium

DTS and/or the control system associated with the data management (include the temperature display unit)

Tube, jumpers, housing, banding and more generally all items associated with the monitoring system

Light source (DTS processor)

Local PC for configuration control and data management

Local cabinet in Central Instrument Room

Installation, calibrating and on-site testing tools

Spare parts for commissioning and two years operation

Serial link to the ICSS (MODBUS)

Remote data management via a modem and the dedicated software is not part of this scope.

5 REQUIREMENTS

5.1 General

The monitoring system shall be based on fiber optic technology

Temperature monitoring shall be done on the outer surface of all 12" production riser, along the entire length, from the riser base up to the top . The 100m above seabed is the critical point. Special attention at this area shall be paid.

The measurement device shall be non-intrusive i.e. there will be no contact between the sensor and the production fluid.

For integrated solutions, where the replacement of the sensors will not be possible after manufacturing, intermediate connection shall be avoided in order to reduce the risk of failure.

The sensors shall be banded directly to the OD of the inner pipe

A sensitivity analysis shall be performed on all criteria that can affect the reliability of the entire system

systems shall be calibrated to determine internal temperature based on the heat transfer gradient.

Contractor shall demonstrate during the engineering phase that the insulation is sufficient to reach the requested accuracy of the measurements, whatever are the temperature conditions of the fluid and the environment all along the riser.

Contractor shall fully justify that the proposed system will keep its performances for the design life, whatever will be the movements and mechanical constraints applied to the riser. Special attention shall be paid to possible vibrations of the riser and influence on the conduits position versus riser outer surface and thermal insulation.

5.2 Design criteria

The design criteria are:

Design life: 20 year (*)

Accuracy: +/- 1°C

Resolution of the position of measurement: +/- 2m minimum

Minimum rate of data acquisition: Measurements shall be updated every minute

Capacity: Minimum 1 points of measurement every 20m (on horizontal & vertical sections)

Temperature range: 90 °C / -20°C

5.3 RAM analysis

RAM analyses shall be conducted on the entire monitoring system in order to demonstrate that the selected technical solution will meet the requirements in this specification.

RAM analyses shall performed in accordance with "DALIA Project Reliability Strategy" document number AO32-1-009-000-00-00-QH-006.

Specific attention shall be paid to system components that are non-retrievable. The RAM analyses shall demonstrate that such components are provided with sufficient redundancy in order to ensure that the monitoring system will fulfil its function over the field life time.

All failure and repair data used in the analyses shall be made available to COMPANY, and all data sources shall be clearly identified.

Results of this analysis shall be submitted to COMPANY for approval.

Since ageing of the fibre is a problem that is not clearly controlled, contractor shall include in its proposal contingencies to cater for premature failure of the system

5.4 installation constraint

In order to increase the maintainability of the system, replacement of monitoring sensors shall be made from the top of the riser

Where any part of the monitoring system is included in the annulus area of the riser, integrity i.e. watertighness is the key constraint. Impact of inclusion of such system inside the riser, and compatibility of gauges or fibre optic tubing with the annulus geometry shall be fully evaluated.

No modification of the production pipe dimension will be allowed for integration of the sensors.

Accidental flooding of any tubing and or connection used to house cables and or fibre optics shall not result in an annulus flooding.

Fibre optics shall be installed in one continuous length (single ended or double ended) without any intermediate joints, splices and connections, from the bottom to the top of the riser, that would affect the reliability of the system.

Independent jumpers or umbilicals shall be used (if needed) from the top of the production riser to the FPSO ICSS control room, in order to make the installation and the maintenance easier. Contractor shall define characteristics of the surface part of the system (cable/fibre, splices, connectors, housings, installation requirements) so that the system will be fully operational with the requested performances after installation.

Only oilfield approved materials shall be used.

A double ended configuration shall be done.

Engineering of the system shall be done in the mean time as the production riser itself, particularly at pipe joints and during detail engineering of the termination end of the production riser.

No modification on qualified equipment will be allowed for integration of the temperature monitoring. Qualification of production riser shall be done with all necessary tubing or housing already integrated to the system.

5.5 Monitoring & calibration

Since the sensors will be located on the outer surface of the production pipe (non intrusive), contractor shall take into account the inaccuracy of the measurement and correct it, based on a sensitivity analysis done on the fluid temperature, velocity and density parameters.

Where active heating of the riser is used, Contractor shall define the time between powering off the heating system, and reading of temperature of the inner fluid with the requested accuracy.

5.6 Banding & tube material

Banding material used to secure the sensor and or the tubing along the production riser shall be of stainless steel.

Contractor shall insure that material used will be protected against corrosion, and that bi-metallic corrosion will be avoided.

Conduit to be used shall be of hydraulic type. The same requirement applies to intermediate connections (if needed).

For steel tube components, a fatigue analysis shall be performed to evaluate the cumulated damage induced during the manufacturing, installation and service life of the production riser.

5.7 DTS and or Control system

The surface unit shall be redundant and have several functions:

Acquisition and processing of sensors information: Parameters acquired during the calibration process shall be used to compensate raw values obtained from the sensors. The surface unit shall transform raw values in engineering units and associate a validity check to each measurement.

Maintenance of the system: A dedicated engineering console shall be connected to the surface unit, giving a password protected access to calibration and processing parameters for reading and modification. This console shall allow direct acquisition, and presentation on a dedicated display, of all the data and presentation of raw values, engineering values and associated parameters. Use of the console shall not stop the data to the ICSS, and shall generate an additional information for the ICSS operator. A built-in test system shall generate alarms for any malfunctioning.

Management of the link to the ICSS: Contractor shall provide, from the surface unit to the ICSS, a dual redundant serial link. Selection of standard to be applied shall be made with the ICSS contractor and shall be within standard protocols defined by the Foxboro IA series controllers. In its selection, Contractor shall take into account the requested updating time for all the subsea data.

Data management: Only compensated data, in engineering values, shall be transmitted to the ICSS. The system shall send, for each riser, to the ICSS the 20 lower and 20 higher temperature points with the location. In addition to these values, the following information shall be made available to the ICSS:

Validation check of the data

Engineering console is in use for maintenance purposes

Failure of the measurement system (one per redundant sensor)

The surface unit shall include some data management capabilities:

Local storage of raw data, compensated data and engineering values for a period of time equal to or exceeding 15 days

Presentation of the stored values in tables, histograms and edition of trends

Alarm settings on measurements are not required in the surface units. They shall be set up at the ICSS level.

6 QUALIFICATION

The complete system shall be field-proven or shall withstand extensive qualification testing corresponding to functions/components that cannot be considered as field-proven. Contractor shall propose a qualification testing program for Company acceptance according to section 4 of the Flowline riser specification

7 TESTING

7.1 FAT

The complete sensor system, associated with the surface unit shall be fully tested in factory prior to being integrated with the riser. This preliminary test shall demonstrate the accuracy of the system without any compensation.

Complete FAT shall be made after integration to the riser. Contractor shall propose the FAT program for Company acceptance.

7.2 SIT and commissioning

A site integration test shall be made prior to installing the riser, equipped with the measurement system. This test shall demonstrate the full functionality of the system, connected to the surface unit.

After installation of the riser, the commissioning of the system shall involve every function including the interface and data transmission to the ICSS. Contractor shall propose the testing program for Company acceptance.

