



Exploration & Production

GENERAL SPECIFICATION

Drilling & Wells

GS EP FP 411

Subsea Horizontal Christmas Tree System

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1. Scope

This document defines the technical requirements for the design, manufacture, assembly and test of the a horizontal subsea Xmas Tree systems for both production and injection (gas and water) wells.

Equipment covered by this specification includes:

- Tubing hangers and running tools systems
- Subsea Xmas Tree, and running tools systems
- Test and handling tools
- Shipping skids, baskets and slings.

Items **not** included in this specification are:

- Wellheads
- IWOCS
- Downhole completion equipment
- Production control system
- Insert Chokes
- DHPT system.

The IWOCS requirements are defined in **GS EP FP 412** while the Wellhead System is described in **GS EP FP 410**.

Contractor shall identify and supply any other equipment, materials, facilities, etc deemed to be necessary or required to complete and/or ensure the satisfactory installation and operation of the subsea trees and associated installation and workover systems.

Contractor shall supply a comprehensive listing with quantities and proposed locations of use of all equipment, jigs fixtures etc. which are not part of the deliverables but which are deemed necessary to complete the fabrication and in-house testing activities.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

This technical specification is supplementary to document **GS EP SPS 001**, and shall be therefore read in conjunction with said document and other COMPANY specifications and standards identified therein. The relationship between the main COMPANY documents defining the requirements to the Subsea Stations is illustrated in **GS EP SPS 001**.

The subsea HXT system shall comply with all applicable industry standards listed in this document such as ISO, API and other referenced standards unless otherwise stated by Company.

If a discrepancy between standard and / or specifications, the more stringent shall apply, unless otherwise stated by Company.



Standards

Reference	Title
ISO 13628	Petroleum and Natural Gas Industries - Design and operation of subsea production systems - Part 1 - General requirements and recommendations - Part 4 - Subsea Wellhead and Tree Equipment - Part 8 - Remotely Operated Vehicle (ROV) - interface on subsea production systems
ISO 10423	Petroleum and Natural Gas Industries – Drilling and Production Equipment – Wellhead and Xmas Tree Equipment Second Edition
ISO 898-1	Part I - Bolts, screws and nuts
SAE AS 4059 E	Cleanliness classification of hydraulic fluids
NACE MR 0175 / ISO 15156	Material Requirements. Sulphide Stress Cracking. Resistant Metallic Material for Oil Field Equipment
ASME	Boiler and Pressure Vessel Code
ISO 9000	Quality Management Systems – Fundamentals and vocabulary
ISO 9001	Quality Management Systems – Requirements

Professional Documents

Reference	Title
API SPEC 6A	Specification for Wellhead and Xmas Tree Equipment
API SPEC 8C	Drilling and Production Hoisting Equipment
API SPEC 16A	Specification for Drill Through Equipment
API SPEC 16D	Control Systems for Drilling Well Control
API SPEC 17D	Specification for Subsea Wellhead and Xmas Tree Equipment
API SPEC 5 CT	Specification for Casing and Tubing
API RP 17H	ROV Interfaces with Subsea Equipment
API RP 16 Q	Design and Operation of Marine Drilling Riser System

**Regulations**

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS EP SPS 001	Design Philosophy and Requirements for Subsea Stations
GS EP SPS 007	Tie-In Systems
GS EP SPS 010	Preservation Requirements for Subsea Package
GS EP SPS 011	Mechanical Completion for Subsea stations
GS EP SPS 012	Documentation Requirements for Subsea Stations
GS EP SPS 015	Subsea Gate Valves and Actuators in Subsea Xmas Tree Systems
GS EP SPS 016	Subsea Insert Chokes and Associated Running and Retrieval Tools
GS EP SPS 019	Subsea Production Control System
GS EP SPS 022	Environmental testing of Subsea Electronics
GS EP SPS 023	Cleaning and Flushing of Hydraulic Systems
GS EP FP 410	Subsea Wellhead and Guidance Systems
GS EP FP 412	Workover Subsea Completion Systems for Horizontal tree



3. Introduction

3.1 Definitions

Further to definitions as listed in Company specification **GS EP SPS 001**, the following shall apply:

Company	Total E&P or their nominated representative(s)
Contractor	The Company contracted for the performance of the work
Surf Contractor	The Contractor in charge of the engineering, supply, construction, transportation, and installation of the Umbilicals, Flowlines and Risers
Well Jumper	Connection between Well and Manifold or ILT
Flying Lead	Recoverable assembly of Electrical cables, chemical and hydraulic piping in between 2 units
Manifold Module (MM)	Retrievable manifold including structure and Piping
Bottom structure (BS)	Frame on top of the suction anchor receiving the MM
Production Jumper/Spool	Connection between Manifold production header and flowline
Manifold Control Module (MCM)	Subsea Control Module (SCM) controlling the Manifold
Tree Control Module (SCM)	Subsea Control Module (SCM) located on the Tree
Permanent Guide Base (PGB)	Base structure on top of the well, for tree orientation and jumper support
Subsea Distribution Unit (SDU)	Subsea Distribution Units are the umbilical network distribution structures incorporating the HDU (Hydraulic Distribution Unit) and the EDU (Electrical Distribution Unit). There are four types of SDU i.e. UCM, UDM, UTP and UTI
Umbilical Distribution Module (UDM)	SDU distributing to two branches
Umbilical Termination Production (UTP)	SDU terminating a production umbilical branch
Umbilical Termination Injection (UTI)	SDU terminating an injection umbilical branch

3.2 Responsibility

It is the responsibility of anyone who supplies equipment to this specification to ensure and document compliance with the requirements defined by this specification, other relevant standards and statutory requirements. Any deviation from any of the requirements defined herein shall be clearly indicated and treated as a non-conformance.

3.3 Abbreviations

The following abbreviations are used in this specification:

AAV	Annulus Access Valve
AMV	Annulus Master Valve
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Non-destructive Testing
AWS	American Welding Society
AWV	Annulus Wing Valve
BOP	Blow Out Preventor
CI	Chemical Injection
CP	Conductor Pipe
CRA	Corrosion Resistant Alloy
DHPT	Down Hole Pressure and Temperature Gauge
EFAT	Extended Factory Acceptance Test
EFTS	Electrical Feed Through System
FAT	Factory Acceptance Test
FPSO	Floating Production Storage and Offloading Unit
GS	General Specification
HAZ	Heat Affected Zone
HP	High Pressure
HXT	Horizontal Xmas Tree
ID	Internal Diameter
ILT	Inline Tee
IMR	Inspection Maintenance and Repair
IRCD	Injection Rate Control Device
ISO	International Standard Organization
ITC	Internal Tree Cap
IWC	Intelligent Well Completion
IWOCS	Installation and Workover Control System
LP	Low Pressure
MCM	Manifold Control Module
MODU	Mobile Offshore Drilling Unit
MPFM	Multiphase Flow Meter



MPI	Magnetic Particle Inspection
MQC	Multi Quick Connection
MSV	Multifunction Service Vessel
MTBF	Mean Time Between Failure
MTHRT	Mechanical Tubing Hanger Recovery Tool
NACE	National Association of Corrosion Engineers
NDT	Non Destructive Testing
PMV	Production Master Valve
PGB	Permanent Guide Base
PSL	Product Specification Level
PTFE	PolyTetraFluoroEthylene
PCV	Production Choke Valve
PFD	Production Flow Diagram
PWV	Production Wing Valve
QA	Quality Assurance
QC	Quality Control
ROT	Remotely Operated Tool
ROV	Remotely Operated Vehicle
SAM	Subsea Accumulator Module
SCM	Subsea Control Module
SCSSCV	Surface Controlled Subsurface Safety Valve
SDU	Subsea Distribution Unit
SIT	System Integration Test
SLV	Service Line Valve
SRT	Site Receive Test
SURF	Subsea Umbilicals, Risers and Flowlines
TH	Tubing Hanger
THRT	Tubing Hanger Running Tool
TRT	Tree Running Tool
VX t	VX seal test
WH	Well Head
WP	Working Pressure
XT	Xmas tree



XMT Xmas Tree
XOV Cross Over Valve

3.4 Documents

Documents : ISO 898-1 , API SPEC 8C, API SPEC 16A, API SPEC 16D, API SPEC 5 CT, API RP 17H, API RP 16 Q are an integral part of this document.

4. System description

4.1 System overview

The Subsea Xmas Tree System comprises of a set of equipment which can be divided into two groups:

- Permanently Installed Equipment
- Workover/Completion Equipment

This specification covers the following permanently installed main sub systems with running tools and auxiliary equipment:

- Tubing Hanger System
- Horizontal Tree Assembly

5. Principal equipment (or product) requirements

5.1 Introduction

The following paragraphs define the principal equipment or product requirements for all units included within the Horizontal Tree (HXT) System. The general philosophies, functional, operational and technical requirements to the subsea station are defined in GS EP SPS 001.

5.2 Scope of the specification

This specification applies to the tubing hanger and HXT Equipment and directly associated tooling. For the Horizontal Tree, the specification does not cover the connector at the end of the flowpool which interfaces with either the template connector or the jumper connector. For this connection, reference is made to document GS EP SPS 007.

The Specification does not cover the Control pod. For this equipment, reference is made to the document GS EP SPS 019.

5.3 General Design Philosophies

5.3.1 General

The HXT System shall be designed to operate on the mudline under the specific field conditions and operating life. Requirements for control of the different valves in the HXT system during the workover/completion and production phases are given in Appendix (see PDF attached).

The basic design pressure for the HXT System is 690 bars (10000 psi). However, some hydraulic functions may require a hydraulic pressure greater than 690 bars. The components of



the units which can be in contact with such high pressures even in the event of a failure on the first sealing element shall be designed to withstand this pressure.

The tree shall provide a pressure containing conduit for the produced or injected fluid. The Xmas tree shall provide the ability to control and isolate the well pressure.

Vertical flow isolation and access shall be achieved by dual slick line retrievable crown plugs in the tubing hanger or in the TH and Internal Tree Cap (ITC). To be able to permanently benefit from the two sealing barriers elements this equipment shall be capable for providing the monitoring of the pressure in the cavity created by the two tubing hanger set isolation plugs.

The cavity in between the installed crown plugs shall be monitored for any pressure deviations during production mode.

All equipment shall be designed for safe and efficient handling and make up with the maximum operating conditions of the drilling rigs.

5.3.2 Horizontal Tree Barrier and Valve Configuration

The location of the HXT below the BOP induces the necessity for the tree to abide by a double barrier against any pressurized effluent between the well and the environment during all drilling, completion or work-over operations. This requirement adds itself to the double barrier philosophy always demanded for production phases and intervention operation. It has strong implications on many equipment specifications, such as the sealing ability of the tree bore protectors in front of the penetration, the use of an additional barrier (compared to the sole VX type gasket) on the tree lower connection, the doubling of the production and annulus tree valves. One shall refer to the detailed specification on the related items of equipment.

The subsea HXT System shall be configured in accordance with the dual barrier element philosophy, which implies there shall be two independent testable barriers between the produced fluids and the environment. A barrier element, in this context, is defined as a gate valve, needle valve or bore plug with metal to metal seals.

Well flow and annulus pressure are controlled by gate valves in the lateral bores. As a minimum, the production and annulus master valves and annulus access valve shall be integral with the HXT block.

Vertical flow isolation shall be achieved by use of dual wireline installed plugs. Two (2) options may be considered:

- Dual set plugs in the TH
- One plug in the TH one plug in the ITC.

For both plugs, the primary seals shall be metal to metal.

Both barrier elements shall have the facility to be tested bi-directionally. Additionally, a facility to test and monitor the pressure between the plugs from the work over and production control system shall be provided.

The design shall allow for communication from annulus to production. Communication shall be established downstream the production master valve and upstream the production wing valve.

All valves shall be capable of sealing with low pressure (100 psi) differentials and with marginal pressure gradients. For test requirements in general, reference is made to section 12 of this specification.



5.3.3 Subsea chokes

For some applications, the tree assembly shall incorporate a retrievable choke on the flow loop between the wing valve and the flow line connector. Detailed requirements for the choke and associated running/retrieval tool are described in [GS EP SPS 016](#).

5.3.4 Field Proven Equipment

Proven equipment with verifiable reliability records shall be utilized. Where proven equipment and components are not readily available, Contractor shall advise the status of current design development.

Contractor shall prepare a comprehensive list, for Company review and approval, defining all areas where the recommended system incorporates equipment that has not seen extensive offshore service in the same configuration, water depth or service, or has been modified since qualification, and its proposal as to what qualification work is required.

5.3.5 Simple and Reliable Equipment

The quantity of subsea equipment shall be minimized and simple solutions shall be offered to enhance reliability and reduce the need for maintenance and repair throughout field life. Where necessary and agreed by Company the permanently installed scope may be minimized by incorporating active components in running tools.

The Contractor's proposed design, whilst satisfying all functional and operational requirements, shall offer design simplicity and a minimum number of components/connections in order to minimize the number of potential failure points and thereby maximize the reliability of the system.

5.3.6 Intervention and Inspection Maintenance Repair (IMR) Philosophy

Where applicable, equipment shall be specifically designed for maintenance by ROV/ROT.

Special consideration shall be given to safe equipment transportation and handling during offshore operations. Additional protection is required to minimize damage to equipment during offshore loading from supply boat to rig and vice versa.

The tree system shall be designed for maintenance using ROV, ROT intervention techniques. The intervention systems shall be designed for launch operation and retrieval from both a support vessel or drill rig.

Where ROV intervention is required, Contractor shall design, and verify for acceptance, equipment to enable all ROV or tooling access. Contractor shall be responsible for all technical aspects of any ROV tools and interfaces developed and all communications necessary with the ROV system supplier in order to produce fully ROV compatible equipment.

Contractor shall prepare a matrix defining all ROV override and intervention points, listing Tool Class or characteristics, actual torque values, number of turns, interface dimensions, etc.

The IMR philosophy is defined as follows:

- Intervention interfaces shall be to recognized standards in accordance with [ISO 13628](#)
- SCM and choke insert installation and replacement shall be performed by ROV/ROT means



- Installation and replacement of Multi-Phase Flow Meter (MPFM) shall be performed by ROV or ROT means
- Sand detector shall be replaceable by ROV
- IRCD's shall be adjustable and replaceable by ROV
- Remotely operated subsea production chokes shall feature ROV override facilities and position indicator.
- All subsea valves shall have the facility for ROV over-ride unless specified otherwise
- Installation workover controls (IWOCS) electrical and hydraulic/chemical jumpers intervention shall be performed by ROV
- Replacement and hook-up of control system flying lead assemblies shall be by ROV
- Routine inspection of subsea equipment shall be carried out by ROV. Cathodic Protection measurement points shall be clearly and visibly marked
- It is the Contractor's responsibility to identify, design and provide ROT tooling systems, which address all functional, operational and safety issues associated with use in an offshore environment
- Contractor shall prepare a detailed list of ROV tools and ROT necessary for XMT IMR
- Contractor shall prepare a written summary of contingency ROV repair tasks for Company review.

5.4 Safe and Effective Transportation, handling and Subsea Installation

The tree frame shall provide adequate guidance for guideline-less intervention.

Systems shall be designed for single trip operation utilizing a standard, work class ROV.

The sensitivity of equipment installation and retrieval to adverse weather conditions and vessel motion shall be minimized.

All equipment shall be provided with lifting appliances/slides certified for offshore transportation and use. Lightweight units and tools shall be designed for deployment by drill pipe, wireline and/or ROV methods.

5.4.1 Size and Weight

All equipment run from a MSV shall, when it is fully equipped and together with its running tools and handling equipment, remain within the following dimensions and weight envelope (unless otherwise stated by Company):

- 6 m x 6 m foot print envelope
- 50 metric tons

5.4.2 Installation Efficiency

Contractor shall investigate all reasonable methods of reducing the offshore lifted weight.

The system shall be designed to minimize equipment installation times whilst maintaining maximum reliability of installation operations. Sensitivity to vessel motion and position shall be



minimized and Contractor shall provide equipment operating limitations in these terms within operation manuals.

All consumable parts (i.e. gaskets, seals, in a coupler: the resilient or changeable seal) shall be retained within recoverable assemblies.

All assemblies shall incorporate suitable pad eyes, lifting eyebolt preparations or alternatives, all complete with slings, to facilitate easy shop, test site, sea fastening and offshore handling by lifting or skidding.

All running tools shall complete their operation in a single trip.

All equipment combinations suitable for deployment or recovery shall be balanced to within 1 degree when suspended from the running profile. Counterweights and temporary balance weights shall be included where necessary.

All tool joints shall be designed to allow for minimum one thread cut-off. The tong neck shall accept an iron roughneck. All dynamic equipment that is capable of being placed/commanded to more than one position (e.g. connectors, chokes and valves) shall incorporate a visual means of identifying connection status suitable for ROV video recognition. All position indicators shall provide 'real time' visual positional information while the function is being operated.

A multi-stage guidance system shall be used for deployment of all heavy or sensitive modules.

Prior to all heavy lift operations, the rig shall be moved off station. Design of equipment shall consequently minimize the risks of snagging from slack lift wires, ROV umbilicals, etc.

5.5 Protection Philosophy

Local protection of tree components shall be provided by the tree frame. The framework shall provide protection against damage during lifting, transportation, storage, load-out, running/retrieval, installation and operational activities. Post installation, the framework shall provide protection against accidental damage and impact from remote operated vehicle (ROV) and remote operated tooling (ROT), and their umbilicals, and from dropped objects and snagging of cables associated with intervention or workover operations.

- Protection is to be provided for a dropped object of 100 mm diameter with an impact energy of 10 kJ
- Components, which are sensitive to impact, shall be located in non-exposed positions and/or be provided with removable protective covers provided that access for maintenance is not compromised.

5.6 Standardization and Equipment inter-changeability

5.6.1 Standardization

The reservoir management requirements may impose different types of down hole completions, for injection and production HXTs.

Contractor shall review the comprehensive range of HXT impacts of these particularities, including at least down hole functions penetrations (TH), piping, isolation valves and Electrical Feed Through System (EFTS), thermal insulation materials and methods, sensors specifications and SCM specification.



Contractor shall demonstrate that its standardization choices have reduced to a minimum the amount of HXT types on the project.

Contractor shall further demonstrate that the commonality of parts and materials between different types of equipment (e.g. injection/production HXT or TH) is optimized in order to ensure an optimal flexibility of the sourcing, machining, construction, testing and installation activities.

Where identical equipment could not be achieved, the design shall allow to easily reconfiguring the equipment from a type to another type offshore or at the service base (ref chapter on spares).

5.6.2 Inter-changeability

The need for total operational flexibility is the basis for the request of interchangeability, to be understood as the possibility to interface any serial number of part A with any serial number of part B.

The general rules are as follows:

- Tools shall be usable on any unit in a series of equipment it shall operate
- Any unit in a series of two parts meant to be interfaced can be swapped
- The interchangeability shall be demonstrated by Contractor for Company approval or tested by Contractor
 - Any subsea tree with any wellhead or guide base
 - Any subsea tree with any tubing hanger and tree cap
 - All running tools and test equipment to be fully interchangeable
 - All sets of ROV tools with all interfaces on the equipment
 - Any tree running tool with any subsea tree
 - For operational purposes, any production SCM with any production tree
 - For operational purposes, any injection SCM with any injection tree
 - Any choke insert with any choke insert body
 - For operational purposes, any production choke with any production tree
 - For operational purposes, any injection choke with any injection tree
 - Any SAM with any tree (if tree mounted)
 - Any MPFM with any production tree

Validation of component inter-changeability capability shall be demonstrated by equipment testing, ref. section 12 of this specification.



6. Load Criteria

Levels of loading shall be established and applied to equipment as set out in API specifications. Loads which act upon the subsea tree system are categorized and defined as follows:

6.1 Permanent Loads

These are loads, which shall not be removed during the time covered by the calculation.

They include:

- Bolting pre-load
- Connector and jumper preload
- Pre-stressing of equipment during manufacture
- Welding stress
- Self weight
- Buoyancy

6.2 Environmental Loads

Environmental loads are applied to operational configurations of equipment by wave, wind, current, vessel motion and air and water temperature and pressure.

Transportation loads shall also be included. Environmental data for the development is project specific and shall be as defined in Project Basis for Design.

6.3 Variable Loads

Variable loads occur during all aspects of equipment usage and include:

- Internal pressure and temperature induced loads
- Installation, maintenance and fatigue loads
- Loads applied by ROVs
- Transient flow pressure loads
- Mechanical and pressure test loads
- Vibrational loads
- Added mass effects during installation
- Vessel induced loads through:
 - Lift wires and umbilicals
 - Drill pipe
 - Work string overpull
 - BOPs and drilling riser loads
 - Installation/Workover riser loads



- Jumper installation
- Jumper loads transmitted from flowline ILTs

6.4 Accidental Loads

These loads are diverse in nature, but are considered to include the following:

- Heavy landing shock loads
- Dropped objects
- Snag loads
- ROV/ROT impact loads
- Tugger wire snagging loads (5 tonnes capacity on individual components, 20 tonnes total at trees highest point)
- Loss of vessel position while connected to the subsea equipment by:
 - BOPs and drilling Riser
 - Umbilicals and lift wires
 - Incorrect or loss of riser tension
 - Work string overpull, as applicable (e.g. tree running tool)
- Any other reasonably foreseeable accidental load condition.

All equipment shall be designed to withstand worst case combination loads within the above categories. The following design goals shall be adopted in order of importance:

- Avoidance of a hazard to human life
- No release of hydrocarbons to the environment
- Avoidance of scenarios that compromise vertical re-entry of a well with or without the Xmas Tree in place.

Factors applied to basic loads for load combinations shall be in accordance with the recommendations of the governing design codes and regulations and Contractor shall submit an agreed calculation package which addresses all of the above points for acceptance. Where a component is not covered by a suitable code the engineering assumptions used in selecting load cases and factors shall be clearly presented by Contractor for acceptance. Equipment shall be designed to enable year round tree installation and replacement, and equipment strength shall not impose onerous operational limitations. Equipment shall be designed to withstand the most severe combination of environmental and equipment loadings with pressurized bores at a 5° drilling riser angle and to permit BOPs disconnection in any direction.

Contractor shall advise equipment limitations in the form of calculation packages incorporating operational envelopes for acceptance making specific mention of:

- Tensile capacities of connectors, each module and tools
- Bending capacities of the tree stack-up relative to corresponding vessel offsets and operating conditions
- Shock loading sensitivities



- Expected subsea equipment deployment limitations
- Fatigue life limitations
- Snag load resistance.

In all cases, calculations complete with operating envelope information shall be submitted for acceptance.

A full riser analysis shall be performed. This shall cover operational modes at different bore pressures, fatigue analysis, weak link identification, etc. Contractor shall prepare a brief study basis for Company acceptance prior to commencement of analysis to agree approach, assumptions and format of output data.

7. System General Requirements

7.1 Overall Functional Requirements

All equipment installed on the seabed shall have a 20-year minimum operating life without the need for planned maintenance. Contractor shall analyse all parts of the system for reliability over this duration at all stages of the work. Installation equipment shall be maintainable to give 20 years' operations.

The subsea HXT System shall be configured in accordance with the dual barrier element philosophy, which implies there shall be two independent and testable barriers elements between the produced/injected fluids and the environment. A barrier element, in this context, is defined as a gate valve, needle valve, a bore plug with metal to metal seals or a metal to metal gasket.

The Xmas Tree systems' primary bore shall be capable of service by wireline and coiled tubing, both from a drilling vessel and a multifunction service vessel (MSV).

The systems, and in particular movable and electronic parts such as valves, solenoids, instruments and connectors etc, shall also be designed so that the equipment can be left in situ in an un-powered state at seabed conditions in the period of 2 years between installation and production start up without suffering detrimental effects.

Acid treatment and other treatments via coiled tubing from a workover vessel shall be possible.

Annulus pressure shall be controlled by venting into the production line via the tree crossover loop.

All equipment shall be designed specifically to avoid malfunction due to hydrate build up in produced fluid, irrelevant of the hydraulic fluid immunity to hydrates.

Metal-to-metal seals shall be used at all primary interfaces and barriers, which may experience well pressure. Resilient back-up seals may be utilized if their function is proven by qualification tests to be secondary to the metal seal. Company shall have the right to determine what constitutes the primary seal where "combination" seals are proposed.

All interfaces made-up at installation shall be remotely testable from an overhead vessel such that leakage location can be identified. Internal pressure tests of interfaces are in all cases preferable to external tests.

All connectors shall incorporate proven positive mechanical locking arrangements to avoid accidental unlocking resulting from vibration, operational bending moments or from impact loads.



Components which will be run through the marine riser shall be designed to avoid snagging. Loose items shall be avoided to prevent dropping of objects in the well bore.

All hubs, stab plates and receptacles shall be accessible by ROV for washout of silt, etc.

The system shall be designed to integrate fully with production and workover control systems.

The system shall incorporate an orientation device to interface with the 36 inch housing/guide base.

Contractor shall fully investigate how the required orientation tolerance can be achieved during installation and shall make a recommendation for acceptance. Investigation shall include tolerance studies to establish system capabilities and to identify any specific installation requirements such as jig setting.

7.2 Overall Design Requirements

The system shall be designed to be compatible with produced and injected fluids and environmental conditions as specified in the specific Project Basis for Design. In addition, materials and the design of the equipment shall be compatible with the injection or back flow of spent stimulation acid to the rig or to the FPSO.

Contractor shall ensure that all metallic and non-metallic materials used throughout the equipment are compatible with all Company specified fluids, each other and those of rental equipment, and shall submit a report for acceptance.

3-way ball valves shall not be used on permanently installed equipment.

Particular attention should be paid to material selection and surface coatings to ensure that galling of interfacing parts is avoided.

Positions of pressure and temperature sensor ports shall be located to ensure maximum measurement accuracy and to minimize the risk of blockage.

All non metallic seals used in the HXT System shall be compatible with the fluids in direct or indirect via leakage contact. This compatibility shall be either field proven or assessed by extended compatibility tests with the related fluid.

All assemblies shall be fitted with anodes to provide cathodic protection to the necessary level. The tree frame shall provide cathodic protection to all systems that are connected to, or mounted on, the tree. An allowance shall be made for well drain in accordance with Company rules and project specific documentation related to corrosion prevention methods.

8. Guidance System and Flow Base Requirements

Reference is made to **GS EP FP 410**.



9. Subsea Xmas Tree System

9.1 General

9.1.1 Description

The Subsea Tree shall comprise (if applicable):

- Wellhead connector
- Tree framework
- Tree to manifold/ILT, jumper connector
- DHPT and Down Hole Flowmeter
- Tree body and valves
- Sensors
- Tree debris cap
- Retrievable MPFM
- Choke, retrievable or with retrievable insert
- ROV panel
- Production and crossover flowloops
- IWC and SCSSV interface equipment
- Subsea production control system equipment
- SCM
- Data logger mounting base (or stab plate connection)
- Retrievable chemical injection valves and filters

9.1.2 Functional Requirements

9.1.2.1 In operation (production/injection)

The following functional requirements shall apply:

- The tree system shall be designed to offer sufficient thermal inertia, by the use of insulation systems, to meet the cool down periods defined in specific Project Basis for Design

9.1.2.2 Work Over and Installation

The following requirements shall apply:

- Two modes shall be taken into account:
 - The HXT Mode (running and retrieval of the HXT)
 - The TH Mode (Running of the completion into the marine riser and BOP with the landing string, commanded by the WOCS)



- The HXT installation, connection to the well head and test (HXT Mode) shall be possible with the use of one (1) single working class ROV only
- In HXT mode, the HXT connector lock, unlock, secondary unlock shall be accessible to operate and test the HXT connection to the well head. The HXT connector functions (lock, unlock and secondary unlock) shall be kept separated from all other IWOCS or permanent functions
- The selected connection and hydraulic fluid to operate the HXT connector shall have a 20 years design life (preventing risks associated to water ingress in the connector pistons during life of field)
- In TH mode, the HXT shall be controlled and monitored from the surface installed WOCS through an umbilical. This umbilical shall supply the LP and HP hydraulic power and the electrical Power and communication to the HXT SCM
- In TH mode, all HXT functions and down hole functions and sensors shall be monitored and commanded from the WOCS through the HXT SCM, with the exception of the HXT connector (lock, unlock and secondary unlock) not accessible through the XT umbilical
- The access to the HXT connector functions (lock, unlock, VX test, used in HXT installation mode) shall be separate from the WOCS access
- In the TH mode, the HXT shall accommodate a direct access from the WOCS (through the WO umbilical) to the penetration gallery and the port between the TH plugs
- During drilling or other down-hole operations adequate protection of the HXT internals, such as seal areas and landing/locking profiles with the TH Assembly removed, shall be provided by means of bore protectors/wear bushings. The protectors shall avoid mechanical damage to all relevant profiles and seal areas, and shall prevent deposition of particles in the lateral outlets and corresponding valve cavities
- The location of the HXT below the BOP induces the necessity for the HXT to provide a double barrier against any pressurized effluent between the well and the environment during all drilling, completion or work-over operation. This requirement adds itself to the double barrier philosophy always demanded for production phases and intervention operation.
- Both TH plugs shall have the facility to be tested bi-directionally. Additionally, a facility to test/bleed between the plugs from the work over control system and monitor from work over and production control system shall be provided
- The guidance system shall provide for proper alignment prior to engage the isolation sleeve seals
- The tree system shall be capable of being installed on the seabed at a specific orientation relative to seabed regardless of method (drill pipe or wire).

9.1.2.3 Annulus Monitoring

The basic principle of bleeding down any excessive annulus pressure is via the service- to production line.

Continuous annulus monitoring shall be performed with two (2) off independent sealing barrier elements to environmental. One of these valves shall as a minimum be remotely operated with fails safe close function from the IWOCS.



Implementation of B and C annulus monitoring is considered project specific.

9.2 Design Requirements

9.2.1 Material

All surfaces in contact with the produced or injected fluids shall be as a minimum inlaid to meet following requirement:

	Oil Producer	Gas Producer	Gas Injector	Water Injector
ISO 13628-4 PSL	3G	3G	3G	3
API Temperature classification	P - U (-29 - 121°C)	P - U (-29 - 121°C)	P - U (-29 - 121°C)	P - U (-29 - 121°C)
API retained fluid classification	Project specific	Project specific	Project specific	Project specific
Working Pressure (bar)	690	690	690	690

Notes:

- Corrosion Resistant Alloy (CRA) is required for production wetted surfaces.
- Xmas Trees for water injector wells: martensitic stainless steel shall be avoided for all areas in contact with injected fluid
- All sealing areas shall be inlaid with alloy 625 as per API specification
- 17-4PH materials to be excluded for both tubing and casing hanger, as well as for any pressure containing component of the well equipment
- For stainless steel and nickel alloys: the supplier shall provide a detailed documentation (internal specifications, QA/QC programs) about the specific precautions undertaken for preventing metallurgical defects and risks of failures
- Bills of material for all equipment shall be submitted for acceptance.

9.2.2 Design

The following design requirements shall apply:

- There shall be one 5-1/8" ID master production/injection valve integral with the tree spool/body. Larger size valve may be considered. Such design alteration shall be considered project specific and be according to the Project Basis for Design
- There shall be one 2 1/16" ID annulus master and one 2 1/16" ID annulus access valve integral with the tree spool/body
- All side outlets in the HXT spool shall be designed with the objective of avoiding debris settlement and hydrates blockage.
- All valves shall be capable of sealing with low pressure (100 psi) differentials.
- All hydraulic piping and fittings intentionally left unpainted shall be connected to the cathodic protection system



9.2.3 Sub Part Functional Requirement

9.2.3.1 General

An access to the cavity between the crown plugs within the tubing hanger shall be provided. The access shall incorporate a remote operated isolation valve (TCTV), and a pressure sensor. Three functions shall be assigned to this port:

- Flow-by area when setting the TH upper isolation plug
- Test port to control the sealing ability of isolation plug(s)
- Pressure monitoring/potential bleeding of the cavity during production or upper isolation plug retrieval.

An access to the "TH Gallery seal" shall be provided. The access shall incorporate a remote operated isolation valve (THTV), and a pressure sensor. Two functions shall be assigned to this port:

- Test port to control the sealing ability of penetrators secondary seals (upper and lower)
- Pressure monitoring/potential bleeding of the cavity during production.

Well flow and annulus pressure are controlled by gate valves in the lateral bores.

The Upper hub shall be integral to the tree spool/ block. It shall provide an external H4 locking profile. The hub profile shall be similar to the wellhead high pressure housing top profile as they interface with same BOP connector. The tree spool/profile shall withstand the clamping force from a heavy duty BOP connectors without any distortion. A back up sealing area shall be provided.

A dedicated flanged connection for the production/injection wing block size of which is project specific are to be provided.

A dedicated flanged connection for the annulus wing block, size of which is project specific and are to be provided within the project design basis.

An access to the well annulus for heavy work-over operation or circulation with the tubing hanger installed (e.g. with a subsea BOP and a drilling riser, using the kill & choke lines or C/WO), shall be provided, allowing the by pass of the TH pack-off sealing to the HXT.

Bending moments and shear stress capacity HXT connector and HXT 18 3/4" hub shall be documented. These shall be cross referenced to induced loads associated with all operations e.g. Installation, Drilling, Completion, Production and EWT.

9.2.3.2 HXT Production Wing Block

A production wing block shall be flanged to the HXT tree spool/ body. Its main objective is to provide the HXT with a secondary production/injection path closing facility, namely the production/injection wing valve.

The following design requirements shall apply as minimum:

- One 5 1/8" production/injection wing valve
- One 5 1/8" flanged connection for the production/injection choke module
- One 2 1/16" flanged connection with valve for the crossover line (communication of the production/injection flow line with the annulus wing block). A 2 1/16" access shall be

provided in the production/injection wing block to connect a cross over line from this connection up to the annulus wing block. The cross over line shall intercept the production/injection bore between the production/injection wing valve and the production master valve

- One 2 1/16" flanged connection with valve for the methanol/ service line. The methanol/service line shall intercept the production bore upstream of production wing valve and production flow loop downstream of choke and run to field methanol/service line
- One flanged connection and access port to the production/injection flow line to fit pressure and temperature sensors.
- Chemical penetrations shall be project specific.

9.2.3.3 HXT Annulus Wing Block

An annulus wing block shall be flanged to the HXT tree spool/ body. Its main objective is to provide the HXT with a secondary annulus service path closing facility, namely the annulus wing valves. The following design requirements shall apply:

- One 2 1/16" annulus wing valve
- One 2 1/16" flanged connection for the annulus cross over line
- One 2 1/16" annulus access
- One flanged connection and access port to the annulus line to fit two pressure (and temperature) sensors, for monitoring purposes, upstream the annulus master valve (injection direction).

9.2.3.4 HXT Lower Tree Connector

The following design requirements shall apply:

- The lower tree connector shall be integral to the tree spool/body. The lower tree connector shall be interfaced with the wellhead high pressure housing top profile.
- The HXT lower connector shall be capable of being connected to an H4 18 3/4" mandrel external profile with a VX/HX (or equivalent) internal sealing profile. The connector upper body shall be integral with the tree spool/body. The lower tree connector is to be operable from the TRT or via external marine completion/ workover umbilical through an independent tree mounted MQC plate
- Sealing shall be provided by a VX type gasket. A VX type gasket release mechanism shall be provided and allow ROV change out.
- The bending capacity of the connector shall be high enough to withstand the combined bending, shear and tensile loading induced by the riser/BOP-LMRP, riser tensioners and rig offsets and motions during the drilling and completion operations
- The primary locking and unlocking mechanism shall be mechanically or hydraulically operated. If a hydraulic connector is proposed, a secondary independent unlocking mechanism shall be provided by means of either hydraulic operated or a mechanical secondary unlocking mechanism, ROV operated.
- The hydraulic or mechanical locking mechanism shall withstand the vibrations originated by all operations envisaged during field life, including drilling activities



- The HXT connector shall be designed such that it is impossible to disconnect by an unplanned operation
- The lower tree connector shall be provided with a visual indication for ROV to verify that the connector is locked or unlocked
- The lower tree connector shall have a test port fitted with ROV operated valve to provide the ability to test the connector sealing. The valve shall be flanged directly on the HXT spool/ body with a pressure rating corresponding to the rating of the connector. The test shall be carried out through the completion/ work over or TRT control umbilical(s). Refer to HXT - Isolation Sleeve
- A seal between the lower tree connector and the 18 3/4" HP wellhead housing to prevent hydrate formation shall be provided within the lower tree connector.

9.2.3.5 HXT Isolation Sleeve

The isolation sleeve isolates the wellhead to HXT connection. In order to fulfil the double barrier element philosophy required for drilling operations, the seal created with the VX type gasket shall be backed up by a secondary pressure containment means using the isolation sleeve.

The following design requirements shall apply:

- The isolation sleeve shall provide pressure sealing above the VX type gasket (in the HXT spool/body) and below (in the wellhead system namely production casing hanger). It shall be permanent equipment
- The lower sealing can be achieved inside the HP wellhead housing or inside the production casing hanger.
- Secondary metal to metal sealing profile on different WH sealing surface shall be provided as a contingency solution
- The isolation sleeve shall be run as an integral part of the HXT and set when landing the HXT. The above required sealing shall be obtained as soon as the HXT is landed
- The pressure rating shall be the same as the HXT connector
- A port shall provide a hydraulic access to the cavity existing between the VX type gasket and the isolation sleeve for gasket test purposes and pressure monitoring during the internal test of the isolation sleeve. Test pressure shall be equal to the working pressure -690 bars.

9.2.3.6 HXT Penetrations

The communication to the electric and hydraulic functions to the TH and in the hole shall be provided by lateral penetrations through the HXT body. The penetrations shall be located above the production bore. The stab couplers between the HXT and the tubing hanger can be either hydraulically operated, ROV operated or passive (automatic actuation when landing the tubing hanger).

Supplier shall indicate the maximum number and possible combinations of penetration opportunities that can be accommodated.

The couplers or penetration seals shall be primarily metal to metal.

All penetrators lines shall have an isolation valves on the HXT.



A contingency solution to retract the penetrations shall be proposed. The solution shall be evaluated and documented by Supplier.

Numbers of penetrations (hydraulic, electric, fiber optics, etc.) is project specific.

Seawater or well completion fluids shall be prevented from ingressing into the stab couplers during make up.

The hydraulic penetrators shall be capable of being made up with full operating pressure on function line(s).

9.2.3.7 HXT - Sensors, Detectors and Monitoring (minimum required)

Pressure and/or temperature sensors shall be fitted to the HXT at the following levels:

- Dual P & T upstream choke (between the production master valve and the production wing valve) and Upstream MeOH Injection
- Dual P & T downstream of choke
- Dual P (& T if deemed applicable) on the annulus bore (between the annulus master valve and the annulus wing valve)
- If not combined to the above, a P sensor shall allow monitoring of the integrity of the cavity between the TH plugs and gallery seals.

The Sand Detector shall be located where the probe is likely to give the best signal for sand monitoring purposes and according to manufacturer's specifications.

The detector shall be positioned as far away from any choke valves as is reasonably practicable, as noise generated from fluids moving through the choke may disturb the detector and cause false alarms.

Contractor shall ensure that the sand detector is located in a position that enables the detector to give positive indication of sand production rates of 10 ppm and higher throughout the life of the field.

Final selection of the sand detector location shall be approved by sand detector supplier and Company.

Additionally the sensors shall withstand the vibrations and shocks induced by the drilling activities through the HXT. Further reference is made to **GS EP SPS 022**.

9.2.3.8 Flow Control (Choke, PT TT and Multiphase Flowmeter) - Optional

The HXT design shall incorporate diverless methods and tool packages for replacement of the SCM/data logger, choke module with the debris cap in place.

Should the project specific subsea system specifications call for a multiphase meter, Contractor shall perform an assessment to include optimal meter location. Should the MPFM be integrated as part of the HXT, the Contractor shall provide a system that allows retrieval of the MPFM critical components on one or more packages, comprising at minimum the electronics and measurement package, including any radioactive or similar sources. Retrieval shall be accomplished by guideline-less means, independently from the tree. The MPFM shall be installed upstream the choke in order to limit the instability that could occur downstream the choke.

9.2.3.9 HXT - Sampling Connection Point/Hydrate Plug Remediation - Optional

A connection point shall be provided in order to allow sampling and connection of Hydrate Plug Remediation Skid.

For the HXT sampling point, the following design requirements shall apply:

- The connection shall be located at a low point
- The length between the production bore and the first isolation valve shall be as short as possible to reduce dead leg length
- The connection line shall be as short as possible to allow this part of the system to be warmed up by the production fluid
- The connection line and associated valves shall be thermal insulated and satisfy the same thermal requirements as the rest of the HXT
- The HXT sampling point shall be fitted with a mechanical connector rated to 690 bars pressure differential. The protection device shall act as a barrier element during normal operation
- The sampling skid connection/connector to HXT shall be of field proven and qualified design. Make-up of connector to HXT sampling point shall be done by a single WROV
- The volume between the sampling point isolation valves shall be run/left filled with anti hydrate glycol mix or methanol as specified by project.

9.2.3.10 HXT Frame and Roof

The HXT tree frame shall support the HXT system and auxiliary components.

The tree frame in its upper part may provide a guidance system for the BOP landing. The Supplier shall set contact with the drilling SUPPLIER, when elected, to adapt both BOP (if required) and tree frame for an effective system.

The tree frame shall provide protection of the HXT during surface handling and subsea running or retrieving operation.

Critical components mounted on the HXT (actuator, wing valves, SCM, rods, etc.) shall be protected by the tree frame against falling objects from surface.

The design requirements of the HXT frame shall not create any limitation in ROV accessibility for operations of good visibility for the ROV.

The tree frame shall incorporate the required number of docking points and grabbing bars for the ROV to operate during all the phases of installation, production and work-over operations.

ROV panel(s) shall be located on one (1) but no more than two (2) sides of the HXT.

9.2.3.11 ROV Panel

The following design requirements shall apply:

- A single panel, where practical shall be provided on the HXT for the valves ROV actuation, according to the following
- The ROV panel(s) shall give access to the ROV override functions for all the remote operated valves



- The ROV panel(s) shall also give access to all ROV operated valves
- All torque transfer mechanisms shall be designed for long term exposure to a subsea environment and shall not add to the operating torque
- The panel shall include the valves and plates marking designation and shall include parking receptacles for ROV hot stabs, dummy plugs and caps, flying leads, etc. The marking system shall remain legible for the design life of the HXT
- Marking shall consider the potential for marine growth. Underwater visibility shall be considered in the choice of marking color and finish
- ROV grab handles shall be included to assist in ROV operations
- Panel(s) shall be connected to the CP system
- Panel(s) shall be designed for all loads (impact or operational) imposed by ROV
- Critical components of the HXT shall be protected by the HXT Frame. However, unprotected components (typically the flying leads) shall be positioned away from the ROV panels area where the ROV is likely to damage them by accidental contact.

9.2.4 HXT System - Other Parts

9.2.4.1 Debris cap

A debris cap is run to prevent debris from falling into the HXT and for corrosion protection inside the 18 3/4" tree spool/body re-entry hub. The following design requirements shall apply:

- The debris cap shall be capable of being used on the HXT spool and the 18 3/4" HP wellhead housing
- The debris cap shall allow injection of corrosion inhibitor to protect the seal surface contained within the TH/HXT spool or 18 3/4" wellhead housing. The debris cap shall include necessary facilities for injection of the inhibitor
- The Debris cap shall contain a locking mechanism to secure it to the H4 profile. It shall be equipped with a lift eye compatible with an ROV shackle
- The debris cap shall be run and retrieved by use of ROV (as base case) and/or Wire.
- The debris cap shall participate to HXT insulation.

9.2.4.2 HXT Bore Protector

The Supplier shall provide a pressure containing bore protector and the following additional design requirements shall apply:

- It shall be installed in the HXT on surface, and provide an automatic lock down mechanism ("snap in"), as well as an anti-rotation feature
- Although it is designed to remain in the HXT until the well is ready for completion, it shall be retrievable once the HXT is on the mud line at any time, and be reinstalled and locked down. This could be performed several times during the drilling operation
- The bore protector shall provide sealing against debris both upward and downward. The supplier shall insure the ability to change the seals in case the bore protector is pulled out and rerun.



- The bore protector shall provide pressure containing sealing both upward and downward through the penetrations area. The supplier shall insure the ability to change the seals in case the bore protector is pulled out and rerun, whatever the reason
- The bore protector shall mechanically withstand, without permanent deformation, the internal pressure that may come from the well (HXT pressure rating), with an external pressure corresponding to the sea water hydrostatic height. The HXT operation manual shall include procedure for pressure equalizing through the crown plug monitoring circuit
- A bore protector running and retrieving tool shall be provided with an extension on the lower part providing cleaning/jetting functionality while retrieving the bore protector.

9.2.4.3 Tree Running Tool (TRT)

Two ways of installation for the Xmas Tree shall be considered:

- The primary method is the installation on drill pipe from a rig
- The secondary method is the installation on wire from an installation vessel, without umbilical.

The same RT may be used with minor preparation modification or a different tool being provided for each mode.

The following design requirements shall apply:

- The TRT connection to the HXT shall be manual (ROV operated, no hydraulics)
- The TRT shall have a primary and an independent secondary release function
- The top connection of the tree running tool to the drill pipes shall be easy to handle and make up, whether an adapter is required or not
- When the tree is installed on drill pipe the TRT shall allow for body pressure testing of the tree against the casing string at the tree working pressure
- The tree running tool shall incorporate a panel with a parking receptacle to carry the TRT jumper (if any) while retrieving the tree running tool once the HXT is installed or running it for HXT retrieval
- Docking points/grabbing bars shall be provided to suit all possible ROV operations
- The tree running tool shall be able to operate with or without the HXT bore protectors in place
- The tree running tool may have an air vent device for use in the splash zone to purge air from within the HXT spool/body
- Special care shall be taken for the guidance requirement. The isolation sleeve shall not support centralization effort when going through the WH
- If the Xmas Tree lower connector does not protect the isolation sleeve during swallow over the HP housing then a stinger shall be added to the TRT. This stringer shall be telescopic type in order to ease the preparation on the deck and hydraulically extended or spring assist.



9.2.4.4 Tree Handling Tool

A handling tool for lifting the complete HXT assembly is required. The tool shall be designed for lifting from supply boat to rig with a single point lifting wire. The handling tool shall be connected to the external profile of the re-entry hub.

9.2.4.5 BOP Test Tool

After installation of the drilling BOP and riser a test tool shall be run to perform BOP pressure test. The test tool shall:

- Provide sealing at the upper part of the HXT re-entry hub with the bore protector in place
- Provide a top connection allowing the use of a dedicated sub (dummy slick joint) to pressure test the BOP pipe rams
- Be rated to the required working pressure.

9.2.4.6 Slick Joint

The slick joint shall provide:

- A slick section for isolation of the annulus with BOP rams and provide required diameter in front of each pipe rams
- A lower connection to the BOP test tool, and upper connection to the drill string
- Be rated to the required working pressure
- Details for length, diameter, type of drill string connection to be agreed with project team.

9.2.4.7 HXT Test Equipment

Contractor shall identify and include all auxiliary and test equipment required to perform the handling, transportation, pre-operational checks/tests, and any special components required to install, test and operate the Units described in this specification.

In particular, the HXT test stand shall be used to test subsea trees during manufacture and prior to installation at both onshore support base and offshore locations.

Specific requirements for this equipment are as follows:

- The tree test stands shall include a mandrel profile, able to land, lock and test the HXT to its maximum WP. It shall simulate the components mating parts and provide facilities for pressure testing and function testing of the gate valves, isolation valves, hydraulic circuits, penetrations, bore protectors
- Shall consist of an 18 3/4" / 690 bars wellhead stand on a skiddable base for interface with the tree system. The design of equipment shall allow for testing in worst case configurations
- The internal bore of the tree test stand shall be designed with a dummy casing hanger which interfaces with the tree isolation sleeve
- Test ports complete with stainless steel piping, gauges, needle valves, bulkhead plates and stainless steel quick connectors shall be provided as a minimum for the outer VX cavity
- The 18 3/4" VX groove and tubing hanger bore seals area shall be CRA lined



- The tree test stand shall be supplied for offshore use with suitable lifting points and skidding pad eyes, coatings and a protection cover
- Contractor shall thoroughly demonstrate by measurements and interface tests that the tree test stand accurately represents production equipment and that all tree test stands are identical.

9.2.4.8 Transportation Skids

The transportation skids shall be designed for offshore transportation of the HXT associated tools (i.e. TRT, handling tool, etc.).

The skids shall provide protection of components against handling damage, and ease of handling for components and assemblies. Their design shall provide lifting and sea fastening points for offshore transportation. For onshore, skids shall be able to be handled via fork lift, where practical.

The transportation skid shall also provide the correct deck load by spreading the complete XT and installation tools weight to under 5,000 kg/m².

9.3 Drill Through Application

The tree shall provide a suitable interface between the well head and the BOP stack for drilling and workover purposes and between the wellhead and the intervention riser package for light intervention.

For the DTHT, the drill through ability also implies the necessity for the electronic sensors on the tree and the control pods to be resistant to the shocks and vibrations induced by the drill string motion. All tree spools, piping and umbilicals shall be firmly attached to the tree frame for the same reasons. In addition, the lower connector shall withstand the increased bending moments and fatigue loads exerted because of the higher position of the BOP (top of the tree).

For Drill Through Application, the following additional requirements shall apply:

- The Xmas Tree isolation sleeve shall be designed to seal inside the 18 3/4" High Pressure housing
- A dual sealing system shall be used for the isolation sleeve and wellhead, and isolation sleeve and Xmas Tree. Primary seal shall be metal to metal design. External pressure test of isolation sleeve shall be 690 bars
- The Xmas Tree shall be manufactured allowing a 12-1/4" drill bit to pass. Verification shall be by drifting according to [ISO 10423](#)
- All critical surfaces, typically seal areas, latch/lock grooves, penetrator areas etc, shall be protected during the drilling phase. Suitable protectors and wear bushings shall form part of the Xmas Tree system deliverables
- Xmas Tree internal geometry shall be designed to reduce or eliminate risk of debris and drill cutting after complete drilling phase
- Wear bushings shall be landed and latched in a single trip. On retrieval, washing of Xmas Tree internal shall be possible as part of same trip
- Wear bushings shall be designed with anti rotation device.

10. Tubing hanger system

10.1 General

This section defines the requirements of the main Units of the tubing hanger system for HXT. Dependent on Contractor detailed design, other Units or combined Units shall be added/removed as required to achieve a complete system.

The following key aspects are to be included within the TH design:

- The Tubing Hanger System shall be rated to 690 bars working pressure
- The tubing hanger system shall run, install, suspend and lock the production tubing string in the HXT spool/ body and provide a pressure tight transition from the production string to the production flow loop of the HXT
- The TH system shall be deployed inside the marine riser and BOP. All components of the system, including umbilical clamps and connectors shall be designed to minimize the risk of snagging and shall have sufficient strength to avoid deformation affecting the function of the component, or loss of components in the well, in the event of snagging
- The various TH tools with the TH attached shall be capable of passing through the BOP flex joint with the joint deflected to an angle of 2 degrees. These assemblies shall provide two (2) points centralization while being run and landed
- The tubing hanger system shall be designed such that the possibility of collecting and trapping debris is minimized. The system shall include the necessary drill string deployed tools for cleaning of sensitive areas in the HXT and the tubing hanger system, prior to landing of the various Units
- The system shall further include all test/handling tools necessary for onshore and offshore testing and installation. The TH system shall include facilities to support the TH at working level on the drill floor and allow easy make-up of the THRT, without damaging the hydraulic and electric lines. A false rotary (slips) shall be included. The false rotary shall be designed allowing running of the TH on hydraulic THRT and landing string, with the umbilical clamped to the landing string
- The TH system shall have a minimum through bore equal to the max ID of completion string, unless otherwise required by project specific design basis
- Tension load capacity and pressure rating of the various components of the TH system shall be project specific and homogeneous with the maximum pressure and tension expected during installation and operation. The TH System tension load capacity (TH and THRT) is also dictated by the weight of the tubing production and the expected friction during pull out (variable following the well length and deviation) plus some margin. Data to be given as part of the interface activity.

10.2 Tubing Hanger (TH) Assembly

The Tubing Hanger shall suspend the production tubing string in the HXT spool/body and provide a pressure tight transition from the production string to the production flow loop of the HXT by means of metal to metal seal arrangements.

The Tubing Hanger shall be designed in accordance with the following requirements:

- It shall be run, oriented, landed, locked and tested in the HXT in a single trip

- There shall be a sealing system utilizing a primary metal to metal seal above and below the production side outlet. The seal system shall be bi-directional
- TH shall be oriented prior to land inside the HXT. The TH shall be able to be oriented from any initial angular offset (± 180 deg from final orientation)
- The orientation system and the various components of the landing string shall be designed to tolerate the torque and the vertical and side loads generated by rotation of the production string
- The TH shall be fully oriented before the TH seals are energized inside the HXT body
- It shall be possible to verify pressure integrity of each energized seal elements after installation of the TH. Test pressure shall be applied upstream the seal, in the direction of flow
- The tubing hanger shall be machined with one or two landing nipple profiles above the production side outlet to accept isolation plugs (crown plugs). The position of the lower profile shall be designed to give a dead space of at least one plug diameter above the tubing hanger side outlet
- Should an ITC be used, one isolation plug shall be installed in the TH, the second plug shall be installed in the ITC. Such system shall be designed to allow for ITC guidance and easy landing at the defined target inside the HXT. Further, accumulation and pollution of seal surface or trapped volumes causing hydraulic lock shall be avoided
- The bottom connection of the TH shall be a premium connection with re-cut possibility
- The Tubing Hanger shall be supplied with a pup joint made up to the torque required for the actual thread type and pressure tested in the plant. The pup joint shall be supplied complete with protectors. Length of the pup joint, type of thread shall be project specific
- The TH lock down mechanism shall be designed to prevent movement of the TH resulting from any loads acting on it. If a self locking taper type of mechanism is used to lock the TH into the HXT, a secondary mechanical locking arrangement shall be incorporated as back-up
- The TH shall be supplied with a set of test plugs for pressure testing (on surface) of the TH with pup joint to maximum working pressure
- Seal surfaces associated with TH wireline plugs, pack off seal assemblies, all seal surfaces permanently installed subsea, including areas not permanently used and all areas in contact with the produced fluid shall be inlaid with corrosion resistant material
- The connections of electric and hydraulic lines at the bottom of the TH shall be designed in such a way that damage while running the completion inside the drilling riser and BOP is avoided.

10.3 TH and ITC Isolation Plug(s)

After installation of the TH, vertical access shall be blocked and pressure isolated above the production outlet, with use of a wireline retrievable plug incorporating a metal to metal sealing system with non elastomeric back ups.

The metal to metal seal shall be designed to minimize the risk of galling during installation.

The bottom part of the lower plug shall be erosion resistant and protect the metal to metal seal.



Associated running and pulling tools shall be provided.

10.4 TH Penetrations

After installation of the tubing hanger, communication to hydraulic and electric functions in the well shall be achieved by operation of lateral stab couplers, penetrating through the HXT block. Extension and retraction of the stab couplers may be performed by either hydraulic, ROV or automatic mechanical action.

The TH design shall include the following requirements:

- Sealing of the couplers shall be achieved by metal to metal seals. Special care shall be taken when designing for horizontal penetrators to avoid damage during set down of hanger
- Termination at the bottom of the TH shall be swage lock unless otherwise specified
- To reduce the number of leak paths, no cross-overs shall be accepted and all connection points within the penetrator assembly shall be welded
- Special care shall be taken when designing for the horizontal penetrators to avoid damage or ingress of contaminants during the set down and retrieval of the hanger
- The penetrations shall be designed to allow retrieval of the TH if the actuation mechanism fails to retract
- Secondary sealing located both below and above the penetration area (gallery seal) is also to be metal to metal. Both primary and secondary seals are to be designed for the expected maximum pressure of the hydraulic system
- The horizontal stroking electrical connection interface shall be made up with pressure compensated type conductive electrical connectors. The female half of the horizontal stroking connector shall be installed in the TH

10.5 TH Isolation Sleeve

The TH shall be supplied with an internal wireline runable/retrievable isolation sleeve (or straddle), for isolation of the production outlet, to allow circulation of the production string during running/retrieval.

The following design requirements shall apply:

- The TH isolation sleeve shall be designed to withstand internal pressure in the event of a kick while running the completion, well clean up and extended flow test (EWT)
- The TH isolation sleeve shall be locked in place
- The TH isolation sleeve design shall be optimized to maximize the ID according to the tubing burst pressure
- It shall be possible to run the TH with pre-installed isolation sleeve.

10.6 TH Protection Sleeve

During Down Hole operations, adequate protection of the TH internals, such as seal areas and landing/locking profiles, shall be provided by means of wire-line deployed bore protectors.



These shall allow free passage of subsequent wire-line tool strings with smooth transitions to the bore. The bore protectors shall be suspended and locked in the TH.

Protection sleeve inside diameter shall be not smaller than the TH minimum id.

Protection sleeve shall be locked in place.

10.7 Tubing Hanger Associated Equipment

10.7.1 Tubing Hanger Charge Tool

The charge tool shall meet the following requirements:

- It shall allow the testing of the TH down-hole penetration individually (hydraulic and electrical) before running the TH in the well
- Hydraulic penetration to be pressure tested at the maximum working pressure
- Down-hole safety valve penetration to be pressure tested at maximum working pressure and then pressure to be trapped in order to keep the DHSV lock open until the Xmas Tree penetrator is energized. The regulation and monitoring of the pressure to be provided. The trapped pressure value is project specific and shall be defined after contract award.

10.7.2 Tubing Hanger Test Stand

The TH test stand shall meet the following requirements:

- The test stand shall support the TH in vertical position with the production pup joint made up
- It shall allow make-up of the THRT to the TH in both work shop and offshore conditions
- It shall provide access to all hydraulic and electrical functions and TH test caps for connection of test lines and cables
- It shall allow complete function testing of the TH system with the THRT latched onto the TH and accommodate pressure testing of the TH with pup joint
- There shall be access for general cleaning and inspection of the TH assembly
- Lifting from horizontal to vertical position shall be possible with use of the supplied sling.
- The tool shall include a locking feature to avoid accidental unlatching
- The tool shall be rated for an internal pressure based upon the project specific working pressures and shall be capable of lifting the TH including the entire tubing string
- The tool shall be manufactured to **API SPEC 17D**, PLS 2.

11. Tubing Hanger Running System

11.1 Tubing Hanger Running Tool (THRT)

Installation and retrieval of the tubing hanger shall be performed by use of a hydraulically operated tubing hanger running tool on running string.

- The THRT shall be used to run and retrieve the TH
- The THRT shall latch onto the TH and provide pressure tight seals for the production bore

- The THRT shall provide full bore access to the production bore, designed to allow down-hole wire-line and coiled tubing work and installation of TH wire-line plug and associated isolation/protection sleeve
- The THRT/TH latch function shall be maintained in latched position by active hydraulic pressure during deployment of the running string. The latch mechanism shall be designed such that it is unaffected by loss of hydraulic pressure (i.e. a dedicated hydraulic unlatch function is necessary)
- The THRT with the landing string shall have a contingency mechanical release function allowing separation from the TH if hydraulic control is lost
- All interface connections in the TH system (i.e. TH/THRT, THRT/Running String), shall be stab mandrels and control line stabs with non metallic seals and minimize water ingress
- The TH system shall be designed to withstand the external pressure caused by pressure testing to maximum working pressure via the BOP choke/kill line, with the pipe ram closed around the appropriate part of the system
- The THRT shall be designed for re-entry into a locked tubing hanger, to facilitate work-over or retrieval as required
- It shall be possible to establish distance between the wellhead and the rig rotary for riser spaceout purposes, by means of a physical contact between the TH system and the BOP, during installation of the TH and re-entry for retrieval
- The THRT shall incorporate a function to verify correct lock down of the TH in the HXT
- The THRT shall be designed to resist the combined load of maximum rated riser tension, any tensile loads generated by THRT setting pressure. It shall also withstand the bending moments applied by a 3° riser angle.

11.2 Mechanical Tubing Hanger Recovery Tool (MTHRT)

The availability of a Mechanical Tubing Hanger Recovery Tool (MTHRT), making it possible to retrieve the TH completion landing string, is to be made in accordance with the following design requirements:

- The MTHRT shall latch mechanically into the lock down mechanism and seal against the bore of the TH
- It shall remain sealed to the main bore after unlocking of the TH to allow circulation down the production string
- It shall provide a minimum through bore allowing installation or retrieval of the crown plugs and related protection or isolation sleeve
- It shall be capable of unlocking the TH using either direct pull or hydraulic pressure through the drill string or BOP choke and kill lines. No additional hydraulic control lines are permissible
- The upper connection shall be designed to allow the connection of the completion landing string joints
- The tool shall be equipped with a secondary release feature to allow emergency release from the TH



- The tool shall be designed to minimize the dragging and snagging inside the marine drilling riser during running/retrieval
- It shall be designed with a mechanical strength homogeneous with the completion landing string.

11.3 THRT Test Stand

The following design requirements shall apply for the THRT test stand:

- It shall provide sealing onto the hydraulic down-hole penetration line for function and pressure test of the stand in vertical position
- It shall provide connection onto the electrical lines for electrical continuity test
- Act as a protective cap for the lower end of the THRT. The test stand shall be designed to allow racking of the THRT/Lower Landing String Assembly and riser joint/joints in the derrick.

12. Testing Requirements

12.1 General Requirements

Further to test requirements as presented in **GS EP SPS 001**, the following listed requirements shall apply.

Equipment shall be tested in accordance with **API SPEC 17D** and **ISO 13628-4 / API SPEC 6A** PSL 3/3G requirements. For gas production application, PSL 3G requirements shall apply.

All equipment supplied shall have been performance verification tested to **ISO13628-4 / API SPEC 6A** / PR2. Other equipment that falls outside the scope of these standards shall be tested according to procedures with a similar level of thoroughness generated by CONTRACTOR and approved by COMPANY.

Completion system testing shall include but not be limited to the following:

- Component level tests: pressure
- Sub-assembly tests: pressure function
- Assembly tests: pressure - Function - Drifting qualification testing of new equipment
- Stack-up tests: pressure - Function - Drifting interface.

The above tests shall be performed for all equipment, and stack-up tests shall prove equipment performance and operation in all operational combinations of equipment.

Company requires that Contractor's test programmes rigorously test each and every functional feature and interface with adjacent equipment. All new equipment designs, reconfigurations of existing proven equipment or use of proven equipment in different conditions or services shall be subjected to thorough qualification test programmes. Each element of the subsea Xmas Tree system shall be tested according to the above philosophy and Contractor shall produce a summary document for Company review.

Hydraulic cleanliness shall be monitored throughout equipment test programmes to verify that cleanliness is being maintained during equipment operation.



The system shall also be tested to Total General Specifications (refer to standard and codes document). In particular the gate valves and actuators shall be qualified to the General Specification **GS EP SPS 015**.

12.2 Specific Test Requirements

Company has specific requirements in addition to **ISO 10423 / API SPEC 6A** PSL 3G, which are listed below.

Contractor shall consider all aspects of equipment testing and submit a comprehensive and logical test strategy that meets both API and Company specified requirements for acceptance.

Specific testing requirements are as follows:

- Gas testing shall be conducted at the valves design pressure and at the low pressure (100 psi).
- All completed production and gas injection tree assemblies shall be subjected to a submerged **ISO 10423/ API SPEC 6A** PSL 3G gas body test 1 hour duration
- Post tree body and gas test, any pressure tests conducted after reconnection or addition of a flanged, pressure containing component shall be conducted at 1.1 x design pressure
- The minimum time of any pressure test holding period after pressure stabilization shall be minimum 15 minutes or greater as specified
- Equipment shall show no visible leakage and chart recorder output shall display constant pressure unless the effect of temperature changes can be substantiated
- Pressure testing of assembled sub-assemblies may be conducted in the primer painted condition if prior acceptance is given by Company
- Ambient body temperature shall be recorded during testing
- All valves shall be tested in both directions
- All wireline plug profiles shall be tested, with plugs installed, from above and below
- All tests shall be witnessed and records approved by the Company's representative
- Pressure test charts recorded in the range of 500 psi (34.5 bar) to 10000 psi (690 bar) shall show test pressures equal to or plus 5 percent of the required test pressure. Pressure test charts recorded for tests below 500 psi (34.5 bar) shall show pressures within 15 psi (1.0 bar) of the required pressure
- Potable water with an added corrosion inhibitor and anti-freeze if necessary shall be used
- Control lines shall be tested to 1.1 x working pressure on reconnection after any disconnection
- All ROV intervention points, whether for primary or contingency operation, shall be thoroughly tested with the appropriate tools provided by Contractor to procedures generated by Contractor and approved by Company
- Contractor shall provide Company with documented and witnessed test reports of all hyperbaric testing performed on the equipment designs to be supplied. Any design changes from as tested configurations incorporated into field equipment shall, at

Company's discretion, be hyperbarically qualified at 1.1 x WP. Contractor shall provide procedures and shall perform the complete test programme in this eventuality

- One item of every design of equipment supplied shall be hyperbarically tested to 1.1 x WP except where impractical, or agreed by Company after full review with Contractor to be of no value
- Any test not meeting its test acceptance criteria shall, after completed corrective action, be re-tested to verify the component, sub-system or system is fit for its intended service
- It shall not be possible for Company to make any typical rig equipment available for these tests.

12.3 Interchangeability Test

Company requires that equipment inter-changeability is adequately demonstrated and Contractor shall prepare an inter-changeability testing programme for Company review and acceptance.

Interchangeability tests can be combined with FAT, EFAT, stack-up tests or SIT of the XT, WH and IWOCS systems pending Company approval.

12.4 Test Equipment

12.4.1 General

Contractor shall provide full details of its Testing Philosophy for Company's review and approval. Test equipment shall be provided for the following:

- Component Tests
- Assembly Tests
- Factory Acceptance Test
- Stack-up Tests and EFAT Tests
- Integration and System Tests
- Shallow Water Tests
- Pre-installation Tests
- Offshore Tests
- SRT Tests
- Change out of tree to wellhead gasket.

Test equipment shall consist of tree test stumps, test strands and specific test tools and blind flanges, etc. Test stands shall enable tree to wellhead gasket change out, on or offshore with tree weight fully supported on test stand and with trolley or other system to obviate need for personnel to work under tree. It is Contractor's responsibility to identify and provide all necessary auxiliary and test equipment, such as hydraulic test units, fluid cleanliness measuring equipment, test hoses, flushing and test caps, and all test fluid and consumables (including test gaskets and unused gasket for installation) required to perform all functional, interface, pressure test, hydraulic flushing, handling, transportation and pre-operational checks/tests, etc.



Contractor shall identify, design and supply any special components required to ensure that these objectives are met with the maximum of onshore and offshore operational ease and efficiency and safety.

In some cases, the test schedule may dictate that tests shall be performed with the use of dummy equipment or jigs. Contractor shall be responsible for the supply of any additional test equipment, dummy equipment and jigs necessary to meet the agreed schedule and when Company requires contractually supplied test equipment for the scheduled offshore campaign. Contractor shall ensure by providing sufficient test equipment, consumables and trained and experienced personnel that offshore operations requirements do not impinge on the testing and delivery of equipment and tools being manufactured concurrently.

12.4.2 Miscellaneous Test Equipment

Contractor shall supply all other tools necessary for installation, workover, handling and testing purposes, for all phases of the operations including FAT, extended FAT (EFAT), Integration testing, onshore preparation and offshore operations. Sufficient test equipment shall be provided to enable testing of tree systems including running tools.

In particular, the following tools shall be supplied:

- All primary and contingency handling and functional and pressure testing of tools
- Quick connects and test hoses to allow tree system deck testing, installation, maintenance and operation to be carried out with maximum efficiency
- A container suitable for offshore use configured as a spare parts store and workshop
- Test pumps, chart recorders, etc.
- Test equipment shall meet the following requirements
- Enable complete functional and pressure testing of tools
- Be suitable for land or offshore operations
- Where applicable have test lines routed to a common bulkhead plate and terminating in quick connect nipples of type common with the tree test base
- Be configured to facilitate hydraulic flushing, pressure and continuity testing of all circuits
- Cleanliness checking equipment

13. Handling and Protection Equipment

13.1 General

All equipment specified within this document shall be provided with a means of safe handling either on or offshore and all the components vulnerable to damage during handling/transportation shall be provided with a suitable means of protection.

The handling/protection equipment shall be robustly manufactured to achieve the required life and be finished in materials that have good corrosion resistance in an offshore environment.



Specific requirements are:

- All exposed interfaces and sensitive seal areas shall be protected by caps or plugs, etc., which shall be firmly located. All equipment destined for offshore use shall be shipped within a shipping skid or other approved form of protection
- All equipment shall be easily handled and lugs/pad eyes or eyebolts and associated slings shall be provided wherever necessary. These items shall have capacities clearly marked and shall have a load test plate attached in an adjacent position giving safe working load (SWL) and test date information. Special consideration shall be given to offshore handling of equipment in low headroom areas where items can be lifted together, e.g. Tree and test stump, any lifting arrangement provided shall be capable of safely lifting these combinations
- All equipment fitted with lifting pad eyes shall be supplied complete with lifting slings, unless Company agrees to a reduced quantity
- All lifting gear shall be supplied fully certified for its intended use and be supplied with supporting documentation. Lifting equipment shall not require load testing within 12 months of delivery.

Contractor shall give special attention to equipment vulnerability and damage when on an offshore supply boat and shall fit generously sized protection bumpers to equipment. All equipment shall be reviewed for vulnerability and Contractor's protection recommendations shall be approved by Company before implementation.

13.2 Transportation Skids

The transportation skids shall be designed for offshore transportation of the following assemblies:

- Xmas Tree
- Tubing hanger and running tool equipment.

The skids shall provide protection of components against handling damage and ease of handling for components and assemblies. Their design shall provide lifting points for offshore transportation.

They shall provide distribution of the weight so the stack satisfies the 5,000 kg/m² capacity of the MSV deck.

13.3 Preservation and Storage of Subsea Equipment

Contractor shall provide facilities and resources for support of testing, installation and maintenance activities. Procedures shall be supplied and equipment prepared to ensure its readiness for use is maintained during periods of storage and transportation.

Contractor is referred to document **GS EP SPS 010**.

14. Materials

14.1 Pressure Containing Components

Contractor is to analyze fluid data, process, environmental conditions, etc and provide materials, suited to his production processes that meet these requirements.



For material selection input related to fluid properties, temperatures and pressures, reference is made to project Basis for Design.

For corrosion control, reference is made to section 16 of this specification.

All materials exposed to production fluids shall comply with the requirements of [NACE MR0175](#) and be suitable for the specified service.

Bills of material for all equipment shall be submitted for acceptance.

The suitability of all materials in contact with methanol, ethanol or other chemicals over field life and at service temperatures shall be fully confirmed by Contractor.

14.2 Thermal Insulation

Only the production trees shall require thermal insulation.

The following requirements are applicable:

- The thermal performance of the insulation shall maintain the temperature of the produced fluid after a shut-in above the hydrate formation temperature in all areas of the tree flow path. For cool down requirements, reference shall be made to project specific Basis for Design and typically project Flow Assurance Strategy
- All potential cold spot, mainly connection systems and valves, shall be placed at high points within the system where gas pockets (if any) shall be formed after a shutdown. It allows water to drain down in warmer location
- Instrumentation points such as temperature and pressure transmitters shall be placed on the upper third part of the pipe, as near as practical to the 12 o'clock position
- Dead legs shall be minimized. Their shapes shall also avoid water accumulation
- Structure and production equipment support shall be thermally insulated so to limit thermal losses. Feed-back from previous project have demonstrated substantial benefit from thermal insulation of structural part
- The insulation material shall be designed to operate at the design temperature range of the tree system, including any cooling effect across the choke
- The application of the insulation material shall only be performed after all testing is completed and the final coating system has been applied and fully cured
- Insulation shall not hinder or obstruct the view of mechanisms and interfaces on the tree system including valve overrides, connector lock/unlock indicators, flying lead junction plates and visual position indicators
- Application of insulation shall not damage or change the performance of hydraulic control lines, fittings or valves
- General handling during shipping or installation should not cause damage to the insulation that would jeopardize its thermal performance
- The insulation shall be field repairable in the event damage occurs before installation is complete



- Thermal insulation shall be designed for long-term exposure to the subsea environment at the design water depth. It shall not degrade in thermal performance, or its lowest thermal performance shall be adequate to prevent hydrate formation for its design life
- Thermal insulation shall be designed for long-term exposure to direct sunlight and heat in the event the tree is stored unprotected in West Africa. It shall not degrade in thermal performance, or its lowest thermal performance shall be adequate to prevent hydrate formation for its design life
- Contractor shall demonstrate the thermal insulation's system performance by conducting verification simulations and tests. Contractor shall provide full details of its Testing Plans and Procedures for Company review and approval.

15. Manufacturing Requirements

15.1 General Requirements

Subsea completion equipment shall, as a minimum, be manufactured according to Company General Specifications, the requirements of [ISO 13628-4](#) / [API SPEC 17D](#), [API SPEC 6A](#) PSL 3, PR2 and [NACE MR0175](#) and this specification as appropriate.

Production and gas injection equipment shall be PSL 3G.

Ancillary equipment not specifically covered by this standard shall be manufactured according to specifications and standards with a similar level of thoroughness generated by Contractor and approved by Company.

General requirements for the manufacture of equipment shall be as follows:

- Bolting shall be tightened using torque tools to recommended values which shall be recorded
- Bolting shall be supplied with suitable protection from corrosion
- No Teflon (PTFE) thread tape shall be used. Loctite 577 hydraulic thread sealant or approved equivalent may be used where necessary
- Thread locking shall be achieved through application of the correct torque
- Contractor may recommend use of locking compounds or devices to Company where their use is justified
- No equipment that is outside specification may be repaired without permission from Company
- Hydrostatic test fluid used for all tests shall contain a corrosion inhibitor
- Special attention shall be given to the avoidance of contamination of critical areas with shot or sandblast material
- All weld procedures shall be submitted for acceptance. Prequalified procedures may be submitted for acceptance provided that they meet all specification requirements, have been qualified by the applicable fabricator and were subject to third party witness
- Welds within pressure containing items shall be ground to provide a smooth internal bore unless otherwise agreed with Company. All ground areas shall be subject to visual examination and wall thickness checks following grinding, and dye penetrant (DP) or

magnetic particle Inspection (MPI) where access permits. No surface breaking defects shall be revealed

- All NDT shall be completed by operators qualified in accordance ASNT TC 1A Level II or approved equivalent
- All lifting lugs shall be subject to load test and 100% MPI by an independent authority and be provided with certification
- Each size of tube-to-tube and tube-to-branch hydraulic control tubing welded connection shall require separate weld procedure qualification. All hydraulic control tubing tube-to-tube and tube-to-branch welded connections shall be radiographed and dye penetrant examined
- All hydraulic and chemical lines shall be welded using suitable and qualified orbital welding equipment.

15.2 Specific Requirements

Specific manufacturing requirements are as follows:

The minimum specified mechanical property and hardness values shall be demonstrated to be achieved in accordance with [API SPEC 6A](#) sacrificial test blocks in the quench and tempered plus simulated post welded heat treat (PWHT) condition.

The base material hardness shall be verified on each component, both on the external surface and the centre sections adjacent to the bores. All hardness values shall be reported for acceptance.

Well fluid wetted materials shall have a maximum hardness of 237 HB and a minimum permitted hardness complying with [API SPEC 6A](#) when checked on both the inner and outer machined surfaces.

Charpy ISO-V notch impact values for all pressure containing parts shall as a minimum meet the following requirements:

- Notch to be in the longitudinal direction
- Test temperature to be at or below minimum design temperature
- Fracture energy of 3 tests shall be 30 ft.lb (40 Joules) minimum average and 23 ft.lb (31 Joules) minimum individual

All completion equipment shall be manufactured to Quality, Inspection and Test Plans, which as a minimum satisfy all [API SPEC 6A](#) PSL 3 and Company's specific requirements and are approved by COMPANY. Production and gas injection equipment shall be PSL 3G.

All overlay welding shall be completed in accordance with [ASME IX](#) and be subject to visual and dye penetrant examination after machining to the final thickness. Defect acceptance shall comply with [ASME VIII](#) Appendix 8 except that rounded indications greater than 1/16 inches shall not be accepted.

All welds shall be subject to non-destructive testing (NDT) in accordance with procedure agreed with the Company.

Contractor shall demonstrate by qualification testing that materials used for fabrication meet all mechanical property requirements in the final heat-treated condition after bending and fabrication.



Welding procedures for structural components of the completion equipment shall in general be in accordance with the requirements of AWS D 1.1 and be subject to acceptance. The mechanical properties specified for the parent materials shall also be achieved in the weld and Heat Affected Zone (HAZ). Contractor shall provide material specifications and fabrication procedures for acceptance. These structural welds shall be full penetration double sided welds unless otherwise agreed with Company.

15.3 Hydraulic Cleanliness Requirements

Contractor's attention is drawn to Company Specification **GS EP SPS 023**.

Hydraulic equipment with the exception of hydraulic wellhead connectors shall be manufactured and assembled to give a cleanliness level of **SAE AS 4059E** Class 6 B-F or better. Hydraulic wellhead connectors shall be manufactured and assembled to **SAE AS 4059E** Class 8 B-F. Contractor shall demonstrate that the cleanliness level reflects equipment status and is not achieved solely by hydraulic flushing. Contractor shall also demonstrate that hydraulic equipment can operate and maintain this level of cleanliness for an extended period.

The use of an approved fluid cleanliness analysis machine is required.

All hydraulic tubing, fittings and connectors shall be flushed using the specified hydraulic fluid under turbulent flow conditions, ie. a Reynolds Number above 4000, until the required hydraulic cleanliness is achieved.

All components of the hydraulic system shall be supplied filled with the water based hydraulic control fluid specified for the Subsea Production Control System.

Component cleaning and assembly procedures shall be selected so that passages and cavities that cannot be flushed through achieve and maintain the required level of cleanliness. Connecting bores to be inspected by borescope and be cleared of any debris or breakthrough burrs before flushing.

Contractor shall flush and verify the hydraulic cleanliness of equipment at component level prior to hookup of sub-assemblies. Contractor shall verify equipment hydraulic cleanliness at each stage of testing and shall not proceed until project requirements are met. Specific procedures shall be generated and submitted for acceptance for every type of flushing activity required, which shall include as a minimum:

- Single unit valve actuators
- Single unit connectors
- Single unit controls pipe work
- Control lines, actuators and connectors when assembled on the subsea tree
- Miscellaneous items, e.g tubing hangers, tubing hanger running equipment, tree caps and test equipment, etc.

Contractor shall reflush equipment to project requirements before control line reconnection in cases where clean hydraulic pipe work is disconnected from connectors or valve actuators.

Equipment shall be re-flushed on arrival at test or other site after shipment as a part of SRT, and shall be sampled (and re-flushed if required) prior to mobilization for offshore use.

Acceptance shall require three separate samples to achieve required cleanliness level.



16. Corrosion Control

16.1 General Requirements

Corrosion control measures shall be applied to:

- Protect internally against produced and injected fluids which shall include all chemicals/fluids that the subsea tree system may encounter over the life of the field, at ambient and operational temperatures and pressures
- Protect externally against the marine environment, either above or below seawater
- All bolted on components shall have grounding straps to ensure continuity with the cathodic protection system.

Contractor shall be responsible for evaluating and implementing all necessary selection of materials and corrosion control methods and procedures required to ensure that the system is fully protected against all types of corrosion during the design life. Contractor shall detail material selection, coating and cathodic protection systems in a report(s).

Reference is made to Company General Specifications and project specific Basis for Design and project issued Corrosion Prevention Methods.

16.2 Specific Requirements

External corrosion prevention shall be provided by a combination of anti-corrosion coating and cathodic protection in accordance with Company General Specifications and project issued specific requirements related to Corrosion Prevention Methods.

This shall cover the application of anodes and protective coating (paint or otherwise) as necessary on all components of the system. Surface coatings shall be used in addition for components with complex geometry and where found to give cost effective design.

Where external thermal insulation is applied, allowance shall be made for its effect on cathodic protection performance.

A CP system design common with other equipment supplied under this contract shall be prepared and adopted, and shall be in accordance with the referenced documents.

This shall cover the application of anodes and protective coating (paint or otherwise) as necessary on all components of the system. Contractor shall submit a CP design report for Company acceptance.

The cathodic protection system design shall allow for current drain to the well.

Materials shall be selected with special regard for possible effects associated with the use of dissimilar metals and with corrosion mechanisms including crevice corrosion and hydrogen embrittlement. Such matters shall be addressed at all interfaces.

Contractor shall perform a thorough materials investigation and provide a report for acceptance.

Anodes shall be located to be clear of drill cuttings and cement.

Contractor shall submit painting procedures for polyamide epoxy paint systems for acceptance, clearly indicating the extent of application of each system. All painting procedures shall be in accordance with Company General specifications and project specific specifications issued for Corrosion Prevention Methods.

In addition, the following shall be submitted for acceptance:

- Running tool painting specification
- Test skid and equipment painting specification
- PTFE coating specifications and usage
- Specifications of any other coatings used, e.g. Parkerizing
- Paint color system - in accordance with [ISO 13628](#).

17. Functional Boundaries and Interface

Interfaces are of critical concern to Company, and Contractor is required to specifically address the careful management of all internal and external interfaces of the Xmas Tree System and all other systems that are part of the Contractor's SPS system supply.

Contractor shall clearly define the functional boundaries of his system and subsystems, and the hardware boundary of his equipment. Required interface across functional interfaces shall be clearly specified.

Contractor shall maintain a detailed interface register which shall identify all key interfaces to be addressed, data required to be issued and/or received, together with milestone dates by which such data shall be completed.

The Contractor shall take full responsibility for the interface compatibility for all external and internal interfaces within his scope of supply. Interface agreements that cause functional changes to Xmas Tree System or interfacing Contractors systems shall be highlighted to Company.

Contractor shall ensure that the interface register or schedule is available for submission to third parties, and similarly dates for when information is required are established and agreed. Regular updates of this register are to be included within the periodic report submission.

Contractors are adequately controlled and are part of Contractor's change control system. Such control shall ensure that all details and requirements are defined in accordance with test and delivery schedules and shall be fully backed up with extensive test programmes to demonstrate adequate completion to Company.

18. Marking Requirements

Reference is made to [GS EP SPS 001](#) and [ISO 13628 -1 and 4](#).

19. Spares Requirements

Contractor shall propose spares levels for the following stages of the project:

- Offshore installation and commissioning prior to first oil
- 2 year of operations

Contractor is to submit with the tender a list that outlines what spares are recommended for each of the stages noted above. Spares holdings shall be based on historical data, field experience and component mean time between failure (MTBFs).

Contractor is to review functional requirements of all Xmas Trees and running and intervention equipment and adopt a level of standardization to minimize the number of spares and to provide operational flexibility during manufacturing phase.

It is expected that the production and injection Xmas Trees will be different designs justifiable by the number of assemblies of each being produced but may be convertible one to the other.

Contractor shall consider whether gas/water injection Xmas Trees can be easily configured by conversion of a production tree.

The production trees shall have sufficient functionality to be convertible to gas injection trees by blanking off redundant functions.

Tubing hanger designs may be different for production and water injection.

Contractor shall consider if gas injection tubing hangers can be configured by blanking off unused functions in the production TH.

Contractor shall detail procedures, expected times and possible sites (service base, rig) to convert:

- Production tree to gas/water injection tree
- Production TH to gas/water injection TH

20. Other Considerations

20.1 Mobile Offshore Drilling Unit (MODU)

The Contractor shall identify at an early stage any operational constraints that the equipment imposes on the selected drilling unit or vice-versa and those that limit or restrict equipment handling, running and testing operations. The list below covers what are considered to be the main items but any requirements are not limited to those items noted:

- BOP envelope dimensions and functions, e.g. ram location, type, rating, drilling connector type, size, rating and BOP running and storage mode/orientation
- Handling constraints on the rig imposed by onboard cranes e.g. rating, reach, location and connection details
- Moonpool sizes and running and handling clearances
- Derrick drilling loads and clearances
- Deck and guideline winch availability
- Utilities requirements e.g. pneumatics', hydraulic and electrical
- Rig Support ROV System type and suitability for intervention work
- Simultaneous operations.

Contractor shall ensure that all the requirements noted above are clearly defined and actioned prior to mobilization of any equipment to the MODU.

20.2 Operations Support and Training

The Contractor shall provide as part of his Contract operational personnel for any activities related to the specialist equipment being provided. Company reserves the right to review the



nominee's resume', credentials and qualifications prior to the nominee being allowed to participate in related project work.

Contractor is required to maintain a core group of support personnel with specific equipment operational knowledge for the duration of the contract. The limit of this support is one year after the date of final equipment delivery, installation and commissioning.

Company require Contractor to provide essential personnel i.e. those belonging to Company, drilling Contractor, control system supplier service (both on and offshore), drilling, completions and subsea personnel with specific equipment training.

Contractor shall carry out training concurrently with the equipment integration testing program in order to maximize equipment operational knowledge for all involved with the project.

Contractor shall provide Company with their bid, details and approximate timing of training courses and their content that Contractor is to offer to Company as part of their proposal.

21. Documentation

Documentation shall be in accordance with **GS EP SPS 012** and **ISO 13628-4 / API SPEC 6A**.

Equipment status shall be tracked from production and testing through to installation and commissioning utilising a Mechanical Completion philosophy. Further details are given in document **GS EP SPS 011**.

Six weeks before delivery of the first wellhead system, Contractor shall provide Company with five copies of the wellhead Xmas Tree system stack up drawing, items drawing (hanger, etc.), technical description, running, installation and emergency manuals. This requirement shall also apply to other systems such as tubing hanger and tree.

Running/Installation procedure shall highlight areas of potential difficulty and identify contingency procedures to be followed.

All manuals shall be controlled copies with an auditable documentation system.

Contractor shall make available at no cost, if so requested by Company, all technical drawings, dimensions, tolerances, etc. of its system to allow for interfacing with other parties.

22. Quality assurance

22.1 General

The SPS Contractor shall develop operate and maintain a quality assurance system for the duration of the contract. Such a system shall be in accordance with the requirements of **ISO 9001**. Software Quality Assurance Systems shall be based upon the requirements of **ISO 9000**, Part 3.

The SPS Contractor shall be required to demonstrate performance of the work in accordance with the plan by both submission of documentation to Company for review, and by audit internally by SPS Contractor's own management system and by Company.

SPS Contractor shall be required to provide documentation for review and access for testing by both Company and third parties in support of the Contract.

The SPS Contractor is required to issue documentation as required to the Independent Review/Certification authority appointed by Company, in support of the system's Third Party



Exploration & Production

General Specification

Date : 01/2012

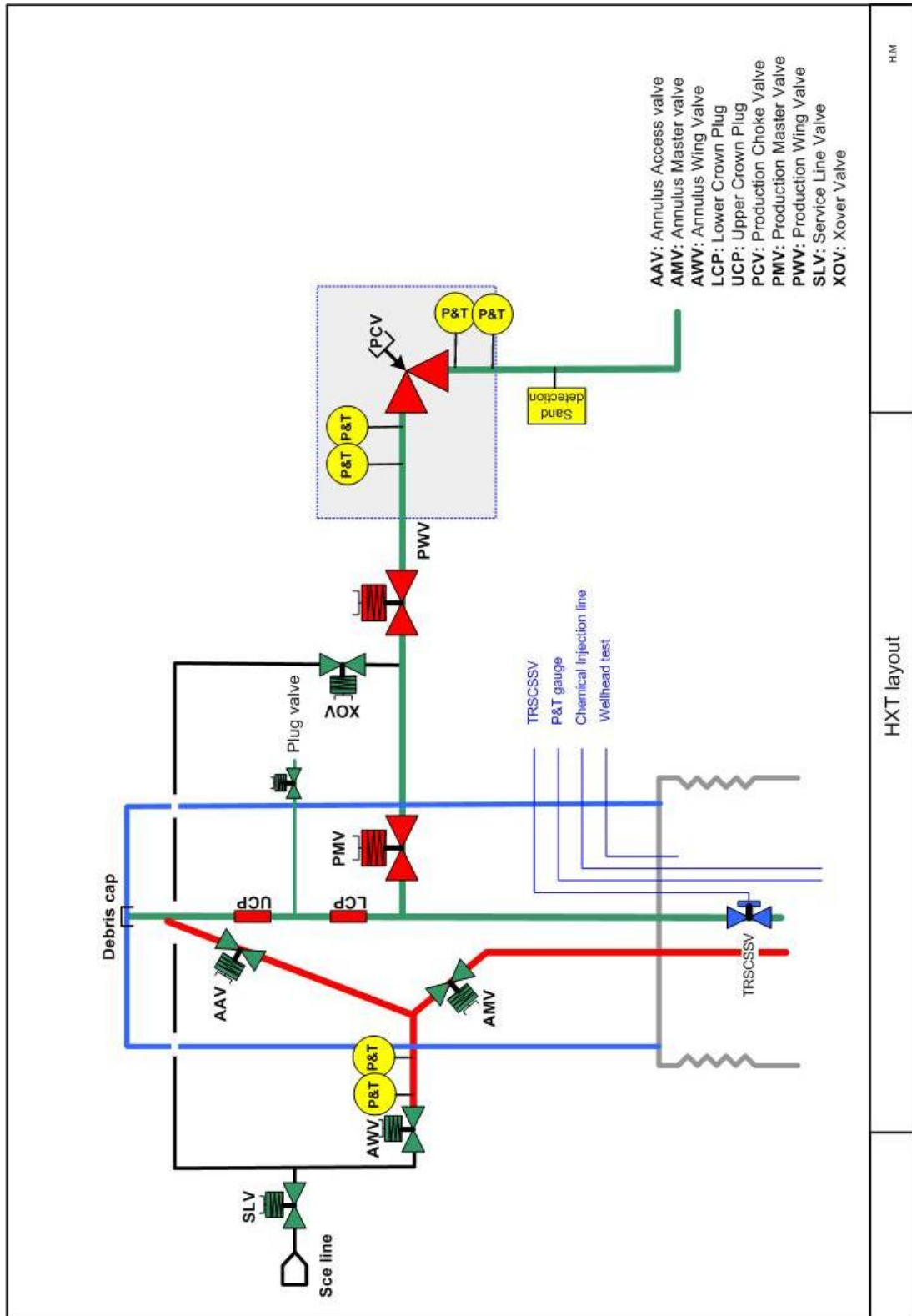
GS EP FP 411

Rev : 02

Verification scheme. Such a review shall ensure SPS CONTRACTOR compliance with Local regulations and statutory requirements.

Appendix 1

Appendix 1 Horizontal production tree - Indicative PFD for production tree





Appendix 2 Valve configuration and operation modes for the HXT

Valve Description	Operation mode		Production mode	
	Control	Failure	Control	Failure
Production Master Valve (PMV)	IWOCS	FSC	PCS	FSC
Production Wing Valve (PWV)	IWOCS	FSC	PCS	FSC
Production Choke Valve (PCV)			PCS	FAI
Annulus Master Valve (AMV)	IWOCS	FSC	PCS	FSC
Annulus Wing Valve (AWV)	IWOCS	FSC	PCS	FSC
Annulus Access Valve (AAV)	IWOCS	FSC	PCS	FSC
Service Line Valve (SLV)			PCS	FSC
Xross Over valve (XOV)			PCS	FSC
Surface Controllable SubSurface Valve (SCSSV)	IWOCS	FSC	PCS	FSC
Chemical Injection (CI)	ROV	FAI	ROV	FAI