

NORSOK STANDARD  
COMMON REQUIREMENTS

# SUBSEA PRODUCTION CONTROL SYSTEMS

U-CR-005  
Rev. 1, January 1995

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Please note that whilst every effort has been made to ensure the accuracy of the NORSOK standards neither OLF nor TBL or any of their members will assume liability for any use thereof.

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## 1 FOREWORD

This standard has been developed by the NORSOK Standardisation Work Group for the widest possible national and international application.

Annexes A and B are informative.

## 2 SCOPE

This standard is applicable to design, fabrication and testing of subsea production multiplexed electro-hydraulic control systems.

## 3 NORMATIVE REFERENCES

|                   |                                                                                                              |
|-------------------|--------------------------------------------------------------------------------------------------------------|
| IEC 870           | International Electrotechnical Commission: Telecontrol equipment and systems. Part 5: Transmission protocols |
| ISO 3511          | Process measurement control functions and instrumentation - Symbolic representation                          |
| DnV               | Det norske Veritas Certification Note 2.7-1: Offshore Freight Containers Design and Certification            |
| DnV-1980          | Technical notes for fixed offshore installations, Volume B.                                                  |
| IEC 92.101        | Electrical Installation in ships. Definitions and General requirements.                                      |
| IEC 529           | Classification of degrees of Protection provided by enclosures.                                              |
| NS 5922           | Verification of material compatibility with fluids.                                                          |
| ISO 4406/NAS 1638 | Evaluation of hydraulic fluid contamination.                                                                 |
| SAE J517          | Hydraulic hoses.                                                                                             |
| SAE J343          | Test and procedures for SAE 100R series hydraulic hoses and assemblies.                                      |
| BS 6360           | Specification for conductors in insulated cables and cords.                                                  |

### NORSOK Standard

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| U-CR-001 | Subsea Colour and Marking. |
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Requirements for surface preparation and protective coating, cathodic protection and sacrificial anodes will be identified in project requirements. The same applies to requirements for an uninterruptible power supply.

## **4 DEFINITIONS AND ABBREVIATIONS**

### **4.1 Definitions**

### **4.2 Abbreviations**

|      |                                       |
|------|---------------------------------------|
| SEM  | Subsea Electronics Module             |
| ROT  | Remotely Operated Tool                |
| ROV  | Remotely Operated Vehicle             |
| RT   | Running Tool                          |
| THPU | Test Hydraulic Power Unit             |
| BER  | Bit Error Rate                        |
| CASE | Computer Aided Software Engineering   |
| CPU  | Central Processing Unit               |
| DnV  | Det norske Veritas                    |
| DP   | Dynamic Positioning                   |
| DSP  | Digital Software Processor            |
| ESD  | Emergency Shutdown                    |
| FB   | Function Block                        |
| F&G  | Fire and Gas                          |
| HPU  | Hydraulic Power Unit                  |
| IE   | Intrinsic Earth                       |
| ICS  | Intervention Control System           |
| PCS  | Production Control System             |
| PCU  | Process Control Unit                  |
| PE   | Protective Earth                      |
| PSD  | Process Shutdown                      |
| RE   | Signal Reference Earth                |
| SCM  | Subsea Control Module ("Control Pod") |
| SCU  | Subsea Control Unit                   |
| S/N  | Signal to Noise Ratio                 |
| SPCU | Subsea Power and Communication Unit   |
| SAS  | Safety Automation System              |
| UPS  | Uninterruptible Power Supply          |
| VDU  | Video Display Unit                    |
| VMU  | Valve Manifold Unit                   |
| WOCS | Workover Control System               |

## 5 TECHNICAL REQUIREMENTS

### 5.1 Basis of Design

|                           |                                                      |
|---------------------------|------------------------------------------------------|
| Environment               | Typical North Sea                                    |
| Water Depth               | < 500 m                                              |
| Intervention Requirements | Diverless or diver assisted                          |
| Intervention Vessel       | Drilling rig and DP vessel                           |
| Process conditions        | Oil and gas producers, water and gas injection wells |

Project specific requirements will be given.

#### 5.1.1 General

The PCS "life-cycle" cost shall be used as a criterium for the evaluation of the system. This includes engineering, fabrication, documentation, spare parts, and production loss during system repair and maintenance aspects. Other criteria are safety and environmental effects.

The design shall provide for reliable and safe operation of the subsea equipment. The design shall also provide means for a safe shutdown on failures of the equipment or on loss of control from the remote control point.

Level of redundancy throughout the system will influence cost and reliability, and shall be analyzed for all parts of the system, i.e.:

- SCU
- Topside modems, umbilical lines and connectors
- Umbilicals
- Hydraulic lines and couplers
- Subsea Electronic Modules
- Sensors and solenoids
- Subsea hydraulics.

Due consideration should be made with respect to:

- fabrication costs
- production availability requirements
- standardization
- operating costs.

#### 5.1.2 Control Functions

Subsea control systems shall be designed hydraulically fail safe, and can also be electrically fail safe, if required. All subsea valves related to safety functions shall return to safe position on loss of hydraulic pressure.

The following number of control functions may be applicable:

- Surface Controlled Subsurface Safety Valves (SCSSV/DHSV)
- Production Master Valve (PMV)
- Production Wing Valve (PWV)
- Annulus Master Valve (AMV)
- Annulus Wing Valve (AWV)
- Crossover (Injection) Valve
- Methanol/Chemical Injection Valve
- Scale Inhibitor Injection Valve
- Corrosion Inhibitor Injection Valve
- Production Choke valve (PCV)
- Injection Choke valve (ICV)
- Manifold Valve(s)
- Chemical Injection Control Valve.

The supply can be provided from either a platform located HPU or a subsea HPU.

### **5.1.3 Redundancy**

Level of redundancy shall be dependent of the actual field development. Redundancy level throughout the system shall be analyzed for all parts of the system. Generally the following guidelines are applicable:

- Effort shall be taken to optimize the umbilical system design to minimize costs.

Electrical distribution system:

- The electrical distribution system should as basecase be redundant to each control module.
- If the number of cable pairs in the umbilical are restricted, the system architecture has to be carefully evaluated. However the maximum number of SEMs connected to each cable should not exceed four.

Subsea Electronic Module:

- The SEMs should as basecase be redundant. However redundancy shall be evaluated for each application.
- Each half of a redundant system shall be independently capable of performing all control and monitoring functions.

Hydraulic system:

- The hydraulic distribution system shall as a minimum have spare tubes which easily can be modified to a LP or HP system.

#### **5.1.4 Monitoring**

The criteria for selecting the extent of monitoring and the technique to be applied should be:

- How essential are the data for production operations
- How can it be implemented with minimum impact on reliability and safety
- Required accuracy on instruments.

#### **5.1.5 Topside Systems**

Subsea wells shall be monitored and controlled from standard SAS operator stations. Temporary operator stations for testing, commissioning, programming and maintainance can be included.

The operator station VDU pictures shall be designed to topside system standard and be fully integrated.

The platform installed subsea control system shall functionally be part of the platform Safety Automation System (SAS).

The production control system application software should be integrated with the SAS software. Preferably from SAS the control and monitoring of subsea functions shall be as similar to control of topside located equipment as possible.

Control of topside utility systems for the subsea installation ( HPU, SPCU and UPS ) should be performed by standard SAS nodes.

#### **Analysis**

The following analysis shall be performed during the production control system detail design:

- Reliability availability and maintainability analysis.(RAM)
- A failure mode, effect and criticality analysis (FMECA).
- A hydraulic response analysis.
- An electrical power network analysis.
- A signal network analysis.

### **5.2 Functional requirements**

#### **5.2.1 Subsea Instrumentation**

In general, instrumentation on x-mas tree and other process modules should be as simple as possible, so that the number of electrical and hydraulic connections to the SCM is a minimum. Well fluids should not be communicated to the SCM.

For sensors having to interface the process medium directly, plugging of this interface by sand or hydrates shall be given due consideration.

Methods of in-situ calibration or adjustment of the measurements shall be taken into consideration when designing the system.

Signals from sensors located downhole or on separate modules other than control module should preferably be of frequency or serial data type.

Valve position for production system on-off valves can be inferred by measuring hydraulic pressure to each actuator or alternatively by accumulated hydraulic flow measurement.

### **5.2.2 Hydraulic System**

Hydraulic systems shall be designed for a pressure of minimum 10 % above maximum operating pressure. Max. operating pressure should be 5 % above normal operating pressure. Preferred design pressures are 207, 345, 517 or 690 bar(g). Operating pressure is defined as differential pressure the component is exposed to during operation.

Safety valve setting shall not exceed design pressure.

Component test pressure shall be minimum 50 % above design pressure.

All parts and components of the subsea control system shall be clean before and during assembly. Cleanliness of the system according to NAS 1638, Class 6 or better, shall be demonstrated at flushing conditions before delivery. Stability of cleanliness after a storage period of minimum 3 days shall also be demonstrated.

Methods for circulation and flushing out seawater and solid particle contamination should be incorporated.

The subsea hydraulic system shall be robust and designed to tolerate accidental contamination of seawater and particles. It should be designed to avoid accumulation of such contamination. All components shall be qualified for operation in fluid contaminated with solid particles. Vulnerable parts with very low fluid consumption (e.g. directional control valve pilot stages) should be protected by filters. Otherwise strainers should be used.

### **5.2.3 Subsea Control Module**

The Subsea Control Equipment and instrumentation should be packaged in a retrievable unit/housing called The Subsea Production Control Module (For simplicity called " Control Module" in this document.) and should basically consist of:

- Subsea Electronics Module(s) (SEM)
- Electro-hydraulic directional control valves (DCV) and other valves
- Feed through connectors (electrical and hydraulic)
- Control Module base
- Control Module housing
- Lock/unlock mechanism for running tool
- Internal sensors and transmitters
- Filters/strainers
- Accumulators
- Pressure intensifiers (optional)
- Pressure reducers (optional)
- Chemical injection regulation valves (optional).

All active electronic circuits should be enclosed in one atmospheric gas filled enclosure(s) designed for the waterdepth involved with a good safety margin. Although protected from the environment, the electronic enclosures and all interconnecting cables and connectors shall be suitable for direct exposure to the sub-sea environment, thus providing a double barrier against seawater induced malfunctions.

Leakage in the hydraulic part of the system shall not have any impact on the integrity of the electric system.

#### **5.2.4 Communication and subsea electronic module**

A reliable and suitable communication system preferably based upon industry standard, is required for supervision, remote control, shut down and data transfer. Reliability shall be documented. The SEMs should be standardised to enable interchangeability.

The subsea sensor parameters monitored are typically:

- Production pressure
- Annulus pressure
- Production temperature (optional)
- Hydrocarbon leak detection (optional)
- X-mas tree valve position (direct or inferred)
- Production choke position (optional)
- Sand detection (optional)
- Down hole monitoring (optional)
- Multiphase flow (optional).

The following housekeeping data are also required:

- Hydraulic supply pressures
- Hydraulic return pressure (optional)
- Communication status
- Internal voltages in SEM
- Self diagnostic parameters
- Insulation resistance (optional)
- Hydraulic fluid flow (optional).

Special attention shall be put on self diagnostics for external sensor systems connected to the control module ( ex. down hole monitoring, multi flow meters, sand detectors etc.). The control system should be capable of performing specific diagnostics in case of a malfunction in a sensor system.

##### **5.2.4.1 Main Components**

The SEMs normally consist of the following main components:

- Subsea control electronics and data storage
- Subsea modem
- Electrical connectors/penetrators and cables
- Power supply.

#### **5.2.4.2 Interface**

The interface between the PCS and the topside SAS shall as basecase be between SCU and SAS system. Optionally the subsea/topside interface can be defined between SCU and SPCU. Hence the topside modem shall always be regarded as functionally part of the subsea system.

#### **5.2.4.3 Communication**

The communication shall transport the defined data signals with high reliability and sufficient capacity to handle the required traffic in all foreseeable situations.

Standard systems shall combine power and signal on the same pair of wires for both transmission cable and subsea distribution. Voltage shall be established based on overall system requirement, taking into account interface and conversion details together with system losses. In order to minimize stress on conductive connectors, voltage level should be kept as low as practical.

The modulation method used by the modems shall withstand the normal noise and disturbances which might occur on a platform without malfunction. The communication shall not be sensitive to frequency drift.

The SAS should always be governing end of the link.

Communication shall as base case be combined with power on the same cable.

The communication shall be based on formatted messages. The format shall have a reliable identification of message start and a defined length.

Message "time out" shall be included.

Reception of corrupted message and "time out" shall result in retransmission of the corrupted or lost message.

Each message shall have Cyclic Redundancy Check (CRC) or similar of a type leaving no possibility for faulty messages to be received and interpreted as correct.

The message format shall be flexible and suitable for both short and long messages. Long messages can be divided into a number of shorter messages.

The protocol should be convenient for loading of SEM software and auxilliary computer software.

The Topside Modem shall have a RS 232 link to the SCU.

The same communication protocol shall be used throughout all the subsea control system. Communication protocol shall be based on IEC 870-5, section 1-3 /2/, or equivalent international standard, and shall be described in a separate document.

Communication link performance shall be measured as "bit error rate" (BER) without any form of error correction. Minimum requirement is  $BER < 1 \times 10^{-6}$ .

System performance should include a 10 dB margin between the signal-to-noise ratio (S/N) required for  $BER < 10^{-6}$  and the S/N measured in the system under normal conditions.

#### **5.2.4.4 SEM hardware**

The SEM hardware shall be based on the use of microprocessors in order to obtain maximum reliability and flexibility in the design.

All electrical parts of the Subsea Control Module shall be protected for water intrusion by two separate and testable barriers. The outer housing and the dielectric fluid can be considered as a barrier.

The subsea electrohydraulic components should be mounted in a dielectric fluid filled and pressure compensated compartment of the SCM.

When installed subsea, temperature of the gas atmosphere inside the SEM shall not exceed 40 °C during all operational modes. SEM electronics shall be designed for a temperature of minimum 70 °C.

The SEM software shall be structured in functional tasks or modules (Functional Blocks, FB's), that shall be designed and coded as independent units. These modules shall typically conform to the defined tasks, including interrupt tasks in the real-time operating system, or the main program calls in a real-time monitor if a simple round-robin-loop is used. The module- and overall software structure shall be designed to make later software updating and maintenance easy to perform.

Coding of software modules shall be done in the ANSI "C" or similar high level programming language. Only for small, very time-critical tasks may assembly language be used. Preferably CASE tools shall be used in design and documentation.

The SEM software shall have built in diagnostic functions to simplify testing and debugging of the communication, modem, subsea computer and sensors.

Subsea Electronic Modules should have installed minimum 25 % spare memory capacity. The rack shall have minimum 2 slots or 25 % spare slot capacity for I/O modules, etc.

The SEM shall have possibilities for including signal filtering of critical measurements, if required.

Current limitation shall be provided for all SEM outputs and sensor excitation supplies.

SEM interface to sensors and directional control valves shall be standardized to a minimum number of signal types and formats.

Acceptable formats are:

- Analog inputs:
  - Current input 4-20 mA
  - Excitation 24 +/- 6 VDC
  - Voltage input 0-10 VDC
  - Excitation 12 V, 24 V
  - Frequency Max. 500 kHz
  - Signal level TBA
  - Excitation 12 V, 24 V
- Digital inputs:
  - Potential free (floating) contact
- Digital outputs:
  - Max. current 2 A
  - Max. frequency 250 Hz
  - Voltage 12 V, 24 V
- Motor drive TBA
- Auxiliary computer interface:
  - Communications Half duplex, asynchronous
  - Bit rate Max. 9600 b/s
  - Excitation voltage 24 +/- 6 VDC
  - Power consumption TBA
  - Signal RS 232C 2 conductors (x-on, x-off), RS 485 or RS 422A

Description of signals shall be specified for each application by reference to international standards, or by detailed description of signal type and tolerances at several operating and fault conditions (open end, various loads etc.)

#### **5.2.4.5 SEM software**

The SEM should be capable of performing sequenced monitoring operations based on one command from the SAS.

The SEM shall be programmable and allow for reprogramming from the surface while in place.

The SEM should have capacity to temporarily store all relevant data gathered from the subsea production system.

#### **5.2.4.6 Hydraulics**

If the hydraulic supply to the control module is redundant, it shall be documented that the redundant system design has a significant higher availability/reliability than compared to a "single system design".

The design of the hydraulic system shall be such that a robust system is achieved with respect to tolerance to contamination. This should be done by combining different philosophies like:

- Use of a fluid with high degree of cleanliness.
- Using contamination tolerant components, as far as possible.
- Designing the system to obtain best possible configuration for flushing.

All solenoid operated valves shall be of documented, high quality. In order to minimise the electrical power consumption, these valves should be pulse operated and hydraulically latched.

All components used subsea shall be qualified either by being field proven or by qualification testing in the environment and application it will be used. Extreme care should be exercised in the selection of materials to prevent galvanic corrosion.

#### **5.2.5 Distribution system**

##### **5.2.5.1 Electrical**

The number of electrical connectors in series shall be kept to a minimum. Redundant routing to the module connectors should if possible follow different paths.

The cables should be installed into self pressure compensated fluid filled hoses. The fluid shall be of a dielectric type. Dual barriers shall be provided between water and the conductor. Both barriers should each be designed for operation in seawater.

Manifold electrical distribution cabling and jumper cables from umbilical termination to the Subsea Control Module (SCM) shall be replaceable by the use of ROV. Removal of the faulty cable is not necessary.

In case of a failure in the distribution system, it should be possible to run several SEM's on one pair after having used a ROV for reconfiguration.

If one electrical line is supplying more than two SEMs, the distribution and isolation units can be located in a separate, retrievable distribution module.

Connection of electrical distribution cabling and electrical jumpers shall be made by ROV using simple tools, with minimum implications on rig/vessel time.

The cable assemblies should be designed and installed such that any seawater entering the oil will move away from the end terminations by gravity.

### **5.2.5.2 Hydraulic distribution**

When the hydraulic supply to the control modules is redundant, routing of the redundant supplies should if possible follow different paths.

The hydraulic distribution system should be reconfigurable.

The template/manifold hydraulic distribution system shall have ROV operated isolation devices so that a leakage can be isolated from the system.

Continuous tubing/piping shall be used whenever possible. The amount of screwed fittings shall be minimised. Welded connections shall be used whenever practical.

### **5.2.5.3 Umbilical**

Reference is made to separate Specification for subsea control and service umbilical.

Platform installed subsea control unit

The platform SAS system governs all platform process and utility systems.

It should be possible to store all detected faults on the communication system for later review or statistics. It should be possible to store the amount of retransmitted messages for later statistics.

Power/signal circuits shall be galvanically segregated from each other and from other systems.

The application software should be as simple as possible. Software overrides should primarily be used only for shut down application.

Start up operations after a shut down situation should be defined as a non-hazardous situation thus allowing the control room operators to be fully responsible for the operation. Software interlocks restricting operating actions should be avoided.

Reference is made to requirements for SAS system.

Uninterruptible power supply (optional)

Each UPS shall have a capacity of 100 % of the total load, including future indicated or planned expansion of the production control system. Only critical components which are necessary for operation of the production control system should be powered from the UPS. HPU electrical pumps should not be regarded as critical.

The UPS battery back up shall be capable of running the system for at least 30 minutes after loss of platform power.

The following parameters should be monitored from the SAS:

- Main voltage
- System current
- System frequency
- UPS bypass mode
- UPS battery mode
- UPS failure.

UPS to the PCS shall be 230 VAC +/-10 %, 50 or 60 +/-1 Hz with maximum 5 % harmonic distortion.

#### **5.2.6 Subsea Power and Communication Unit**

The SPCU shall supply electrical power to the subsea control and monitoring equipment. Modems and filters are included in the unit.

The topside modems shall have a RS 232C link to the SCU.

The voltage shall be individually adjustable for each power pair. Each pair shall be galvanically segregated from the rest of the system. The design shall allow for individual pair connection/disconnection without shut down of the SPCU.

The design shall allow for easy access of individual power/communication systems for maintenance and repair.

The following parameters should be monitored from the SAS:

- Input voltage
- System current
- Umbilical Voltages
- System failure.

#### **5.2.7 Hydraulic power unit**

The HPU shall supply regulated hydraulic fluid to the subsea installations.

The HPU shall contain provisions for obtaining and maintaining the specified cleanliness requirement. Output fluid from the HPU shall as a minimum satisfy cleanliness requirement of NAS 1638 class 6.

The design shall allow to a maximum extent components within the unit to be isolated and serviced without interrupting the normal operation.

The HPU parameters monitored from the SAS should typically be:

- Nonregulated supply pressure(s)
- Regulated supply pressure(s)
- Fluid levels
- Pump status
- Return flow (if applicable).

All pumps including "circulation pumps" should be electrically driven, supplied from the platform electrical power system.

The layout of the HPU shall allow easy access to all components for maintenance and repair.

The hydraulic fluid tanks shall be equipped with visual level indicators.

To prevent an interface between air and hydraulic fluid, a bladder tank or a blanket protection system should be used if recommended by hydraulic fluid vendor.

The hydraulic fluid tanks shall be designed to prevent build up of contamination and make flushing easy. I.e. cylindrical shape or rounded corners.

Same type of fittings shall be used for each pressure class throughout the system.

The accumulators should have visual indication of low nitrogen pressure.

Provisions shall be made for local control.

Monitoring of filter clogging should be implemented by using filters with a local clogging indicator.

The HPU should be designed for operation in a hazardous area.

The hydraulic power unit shall include two separate fluid reservoirs. One reservoir is used for filling of new fluid, return fluid from subsea (if implemented) and return fluid from depressurization of the system. The other reservoir is used for supplying clean fluid to the subsea system.

Fluid reservoirs shall be made from stainless steel, equipped with circulating pumps and filters. Sample points shall be made at the lowest point of the reservoir and at pump outlets.

#### **5.2.8 Test equipment**

The test equipment shall be designed so that introduction of special test equipment is minimized. Where possible, test equipment similar to the production control system hardware shall be used.

The test equipment shall be capable of simulating all primary operations necessary to control and monitor the subsea production equipment in a similar manner as the actual system.

### 5.2.8.1 Main components

The test equipment normally consists of the following pieces of equipment:

- Control module test stand shall:
  - Verify the mechanical and functional interface between the module and the module receiver plate. (Simulating the mechanical interface to the X-mas tree).
  - Verify the interface to external process sensors. (X-mas tree mounted sensors.)
  - Functionally act as a "live" X-mas tree during function test of the production control system.

The control module test stand should be built for rig use in a rough hazardous environment.

- Control module handling tool (if applicable) shall act as a simple lifting gear as a substitute for the control module running tool for onshore handling.
- Test hydraulic power unit (THPU) shall supply hydraulic fluid at system operating pressures to the control module test stand, X-mas tree mounted separately or mounted on relevant structure during test operations. The THPU shall be capable of performing flushing operations of a X-mas tree with a dummy module mounted.
- Test umbilical
- Dummy control module shall be used for verifying the interface to the module receiver plate on the X-mas tree. The dummy module shall hydraulically be similar to the control module. The dummy module shall be equipped with manual valves simulating the real directional control valves, and shall be used for:
  - Test hydraulic hoses with quick connectors
  - Test electrical cables
  - Umbilical termination head simulator ( if applicable )
  - Cable simulator shall simulate the real part of the electrical umbilical during function testing of the production control system.
- Electronic Test Unit (ETU) shall contain a sub-set of the subsea control system application software. All commands described in the communication protocol shall be supported. In addition the ETU shall be able to simulate a complete control module. The ETU shall be a modular unit including computer and necessary modems.
- Portable PC for monitoring and debugging of communication topside/subsea.
- Communication Test Unit (optional) shall comprise a computer of identical hardware as used in the SAS system. It will be used to verify communication if the real topside node is not available.

## 5.3 Operational requirements

### 5.3.1 General

System responsetimes for operation and ESD shall be calculated and tested. This include times for individual valve operations and total well closure on receipt of a shutdown command. These values shall not exceed values speciefied by the authorities or Company.

The production control system shall permit individual operation of all remotely controlled subsea valves.

The production control system shall provide the operator information necessary to indicate the status of the control system as well as the process it is controlling.

#### **5.3.1.1 Subsea installed equipment**

The subsea installed equipment shall be designed such that it is easy and safe to install and operate. Running, landing and retrieving shall be possible without hazard to personnel, equipment or environment.

Installation and retrieval of one control module shall not affect the operation of any other SCM.

All subsea retrievable items shall be fully interchangeable. They shall be designed to withstand all shocks, vibrations and pressure/temperature variations experienced during transportation including air and sea freight, and offshore operations during all seasons.

#### **5.3.1.2 Platform installed equipment**

The platform installed subsea control unit and the UPS shall be designed for safe area.

The HPU shall be designed to withstand the environmental conditions of an exposed platform deck.

Electrical components on test equipment for use on installation rig deck and other weather exposed areas shall be encapsulated to IEC 529 /7/ class IP 56 as a minimum. For use inside containers etc. class IP 55 is sufficient. Hazardous area enclosures shall be used if applicable.

#### **5.3.1.3 Equipment protection**

Vulnerable areas for connection such as electrical couplers, hydraulic couplers, hubs etc shall be furnished with necessary protection equipment in order to protect the equipment when being unmated.

### **5.4 Design requirements**

Emphasis shall be put on:

- Shut down situations
- Accumulator capacity
- System response time
- HPU reservoir
- Electric power consumption
- Tubing/hose dimensions.

### **5.5 Installation/Intervention Requirements**

All modules and equipment which will be handled between supply boat and rig shall have dedicated lifting equipment certified according to Norwegian Maritime Directorate regulations. Classification shall be based on maximum operational weight, i.e. full reservoirs. The lifting equipment shall in addition be designed and documented in accordance with DnV "Certification Note 2.7-1".

Necessary lifting equipment shall be provided with the modules.

## **5.6 Fabrication Requirements**

Hydraulic components shall be assembled in a verified clean environment. Equipment should be clean before and during assembly. Flushing is not accepted as method of cleaning except for straight piping without dead pockets.

Use of teflon tape in hydraulic system is not accepted.

NPT threads should be avoided.

Welders shall be qualified in accordance with EN 287, ASME IX or equivalent.

Brazing and soldering is not accepted (mechanical systems).

Use of fittings in the subsea hydraulic system should be restricted to a minimum. Wherever acceptable for performing maintenance weldings should be used.

## **5.7 Reliability**

Reliability of the subsea control system should always be optimized to result in minimum lifecycle cost. Thus investment costs must be related to intervention costs and production availability. If, for a specific project, intervention costs can be dramatically reduced by accepting lower reliability, this possibility should be thoroughly evaluated.

Minimum reliability goal for the Subsea Control Modules shall be stated for each project.

Sensor systems located on the x-mas tree shall have component reliability or reliability obtained by redundancy that is sufficient not to influence the frequency of well interventions/x-mas tree removal.

Reliability figures for all components shall be documented and justified by calculations and/or tests.

System reliability shall be documented.

## **5.8 Test requirements**

### **5.8.1 General**

A comprehensive acceptance test program shall be undertaken at the fabrication site to ensure that the permanent performance will meet or exceed the performance and long term reliability requirements of the integrated system.

Testing shall cover the range from material testing through performance verification on material and sub-systems to overall type testing of the completed assemblies prior to being transported out of fabrication site.

At each level of testing it shall be demonstrated that the materials, sub-systems or complete assembly meets or exceeds the specified requirements.

The test procedures for the different test activities should be structured in a manner similar to the Pre-commissioning/Commissioning procedures and applicable Integration Test procedures. Outline Pre-commissioning/Commissioning procedures should be worked out prior to working out the test procedures for the production control system. Hence the end user requirements shall be defined prior to developing the actual test procedures. The idea behind this requirement is to maximize applicable experience from one phase to the next. Hence experience gained during FAT is applicable for test activities during Integration Test and Pre-commissioning/Commissioning.

### **5.8.2 Factory Acceptance Test (FAT)**

Vendor shall develop and implement a comprehensive test program. The program shall demonstrate that all systems and components of the supplied equipment will perform satisfactorily in service and meet all requirements. A complete subsea production control system test shall be part of this program.

The acceptance test program shall demonstrate that:

- The functional capability of the system meets the requirements of the specification.
- The item interface configuration is correct.
- The item envelope is as defined by the assembly drawing.
- The item finish is what has been accepted by Company.
- All "loose" components forming part of the item are present and mate correctly with the main unit.

All relevant documentation shall be available prior to start of the FAT.

During the complete FAT attention shall as a minimum be paid to the following:

- Electro-hydraulic directional control valve performance and leak rates
- Monitoring system accuracy
- Communication system sensitivity and noise immunity
- Pressure test of all tubing, pipework and hydraulic components
- Accumulator precharge pressure
- Relief valve pressure setting
- Fluid and system cleanliness
- Pressure testing of control module
- Verification of equipment mating
- Protective treatment
- Insulation resistance and conductance
- Helium leak testing of applicable cannisters
- Conductance to sacrificial anodes

Environmental stress screening (ESS) shall be applied for all subsea instruments and electronics. All subsea electronics shall pass a program of initial burn-in and vibration, and all 1 atmospheric enclosures shall be helium leak checked. Each SEM shall be pressure tested after final closure.

### **5.8.3 Sensitivity test**

The production control system should go through a comprehensive sensitivity test. This test program shall be done on subsystems or total system as applicable.

The purpose with the sensitivity test is to "vary" key parameters in a controlled manner and monitor system performance and limits of operation. Criteria for system performance shall be developed and the different key parameters impact on system performance shall be documented.

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## **ANNEX A RECOMMENDED PRACTICE (Informative)**

### **A.1 Basis of Design**

#### **A.1.1 Control Functions**

Due to the normally very high operating pressure for the SCSSV, a separate high pressure hydraulic circuit for control of this valve is foreseen as the base case. The high pressure circuit can be a separate parallel system to the low pressure system, or alternatively a common supply for both circuits to the control modules.

#### **A.1.2 Monitoring**

In a redundant system, the possibility of one system to monitor essential diagnostic parameters of the other system should be considered.

#### **A.1.3 Emergency Shut-down (ESD) and Process Shut-down (PSD).**

The main objectives of the shutdown system are to protect personnel, environment and equipment from the consequences that may occur during abnormal operating conditions, release of hydrocarbons or other accidents in line with the NPD regulations. The action initiated will be selective and in line with the requirements for the actual situation to limit the effect on the subsea valves to an absolute minimum.

Two distinct shutdown systems for protection are implemented on the platforms. Emergency Shut-Down (ESD) is initiated as a result of fire and/or gas detection, and release of unacceptable amount of hydrocarbons. Process Shut-Down (PSD) is initiated to avoid such situations by protecting the process equipment from abnormal operating conditions.

The production control system shall typically perform a shut down in the following situations:

- ESD Level 1 Abandon Platform Shut-down. (Initiated from platform).
- ESD Level 2 Emergency Shut-down. (Initiated from platform).
- Automatic Template/Manifold Shut-down from Workover rig telemetry system. (Optional).
- Manually Initiated Well Shut-down.
- Manually Initiated Template/Manifold Shut-down.
- Automatic Well Shut-down due to low hydraulic oil pressure in Control Module LP circuit. (Optional).
- Automatic Well Shut-down due to low hydraulic oil pressure in Control Module HP circuit. (Optional).
- Automatic Shut-down due to low well head pressure detected by Control Module.
- Automatic Shut-down due to low pressure in flowline detected by platform system.
- Automatic Well Shut-down due to loss of electric power to Control Module. (Optional).

ESD/PSD signals to subsea valves (subsea wells x-mas tree and downhole valves, or single valves on manifolds or pipelines) shall normally act in the following way:

- ESD signals shall normally act via a separate control mechanism than for ordinary process control.
- The ESD function shall be Fail to Close.
- If a permanently energized solenoid valve is included in the control module ESD function may be executed by means of interrupting electrical power to the subsea control module (SCM). This shall then cause the dedicated solenoid valve to travel to its fail safe position and thereby bleed down the hydraulic pressure to the ESD valve(s), and allow it to return to safe position by means of its spring return actuator or accumulator pressure. An alternative method could be by applying battery back-up in control pod to initiate shut-down on loss of electrical power.
- In addition electrohydraulic systems, powered by a topside located hydraulic power unit (HPU), shall include solenoid valve(s) located on the hydraulic supply lines energized from the ESD system. This solenoid(s) shall ensure depressurization of the hydraulics in ESD abandon platform situations.

PSD signals shall act via the SCU, enabling a sequenced closure of subsea valves, as required in the various PSD levels.

## **A.2 Functional Requirements**

### **A.2.1 Subsea Instrumentation**

Wherever ROV-installable sensors of clamp on type (not penetrating the piping) are available and acceptable, this will be the preferred option.

A secondary task for hydraulic flowmeters should be monitoring of heavy leaks in the hydraulic system.

### **A.2.2 Hydraulic System**

The hydraulic system shall be designed to meet specific valve operating characteristics and operational requirements, taking into account pressure drops, pump cut-in and cut-out, actuators and accumulator volumes, and pressure build up in return system.

### **A.2.3 Subsea Control Module**

#### **A.2.3.1 Communication and subsea electronic module**

The main functions of the subsea control and monitoring system are:

- Receive and execute commands from the SAS system
- Collect and transmit subsea sensor parameters to the SAS system

For down hole and production pressure monitoring, time correlation and sample frequency are important. At an early stage of a project, detailed requirements shall be developed.

All microprocessor based units in the system shall have automatic self-testing facilities. Typical features can be:

- SCU I/O testing
- Subsea computers self test
- SCM I/O testing.

#### **A.2.3.2 Hydraulics**

The main functions of the control module hydraulic system are:

- Direct pressurised hydraulic fluid to specific valve actuators through dedicated directional control valves, thus causing the valve to open.
- Vent pressurised hydraulic fluid from specific valve actuators through dedicated directional control valves, thus causing the valves to close.

#### **A.2.4 Main components**

The control module hydraulic system normally consists of the following main components:

- Electro-hydraulic directional control valves
- Manifolds
- Filters and strainers
- Supply line pressure transducers
- Actuator line pressure transducers
- Return line pressure transducers (optional)
- Hydraulic couplers
- Accumulators
- Pressure intensifiers (optional)
- Pressure reducers (optional)
- Supply and return line flowmeters (optional)

#### **A.2.5 Distribution system**

##### **A.2.5.1 Electrical**

For a template system the electrical distribution system consists of jumper cables between umbilical termination head and control modules. For a single satellite system the electrical distribution system are defined as the jumper cables between umbilical termination head and control module. For a manifold/satellite system the electrical distribution system comprises manifold jumper cables infield jumper umbilicals and satellite jumper cables.

##### **A.2.5.2 Hydraulic distribution**

The main purpose of the hydraulic distribution system is to direct pressurised control fluid from the umbilical termination to each control module on the template or to the module for the satellite well system.

Platform installed subsea control unit

The main functions of the platform installed subsea control unit are:

- Send commands to the SEM's
- Receive data from the SEM's
- Be the operators interface to the process (optional)
- Control and monitor the HPU (optional)
- Monitor the SPCU
- Monitor the UPS (optional)

The platform installed subsea control unit shall functionally be part of the SAS system.

#### Uninterruptible power supply

As basecase the PCS will be connected to the topside central UPS for the production unit. The main function of the uninterruptible power supply (UPS) is to ensure continuous electrical power supply to the subsea control system regardless the status of the platform electrical power system.

### **A.2.6 Hydraulic power unit**

The main function of the hydraulic power unit (HPU) is to provide Low (LP) and High (HP) pressurised control fluid to the control modules.

#### **A.2.6.1 Main components**

The HPU normally contains the following components:

- Pumps
- Accumulators
- Regulators
- Filters
- Supply and return tanks
- Instrumentation
- Relief valves
- Fluid purifier (optional)

If oil based fluid with a return system is included, control of cleanliness and water content in the return fluid shall be carefully considered. Preferably the return fluid should not be subject to lower pressure than surrounding hydrostatic pressure.

HPU shall be designed to maintain stable hydraulic pressure in the subsea system during all operational situations. Pumps shall have capacity to quick regain operating pressures after a hydraulic depressurization of all systems.

If oil based fluid with a return system is included, control of cleanliness and water content in the return fluid shall be carefully considered. Preferably the return fluid should not be subject to lower pressure than surrounding hydrostatic pressure.

HPU shall be designed to maintain stable hydraulic pressure in the subsea system during all operational situations. Pumps shall have capacity to quick regain operating pressures after a hydraulic depressurization of all systems.

#### **A.2.6.2 Test equipment**

The main function of the test equipment is to provide a method of checking out different sub-systems of the production control system at various stages throughout the life of the system.

The test equipment shall serve three main functions:

- Be a support system for testing of the production control system during the development project test phase.
- Be a maintenance tool for system verification throughout the system life.
- Be a demonstration unit for training of personnel.

#### **A.2.6.3 Interface to control module running tool**

The production control module should be guided during installation. It shall be separate retrievable with a dedicated tool guided on two guidewires or by ROV tooling. An ROV can be used for mating of electrical and/or hydraulic connectors to the control module.

Running tool interfaces should be standardized irrespective of control system supplier.

Running tool (including SCM) shall be designed for maximum landing velocity of 1.8 m/s.

#### **A.2.6.4 Interface to christmas-tree**

The size of the control module and the receiver plate shall be arranged to suit the available space between the christmas-tree, guide posts and manifold.

The module receiver plate should be mounted to the christmas-tree structure.

All tubing and electrical cabling between christmas-tree and module should be connected to the module receiver plate.

#### **A.2.6.5 Interface to control module receiver plate**

The module receiver plate should be permanently fixed to the christmas-tree structure and should provide the following features:

- Establish a landing base for the control module.
- Establish make and brake of all hydraulic and electric connections between the control module and the christmas-tree.

For hydraulic couplers, check valves shall be provided with sufficient capacity to avoid seawater intrusion when unmated.

All seals shall be located on the coupler halves mounted on the control module.

The least vulnerable part of the electrical connectors should be mounted on the module receiver plate. A guiding system shall be provided for coarse, fine and accurate positioning of the control module.

#### **A.2.6.6 Interface to platform**

The interfaces towards the platform are typically:

- SAS interface
- PSD/ESD system interface
- UPS (optional)

Generally the subsea production system shall be regarded as an extension of the platform systems.

All platform based production control system equipment shall be built according to specifications applicable for the platform where the equipment shall be situated. Hence relevant standards and installation specifications have to be part of the contractual documentation for the specific development project.

#### **A.2.6.7 Interface to workover control system**

During "workover-mode" the production control system shall have no control over the vertical well-bore and annulus valves of the well.

In "workover-mode" the production control system might interface the workover control system through the control fluid return system. Emphasis should be put on cleanliness requirements and return system pressure build up in a "workover-mode" situation.

System design should pay attention to possible seawater contamination of control lines during workover operations, and incorporate means for flushing of these lines.

Interface between umbilical and distribution system

The main umbilical shall be installed into an umbilical receiver which, in terms, will also connect into the subsea distribution system. The functions of the hydraulic distribution system should be replaceable. The electrical distribution system should be separately replaceable.

Interfaces between christmas-tree and distribution system

The subsea distribution system shall provide means for make and break connection for all hydraulic lines to the Christmas-tree.

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## **ANNEX B NATIONAL AND INTERNATIONAL REFERENCES (Informative)**

The latest edition and current amendments of the following standards shall apply at the time of order placement, unless otherwise is specifically agreed with Company.

### National Regulations

#### Norwegian Petroleum Directorate (NPD):

- Regulations for productions- and auxillary systems on production installations etc.
- Regulations concerning electrical installations in the petroleum activities, including relevant guidelines.
- Regulations concerning manned underwater operations in the petroleum activity.

#### Norwegian Water and Energy Administration:

- Regulations for Electrical Installations. Maritime Installations, 1990.

#### Sjøfartsdirektoratet

#### National and International Codes and Standards