

Standard for Subsea Production and Processing Control Systems

API STANDARD 17F
FIFTH EDITION, APRIL 2023



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Standard for Subsea Production and Processing Control Systems

1 Scope

This standard is applicable to the design, fabrication, testing, installation, and operation of subsea production and processing control systems (SPCS).

This standard covers surface control system equipment, subsea-installed control system equipment, and control fluids. This equipment is used for control of subsea production and process of oil and gas and for subsea water and gas injection services. Where applicable, this standard can be used for secondary users.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 6A, *Specification for Wellhead and Tree Equipment*

API Recommended Practice 17A, *Design and Operation of Subsea Production Systems—General Requirements and Recommendations*

API Specification 17D (2011), *Specification for Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment*

API Specification 17E, *Specification for Subsea Umbilicals*

API Specification 17H, *Remotely Operated Tools and Interfaces on Subsea Production Systems*

API Recommended Practice 17P, *Recommended Practice for Subsea Structures and Manifolds*

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

API Standard 520, *Sizing, Selection, and Installation of Pressure-relieving Devices*

API Standard 521, *Pressure-relieving and Depressuring Systems*

API Standard 670, *Machinery Protection Systems*

ASME Boiler and Pressure Vessel Code ¹, Section V: *Nondestructive Examination*

ASME Boiler and Pressure Vessel Code, Section VIII: *Rules for Construction of Pressure Vessels, Division 1*

ASME Boiler and Pressure Vessel Code, Section IX: *Welding, Brazing, and Fusing Qualifications*

ASME B31.3, *Process Piping*

ASTM D97 ², *Standard Test Method for Pour Point of Petroleum Products*

ASTM D903-98, *Standard Test Method for Peel or Stripping Strength of Adhesive Bonds*

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM D1141:98, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D1401, *Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids*

ASTM D2625, *Standard Test Method for Endurance (Wear) Life and Load-Carrying Capacity of Solid Film Lubricants (Falex Pin and Vee Method)*

ASTM D2670, *Standard Test Method for Measuring Wear Properties of Fluid Lubricants (Falex Pin and Vee Block Method)*

ASTM D3164-03 (2011), *Standard Test Method for Strength Properties of Adhesively Bonded Plastic Lap-Shear Sandwich Joints in Shear by Tension Loading*

ASTM D3233, *Standard Test Methods for Measurement of Extreme Pressure Properties of Fluid Lubricants (Falex Pin and Vee Block Methods)*

ASTM D4172, *Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)*

ASTM G1:03, *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*

ASTM G46, *Standard Guide for Examination and Evaluation of Pitting Corrosion*

BS EN 14359 ³, *Gas-loaded Accumulators for Fluid Power Applications*

CiA 301 ⁴, *CANopen: Application Layer and Communication Profile*

CiA 309-1, *CANopen Access from Other Networks—Part 1: General Principles and Services*

CiA 309-3, *CANopen Access from Other Networks—Part 3: ASCII Mapping*

CiA 443, *CANopen Profile for SIIIS Level-2 Devices*

EN 10204 ⁵, *Metallic Products—Types of Inspection Documents*

IEC 60060-1 ⁶, *High-Voltage Test Techniques—Part 1: General Definitions and Test Requirements*

IEC 60270, *High-Voltage Test Techniques—Partial Discharge Measurements*

IEC 60502-1, *Power Cables with Extruded Insulation and Their Accessories for Rated Voltages from 1kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV)—Part 1: Cables for Rated Voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)*

IEC 60721-3-2, *Classification of Environmental Conditions—Part 3-2: Classification of Groups of Environmental Parameters and Their Severities—Transportation and Handling*

IEC 60885-2, *Electrical Test Methods for Electric Cables—Part 2: Partial Discharge Tests*

IEC 61000-4-4, *Electromagnetic Compatibility (EMC)—Part 4-4: Testing and Measurement Techniques—Electrical Fast Transient/Burst Immunity Test*

IEC 61000-6 (all sections), *Electromagnetic Compatibility (EMC)—Part 6: Generic Standards*

³ British Standards Institution, 389 Chiswick High Road, London W4 4AL, United Kingdom, www.bsigroup.com.

⁴ CAN in Automation, Kontumazgarten 3, DE-90429 Nuremberg, Germany, www.can-cia.org.

⁵ European Committee for Standardization (CEN), Rue de la Science 23, B - 1040 Brussels, Belgium, www.cen.eu.

⁶ International Electrotechnical Commission, 3 Rue de Varembé, CH-1211, Geneva 20, Switzerland, www.iec.ch.

IEC 61300-3-4, *Fibre Optic Interconnecting Devices and Passive Components—Basic Test and Measurement Procedures—Part 3-4: Examinations and Measurements—Attenuation*

IEC 61300-3-6, *Fibre Optic Interconnecting Devices and Passive Components—Basic Test and Measurement Procedures—Part 3-6: Examinations and Measurements—Return Loss*

IEC 61508, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems*

IEC 61508-3, *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems—Part 3: Software Requirements*

IEC 61511, *Functional Safety—Safety Instrumented Systems for the Process Industry Sector*

IEC 62402, *Obsolescence Management*

IEC 62619, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes—Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Industrial Applications*

IEC 62620, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes—Secondary Lithium Cells and Batteries for Use in Industrial Applications*

Internet RFC 791 ⁷, *Internet Protocol*, <http://www.faqs.org/rfcs/rfc791.html>

Internet RFC 793, *Transmission Control Protocol (TCP)*, <http://www.faqs.org/rfcs/rfc793.html>

Internet RFC 1332, *The PPP Internet Protocol Control Protocol (IPCP)*, <http://www.ietf.org/rfc/rfc1332.txt>

Internet RFC 1661, *The Point-to-Point Protocol (PPP)*, <http://www.faqs.org/rfcs/rfc1661.html>

ISO 4021 ⁸, *Hydraulic fluid power—Particulate contamination analysis—Extraction of fluid samples from lines of an operating system*

ISO 4405, *Hydraulic fluid power—Fluid contamination—Determination of particulate contamination by the gravimetric method*

ISO 9001, *Quality management systems—Requirements*

ISO 9606-1, *Qualification testing of welders—Fusion welding—Part 1: Steels*

ISO 9606-2, *Qualification test of welders—Fusion welding—Part 2: Aluminium and aluminium alloys*

ISO 10945, *Hydraulic fluid power—Gas-loaded accumulators—Dimensions of gas ports*

ISO 11898-2, *Road vehicles—Controller area network (CAN)—Part 2: High-speed medium access unit*

ISO 11898-3, *Road vehicles—Controller area network (CAN)—Part 3: Low-speed, fault-tolerant, medium-dependent interface*

ISO 15607, *Specification and qualification of welding procedures for metallic materials—General rules*

ISO 15609-2, *Specification and qualification of welding procedures for metallic materials—Welding procedure specification—Part 2: Gas welding*

ISO 15610, *Specification and qualification of welding procedures for metallic materials—Qualification based on tested welding consumables*

⁷ Internet Engineering Task Force, 5177 Brandin Court, Fremont, California 94538, www.ietf.org.

⁸ International Organization for Standardization, Chemin de Blandonnet 8, CP 401 – 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 15611, *Specification and qualification of welding procedures for metallic materials—Qualification based on previous welding experience*

ISO 15612, *Specification and qualification of welding procedures for metallic materials—Qualification by adoption of a standard welding procedure specification*

ISO 15613, *Specification and qualification of welding procedures for metallic materials—Qualification based on pre-production welding test*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO/IEC 90003, *Software engineering—Guidelines for the application of ISO 9001:2015 to computer software*

ITU-T G.652.d ⁹, *Characteristics of a Single-mode Optical Fibre and Cable—Single-mode Low Water Peak Fibre Minimum Specifications*

ITU-T G.654, *Characteristics of a Cut-off Shifted Single-mode Optical Fibre and Cable*

ITU-T L.12, *Optical Fibre Splices*

NORSOK M-630 ¹⁰, *Material Data Sheets and Element Data Sheets for Piping*

NORSOK M-710, *Qualification of Non-Metallic Sealing Materials and Manufactures*

SAE AS 4059 ¹¹, *Aerospace Fluid Power—Contamination Classification for Hydraulic Fluids*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

alien crosstalk

Measure of the unwanted signal coupling between adjacent link segments at the near-end.

3.1.2

boost

Pressure maintained on the spring-return side of a subsea actuator for the purposes of improving closing-time response.

3.1.3

closed hydraulic system

System configuration where spent control fluid is returned to the hydraulic power unit (HPU).

3.1.4

commanded-closure condition

Closure of a subsea valve by the SPCS in response to a system input.

NOTE Commanded closure can be manually initiated by an operator or automatically initiated as part of a shutdown sequence.

⁹ International Telecommunication Union, Place des Nations, 1211 Geneva 20, Switzerland, www.itu.int/en.

¹⁰ Standards Norway, Lilleakerveien 2a, NO-0283 Oslo, Norway, www.standard.no/en.

¹¹ SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

3.1.5**communication distribution unit**

Unit that communicates with the host facility and distributes communication signals within the subsea network in an electrohydraulic or electric system.

3.1.6**component**

All elements of the bill of materials (BoMs) such as electronic components, mechanical components, product, tooling, processes, software, and firmware.

3.1.7**condition monitoring**

Data provided to monitor the condition of the equipment.

3.1.8**control path**

Total distance that a control signal (e.g. electrical, optical, hydraulic) travels from the topside control system to the subsea control module (SCM) or valve actuator.

3.1.9**delay skew**

Difference in propagation delay between any two pairs in a cable assembly.

3.1.10**designated subsea barrier valve**

The valve designated to provide isolation from a pressure source; normally associated with a regulatory requirement or a safety requirement.

3.1.11**design life**

The specified operational life of system after a pre-delivery test.

3.1.12**direct hydraulic control**

Control method wherein hydraulic pressure is applied through an umbilical line to act directly on a subsea valve actuator.

3.1.13**downstream**

Away from a component in the direction of flow.

3.1.14**dry-mate connectors**

Subsea connector not designed to be mated underwater.

3.1.15**dual redundant**

Redundancy by duality wherein two identical units (or systems) fulfill the same function.

3.1.16**electric control**

Control method wherein electrical power is conducted to the subsea system and used to open or close subsea valves.

3.1.17**electrohydraulic control**

Control method wherein hydraulic power is transmitted to the subsea system and used to open or close subsea valves in response to an electrical signal.

3.1.18**far-end crosstalk loss**

Measure of the unwanted signal coupling from a transmitter at the near-end into another pair measured at the far-end, and relative to the transmitted signal level.

3.1.19**flashover**

Unintended electrical discharge over an insulator.

3.1.20**flying lead harness**

Single or multiple composite grouping of hydraulic, chemical, electrical power, electrical signal, and/or optical signal carrying conduits used to interconnect various items of subsea equipment.

NOTE Also commonly known as a jumper.

3.1.21**functional safety**

Part of the overall safety that depends on functional and physical units operating correctly in response to their inputs.

3.1.22**hybrid connectors**

Connector with both electrical and optical contacts.

3.1.23**hydraulic circuit**

Arrangement of interconnected components that generates, transmits, controls, and converts hydraulic energy.

3.1.24**hydraulic component**

Individual unit, excluding piping, comprising one or more parts designed to be a functional part of a hydraulic circuit.

3.1.25**insertion loss**

Signal loss resulting from the insertion of a component or link or channel between a transmitter and receiver.

NOTE Often referred to as attenuation.

3.1.26**intelligent well**

Well that employs permanently installed downhole sensors and/or permanently installed downhole flow control devices that are operable from a surface facility.

3.1.27**intelligent well control system****IWCS**

Control system used to operate an intelligent well.

3.1.28**legacy equipment**

Equipment delivered to the operator that may be in operation.

3.1.29**looped hydraulic circuit**

Local subsea valve configuration where spent hydraulic fluid is looped through the SCM to compensate the valve actuator return chamber.

NOTE Return chamber is often referred to as spring side.

3.1.30**near-end crosstalk loss**

Computation of the unwanted signal coupling from transmitters at the near-end into a pair measured at the near-end.

3.1.31**normal operation**

Operating the system to perform the intended basic functionality.

3.1.32**open hydraulic system**

System configuration where spent control fluid is vented locally to sea.

3.1.33**operator**

Person, group, or organization that is the client/customer of the supplier; also a person who operates equipment or a machine.

3.1.34**power sum near-end crosstalk loss**

Computation of the unwanted signal coupling from multiple transmitters at the near-end into a pair measured at the near-end.

3.1.35**pressure (control system)**

— **actuator start-to-close pressure:** operational characteristic; on falling pressure from operating pressure toward ambient pressure, the pressure at which a spring return actuator starts to move from the open position to the closed (spring-loaded) position.

— **design pressure (DP):** maximum pressure at which a system (or an individual component) is designed to operate continuously.

NOTE 1 Also known as maximum allowable working pressure; hydraulic rated working pressure; or design working pressure.

— **directional control valve (DCV) delatch pressure:** operational characteristic; on falling pressure from operating pressure toward ambient pressure, the highest pressure at which a DCV moves from the latched open position into the closed (spring-loaded) position.

NOTE 2 Also known as DCV drop-out pressure.

— **external hydrostatic pressure test:** external test pressure applied to a component at a prescribed factor above the design water depth ambient pressure and held for a period sufficient to verify pressure integrity.

NOTE 3 Also known as hyperbaric test pressure.

- **hydrostatic leak test:** test pressure applied to a previously hydrostatically tested component or system to verify joint sealing integrity.
- **hydrostatic pressure test:** internal test pressure applied to a pressurized fluid component or system at a prescribed factor above the DP and held for a period sufficient to verify pressure integrity.

NOTE 4 Also known as proof pressure test or strength pressure test.

- **maximum operating pressure (MOP):** system operational limit; the highest nominal pressure at which the system can operate in normal conditions; upper limit for either pump control instrumentation or pressure regulator setting.

NOTE 5 Also known as maximum working pressure.

- **maximum relieving pressure:** maximum HPU output pressure experienced during a pressure-relieving event.

NOTE 6 Also known as pressure accumulation.

- **minimum operating pressure (Min OP)—subsea:** system operational limit; the lowest subsea pressure that the system is intended to experience during normal operations.

- **operating pressure (OP):** system operational characteristic; the nominal pressure at which the system is actually operated in normal conditions.

NOTE 7 Also known as working pressure.

- **reset pressure:** pressure at which the system pressure-relieving device fully closes after a system-relieving event.

NOTE 8 This pressure will be lower than set pressure.

- **set pressure:** pressure at which the system pressure-relieving device cracks open.

3.1.36

propagation delay

Amount of time it takes the signal to travel from the sender to the receiver.

3.1.37

qualification design verification

Process of proving a design by testing to demonstrate the conformity of the product to the design requirements.

3.1.38

qualified person

Individual or individuals with characteristics or abilities gained through training or experience or both, as measured against established requirements, such as standards or tests that enable the individual to perform a required function.

3.1.39

redundancy

Existence of more than one means of performing a required function or representing information.

3.1.40

response time

Sum of the signal time and the shift time.

3.1.41**retained fluid**

Actual fluid produced by a well or injected into a well.

3.1.42**return loss**

Ratio expressed in dB of the power of the outgoing signal to the power of the reflected signal.

3.1.43**running tool**

Tool used to install, operate, retrieve, position, or connect subsea equipment remotely from the surface.

NOTE An example is the SCM running tool.

3.1.44**shift time**

Period of time elapsed between the arrival of a control signal at the subsea location (the completion of the signal time) and the completion of the control function operation.

3.1.45**shutdown sequence**

Automated sequence of timed valve close commands issued by the subsea control system to shut down all or parts of the subsea system; initiated either by the operator, in response to subsea control system data, or an external signal.

3.1.46**signal time**

Period of time elapsed between the remote initiation of a control command and the initiation of a control function operation subsea (the commencement of the shift time).

3.1.47**software**

That part of a computer system comprising encoded information and instructions; also used to cover firmware.

3.1.48**structural return loss**

Return loss associated with variations in the cable impedance.

3.1.49**subsea electric actuator**

Device—applied underwater—that produces a linear or rotary movement when excited by an electric or optic signal and power.

3.1.50**subsea electronics module**

Device—applied underwater—containing electronic components to support control and monitoring functions.

3.1.51**subsea hydraulic actuator**

Device—applied underwater—that produces a linear or rotary movement when excited by a hydraulic fluid control power.

3.1.52**subsea processing control system**

Control system operating a subsea processing system during production operations.

3.1.53**subsea production control system**

Control system operating a subsea production system (SPS) during production operations.

3.1.54**subsea umbilical termination**

Mechanism for mechanically, electrically, optically, and/or hydraulically connecting an umbilical to a subsea system.

3.1.55**surface-controlled subsurface safety valve**

Fail closed safety device that is located in the production bore of the well tubing below the subsea wellhead.

3.1.56**unlooped hydraulic circuit**

Local subsea valve configuration where the valve actuator return chamber is compensated by a self-contained volume compensator.

NOTE Return chamber is often referred to as spring side.

3.1.57**upstream**

Away from a component against the direction of flow.

3.1.58**validation testing**

Test conducted to confirm that the requirements for a specific intended use or application of a product have been fulfilled.

3.1.59**verification testing**

Test conducted to confirm that the specified requirements for a product have been fulfilled.

3.1.60**wet-mate connector**

Connector designed to be mated under water.

3.1.61**wire map**

Map showing the configuration of the wire runs.

3.1.62

|

The | character when shown after a hexadecimal number that indicates a subindex, e.g. 0x1018 | 1 denotes object 0x1018, subindex 1.

3.2 Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following acronyms, abbreviations, and symbols apply.

ACRF	attenuated crosstalk ratio at far-end
APC	angled physical contact

AXT	alien crosstalk
BER	bit error ratio
BoM	bill of material
BMS	battery management system
CAN	controller area network
CDU	communication distribution unit
CL	confidence level
COB-ID	Communication Object Identifier
CP	cathodic protection
DC	direct current
DCS	distributed control system (alternative terminology to ICSS)
DCV	directional control valve
DH	direct hydraulic
DHCP	dynamic host configuration protocol
DoD	depth of discharge
DP	design pressure
DUT	device under test
EDS	electronic data sheet
EFL	electrical flying lead
ELFEXT	equal level far-end crosstalk
EM	electromagnetic
EMC	electromagnetic compatibility
EoC	end of charge
EPU	electrical power unit
ESS	environmental stress screening
EUT	equipment under test
FAT	factory acceptance test
FEXT	far-end crosstalk
FFF	fit, form, and function
FMECA	failure mode, effects, and criticality analysis

FT CAN	fault-tolerant CAN
<i>g</i>	acceleration due to gravity
GND	ground
HALT	highly accelerated life test
HASS	highly accelerated stress screening
HMI	human machine interface
HP	high pressure
HPU	hydraulic power unit
HS CAN	high-speed CAN
HV	high voltage
ICSS	integrated control and safety system
I/O	input/output
IP	internet protocol
IR	insulation resistance
ISAS	ISD surface application system (system for acquisition and/or control of ISD)
ISD	intelligent seabed device
iSEM	intelligent well subsea electronics module
IWCS	intelligent well control system
IWE	intelligent well equipment
IWIS	intelligent well interface standardization
LP	low pressure
LSS	layer setting service
MBR	minimum bend radius
MCS	master control station
MDIS	MCS to DCS interface standardization (https://opcfoundation.org)
MEA	malt extract agar
MEG	monoethylene glycol
Min OP	minimum operating pressure
MOP	maximum operating pressure
MPDO	multiplex transmit process data object

NEXT	near-end crosstalk
NMT	network management
NTP	network time protocol
OD	object dictionary
OMP	obsolescence management plan
OPC	open platforms communications
OSI	open system interconnection
PC	personal computer
PCBA	printed circuit board assembly
PD	partial discharge
PDN	product discontinuance notice
PDO	process data object
PFD	probability of failure on demand
PMI	positive material identification
PTFE	polytetrafluoroethylene
PWV	production wing valve
RMS	root mean square
ROT	remotely operated tool
ROV	remotely operated vehicle
RX	receive (signal)
SCM	subsea control module
SCMMB	subsea control module mounting base
SCSSV	surface-controlled subsurface safety valve
SDO	service data object
SEM	subsea electronics module
SG	subsea gateway
SIIS	subsea instrumentation interface standardization
SPCS	subsea production and processing control system
SPS	subsea production system
SUT	subsea umbilical termination

TCP	transmission control protocol
TPDO	transmit process data object
TSB	tryptic soy broth
TX	transmit (signal)
UM	user management
UPC	ultra-physical contact
UPS	uninterruptible power supply
UV	ultraviolet
VAC	volts alternating current
VDC	volts direct current
VLAN	virtual local area network
XT	Christmas tree
β	filtration ratio obtained in ISO 16889 and used to rate the performance of hydraulic filters

4 System Requirements

4.1 General

Figure 1 depicts the typical subsea control system elements.

SPCS normally comprises the following functional building blocks. Note that a) and b) describe two different configurations for the topside functional building blocks.

a) Integrated topside configuration:

- 1) Host facility control and shutdown logic, and all external input/output (I/O) links, are incorporated in the integrated control and safety system (ICSS).
- 2) SPCS control logic is contained in specific ICSS node(s), which are functionally dedicated to the subsea system.
- 3) Automated subsea valve shutdown sequences normally implemented in specific ICSS node(s).
- 4) Subsea communications handling logic are contained in separate processors provided by the SPCS vendor and are often integrated with the electrical power unit (EPU).
- 5) Control and monitoring of associated topside equipment packages (e.g. HPU) are done by local ICSS nodes.

b) Interfaced topside configuration:

- 1) Host facility control and shutdown logic, and all external I/O links, are incorporated in the ICSS.
- 2) SPCS control logic and subsea communications logic are contained in separate logic processors provided by the SPCS vendor and are incorporated in a separate package that is termed the master control station (MCS).

- 3) Automated subsea valve shutdown sequences normally implemented in specific ICSS node(s) or MCS.
 - 4) Subsea communication modems can often be separated from MCS and integrated with the EPU.
 - 5) Control and monitoring of associated topside equipment packages (e.g. HPU, EPU) can be optionally controlled by either MCS or local ICSS nodes.
- c) Stand-alone topside configuration.
- d) EPU: Conditions and controls the subsea electrical power supplies to the desired voltage and frequency; often integrated with the subsea communications modems.
- e) HPU: Provides and controls stable and clean hydraulic fluid supplies to the subsea hydraulic system.
- f) Topsides umbilical termination assembly: Provides termination for all umbilical services at or close to the umbilical hang-off location.
- g) Umbilicals: Used to transfer all required services to the subsea system (e.g. electrical power, electrical/optical communications, hydraulic power, and production chemicals).
- h) Subsea umbilical termination (SUT): Permanently integrated to the umbilical and providing connection interfaces for the umbilical services; sometimes also provides distribution functionality to create multiple output interfaces.
- i) Flying leads: Remotely operated vehicle (ROV) or diver-mateable flexible leads between subsea equipment items for individual or multiple umbilical services (e.g. electrical power, electrical/optical communications, hydraulic supplies, and production chemicals).
- j) Subsea distribution unit: An item designed to distribute incoming umbilical services to multiple output destinations; can be either a passive distribution unit or can feature active signal conversion (e.g. optical-to-electrical media conversion) and/or network routing and/or active power distribution.
- k) SCM: Control node in the subsea communications network providing a local data-gathering hub for associated subsea sensors and, depending on system type, remote-controlled hydraulic switching functionality for associated subsea valves.
- l) Subsea sensors: Sensors located in SCMs (internal sensors) and on Christmas trees (XTs), manifolds, flowlines, and downhole (external sensors) providing subsea system monitoring data.
- m) Subsea valve actuators: Hydraulically or electrically supplied devices typically located on XTs, manifolds, and flowlines providing force and movement for subsea valve actuation.
- n) Subsea valves: Process valves located on XTs, manifolds, flowlines, and downhole providing control of the subsea system.
- o) Subsea safety isolation valves shall be designed according to the probability of failure on demand (PFD) defined in the operator's safety analysis.

This standard covers all variants of subsea control systems, including hydraulic, electrohydraulic, electric, and hybrid system types. Only the relevant subsections should be used.

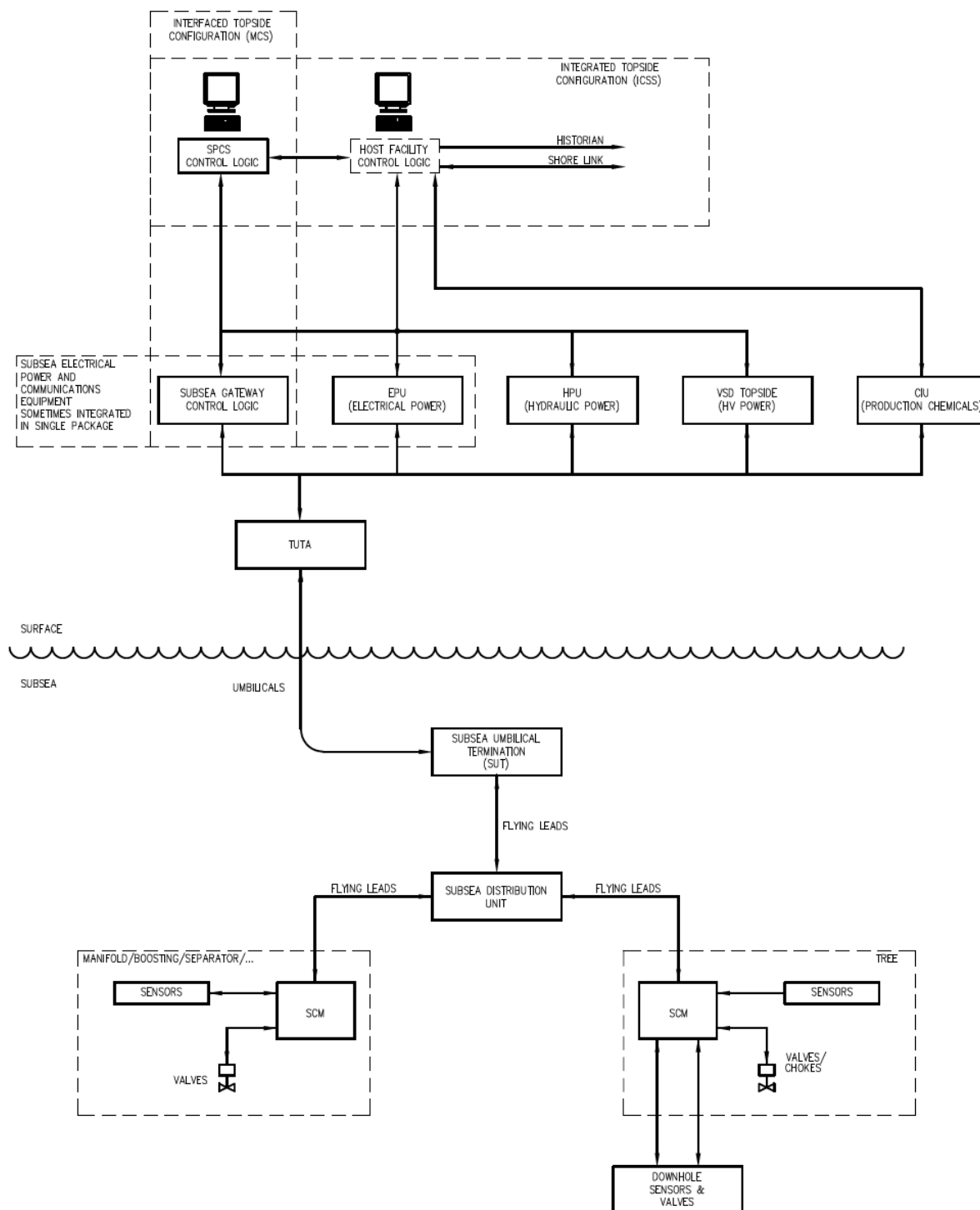


Figure 1—Typical Subsea Control System Elements

4.2 Subsea Control System Functionality Requirements

4.2.1 General

During system design, the following design criteria shall be considered:

- horizontal integration;
- inhibition after unintended shutdown;
- intelligent well application;
- flexibility with respect to electrical load situations (power and communication);
- robustness of hydraulic and electrical system;
- seawater ingress and material compatibility;
- subsea intervention;
- increased scope with respect to number of wells;
- increased scope with respect to number of umbilicals;
- increased scope with respect to control/instrumentation functionality;
- interface toward subsea separation/subsea boosting systems;
- subsea chemical injection;
- downhole instrumentation system interfaces;
- downhole chemical injection;
- human factors;
- life cycle attributes, such as reliability, maintainability, manufacturability, usability, obsolescence management, and cybersecurity risk assessment;
- ease of deployment;
- safety and emergency shutdown.

4.2.2 Horizontal Integration

The potential for horizontal integration of equipment shall be considered during the design of the subsea control system. Horizontal integration can be defined as the ability to use common products for different operating scenarios. Examples of this may include the use of subsea control system components for workover or intervention equipment.

Through the use of horizontal integration, the project may benefit from common spare philosophies, familiarity of operation, and economies of scale.

To maximize the potential for horizontal integration, the specification for equipment should include standard interfaces (e.g. defined in 7.5) that allow different SCMs and sensors/actuators to be used easily between the differing modes of operation and data to be made available to users at the surface.

4.2.3 Intelligent Well Application

If an intelligent well completion is defined as a current or future requirement by front-end engineering, the initial subsea umbilical system and associated distribution system equipment shall support all proposed valve functionality, data retrieval, computational support, and communication pathways.

Any project proposing the implementation of downhole flow control within the SCM should perform a documented review of proposed designs with respect to potential integrity risks and the potential impact on the configuration of the SCM design. Automatic shutdown functionality of hydraulically actuated XT-mounted isolation valves that are installed on intelligent well hydraulic function lines shall comply with operator and regulatory authority requirements. Thermal expansion and contraction shall be accommodated in the design and operation of the hydraulic system and performance of the downhole flow control devices' hydraulic control lines.

When an SCM is used to operate the intelligent well control system (IWCS), the intelligent well control functions shall be vented through a hydraulic circuit other than that used to vent fluid/pressure from other control functions on the XT, including surface-controlled subsurface safety valve (SCSSV).

4.2.4 Flexibility with Respect to Electrical Load Situations (Power and Communication)

Unless otherwise agreed between the manufacturer and the purchaser, the system shall be built to accommodate a large variation in electrical loads to allow for flexibility regarding future expansion.

Unless otherwise agreed between the manufacturer and the purchaser, the communication system shall be built to function on both primary and backup communications (where applicable), within project required range of communications load variations. The communications systems shall be robust with respect to failure modes.

4.2.5 Robustness of Hydraulic and Electrical System

4.2.5.1 General

The hydraulic and electrical system shall be designed to provide sufficient energy margin to ensure actuator operational performance during all modes of operation. Actuation of any individual valve actuator within the system shall not cause alarms or unintended movement of any other valve.

4.2.5.2 Seawater Ingress and Material Compatibility

The hydraulic system shall be designed to minimize seawater ingress in all operational scenarios, including installation and retrieval of individual units. Some ingress may be expected due to API 17D requirement for self-venting couplers on key function lines, generally in the pod base plate and after SCM intervention. All SPCS functional components that can come into contact with seawater (either by design or by component failure) and, in particular, all hydraulic control fluid wetted components in the SPCS should be seawater tolerant (no significant change in material properties upon contact with seawater). The recommended practice for all hydraulic systems, where applicable, is to operate SCMs and other hydraulic products as soon as practicable after initial deployment.

4.2.6 Subsea Intervention

The subsea control system shall be designed for cost-effective subsea intervention tasks, with respect to both ROV and diver applications.

4.2.7 Increased Scope with Respect to Number of Wells

The additional design capacity of the subsea control system shall be agreed between the purchaser and the manufacturer. Limitations shall be documented during the design phase.

Simple additions should be considered to make future expansion possible whilst continuing to operate the system (for example including a nozzle with isolation suitable for expansion of HPU tank, etc.).

4.2.8 Increased Scope with Respect to Number of Umbilicals

As a field develops, there may be an opportunity to tieback additional fields. This capability should be addressed at the design stage.

Also, fields may be developed by connecting additional infield umbilicals; the effect of a system in production during connection of infield umbilicals should be addressed in design stage.

4.2.9 Increased Scope with Respect to Control/Instrumentation Functionality

The majority of systems will not be expanded in this way, but the ability of the system to be expanded by adding functionality should be assessed in the design phase.

4.2.10 Interface Toward Subsea Separation/Subsea Boosting Systems

Subsea separation and boosting systems shall be capable of being operated by a subsea control system, unless otherwise agreed between the manufacturer and the purchaser.

4.2.11 Subsea Chemical Injection

Unless otherwise agreed between the manufacturer and the purchaser, the system shall provide for the required chemical injection services and allow for flexibility with respect to possible chemical-injection scenarios during the operational phase. This flexibility can be achieved by including spare lines in the subsea distribution system, planning for possible subsea chemical injection system add-on, reconfiguring lines, etc. The possible impact on the subsea control system shall be described at an outline level during system design. Refer to API 17Y for subsea chemical injection system configuration and system design recommended practices for more detailed requirements.

4.2.12 Downhole Instrumentation System Interfaces

The production control system shall allow for flexibility regarding interface toward downhole instrumentation systems. The possible impact on the subsea control system shall be described at an outline level during system design.

4.2.13 Downhole Chemical Injection

The SPS shall, if applicable, allow for downhole chemical injection. The possible impact on the subsea control system shall be described at an outline level during system design.

4.2.14 Human Factors

The system design shall take into account human factors in order to optimize the overall system performance.

4.2.15 Life Cycle Attributes such as Reliability, Maintainability, Manufacturability, and Usability

Reliability, maintainability, manufacturability, and usability are the factors that affect run-time behavior, system design, and user experience. They represent areas of concern that have the potential for applicationwide impact across layers and tiers.

4.2.16 Obsolescence Management

For more information on obsolescence management, refer to Annex A.

4.2.17 Cybersecurity Risk Assessment

The assessment is designed to provide a measurable and repeatable process to assess a system's level of cybersecurity risk and preparedness.

4.2.18 Ease of Deployment

Systems shall be designed to be easily deployed using installation aids and available equipment.

4.2.19 Safety and Emergency Shutdown

Systems shall be designed for safe operation and be able to shut down production in a safe and efficient manner that complies with all regulatory and specified requirements.

4.3 General Requirements

4.3.1 Service Condition

4.3.1.1 Suitability for Working Environment

The subsea control system shall be designed and operated with consideration for the external environment. For surface facilities, this includes climatic conditions, temperature, corrosion, marine growth, tidal forces, illumination, electromagnetic compatibility (EMC), and hazardous-area classifications. For the subsea environment, this includes corrosion, ambient pressure and temperature, marine growth, fouling and boring by marine life, fishing activity or marine operations, currents, seafloor composition, EMC, and maintenance considerations. Suitability to the likely storage environment shall be considered. This can include ultraviolet (UV) radiation, ozone, ice, sand, wind, humidity, or temperature extremes.

Product designs shall be capable of withstanding DP at rated temperatures without degradation, exceeding allowable stress and strain levels, or the impairment of other performance requirements for the design life of the system.

4.3.1.2 Temperature Ratings—Surface-installed Equipment

4.3.1.2.1 Without Controlled Environment

Surface-installed equipment covered by this standard that is not installed in a controlled environment shall be designed, tested, operated, and stored in accordance with the temperature and humidity requirements for the intended environment.

4.3.1.2.2 Controlled Environment

Surface-installed equipment covered by this standard that is installed in a controlled environment shall be designed, tested, operated, and stored in accordance with the temperature and humidity ratings that are compatible with the specified controlled environment.

4.3.1.3 Temperature Ratings—Subsea-installed Equipment

Subsea-installed equipment covered by this standard shall meet or exceed the required temperature ranges described in this subsection. In Table 1, the test temperatures refer to pre-deployment testing environments in which the equipment may be operated [e.g. extended factory acceptance test (FAT), systems integration test, deck testing].

Table 1—Temperature Rating—Subsea-installed Equipment

	°C	°F
Design	–18 to 40	0 to 104
Test	–18 to 40	0 to 104
Operate	–5 to 40	23 to 104
Transport/storage	–18 to 50	0 to 122
The temperatures relate to environment, not individual components. Subsea sensors that monitor produced or injected fluid may operate outside the ranges given and shall be rated accordingly.		

Electronics shall have a design temperature rating of –18 °C to 70 °C (0 °F to 158 °F). This refers to the temperature of the atmosphere within the enclosure in which the electronic or electrical equipment is operating.

Unless otherwise agreed between the manufacturer and the purchaser, consideration shall be given to the minimum design and operational temperature ratings of subsea control system equipment that may be exposed to significant Joule-Thompson cooling effects in service (e.g. sensors positioned immediately downstream of production chokes).

4.3.1.4 Electromagnetic Compatibility

The design shall conform to the applicable local regulations regarding EMC for the environment in which the equipment is used.

4.3.1.5 Storage/Test/Transportation Temperature Recommendations

If subsea-installed or surface-installed equipment is to be stored or tested on the surface at a temperature outside its temperature rating, the manufacturer should be contacted to determine whether special storage or surface testing procedures are recommended. Manufacturers shall document any such special storage or surface testing considerations (e.g. exposure to fluctuations in UV, ozone, ice, sand, wind, humidity, or temperature extremes).

4.3.2 Hydraulic Power System

4.3.2.1 General

To allow expansion of the existing installed base of designed, qualified, and field-proven systems and equipment with a safe field-operations history, such systems and equipment may be exempted from the design, working, and test pressure rating subsections in this standard, and they may be accepted for use within projects/systems that specify compliance with this edition of this standard.

4.3.2.2 System Pressure Ratings and Performance Requirements

Hydraulic system design and functional requirements are illustrated in Figure 2 and Figure 3.

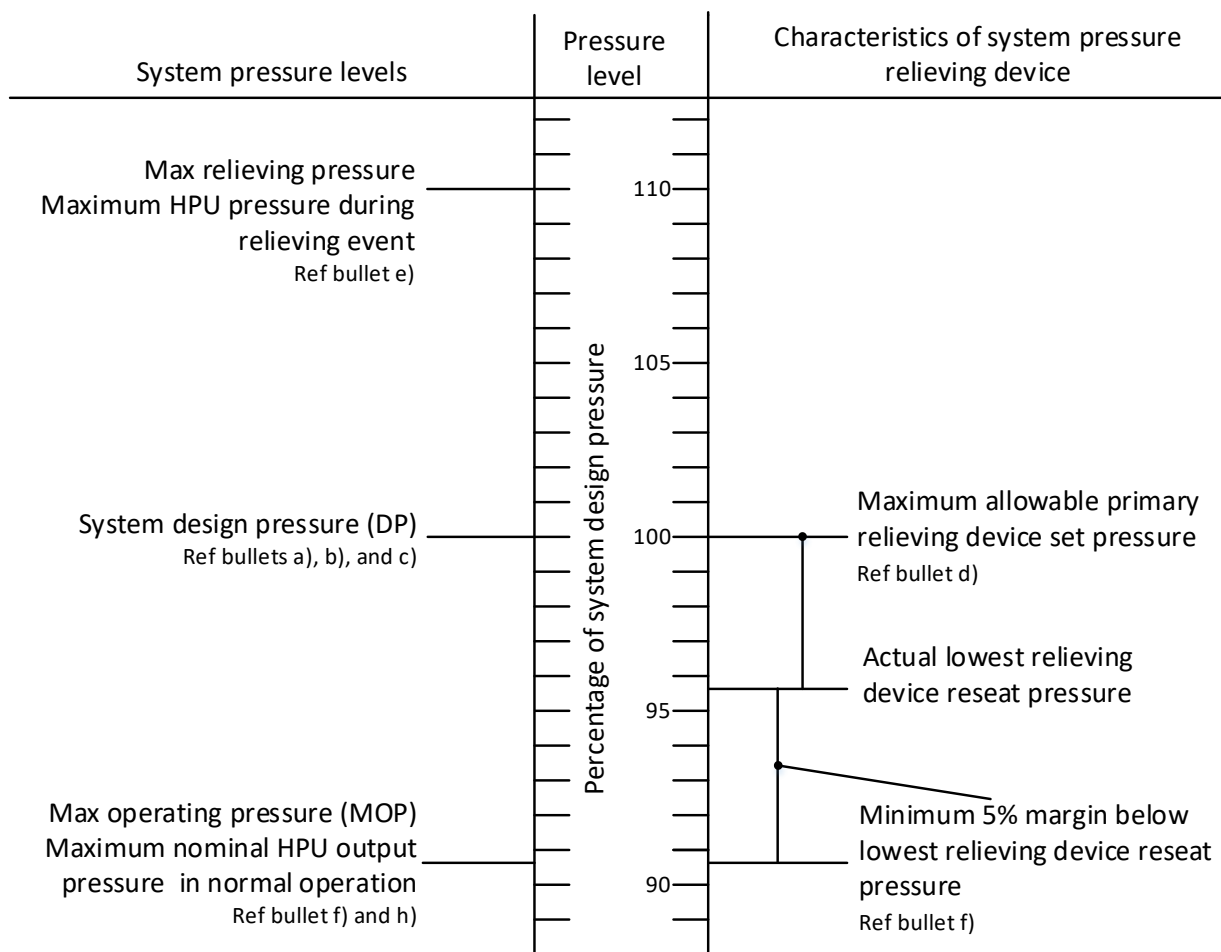
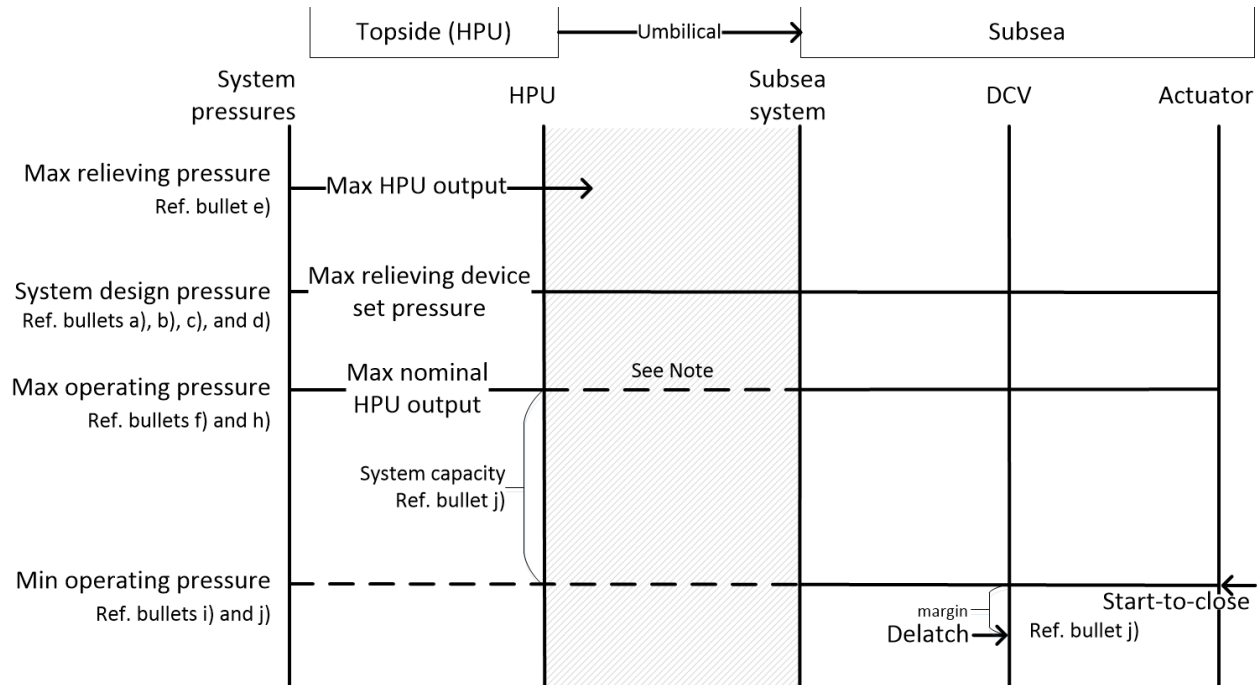


Figure 2—Hydraulic Power Unit Pressure Specification Overview



NOTE Subsea pressures relative to seabed ambient will be affected by differing control fluid and seawater densities and also due to HPU elevation above sea level. The figure is simplified by assuming control fluid density = seawater density and HPU elevation above sea level = 0 meters. Adjustment of topside (MOP) can be necessary, where applicable, if subsea OP > system DP. See bullet g) below.

Figure 3—Hydraulic System Operating Pressures Overview

- a) DP class should conform to one of the typical classes defined in Table 2. The pressure classes refer to the nominal pressure differential between internal and external pressures.

NOTE 1 Improved hydraulic system performance can often be achieved by ensuring that the actuator is designed to operate at two sequential pressure classes (see API 17D actuator hydraulic rated working pressures) and selecting and operating at the higher-pressure class.

- b) The DPs of components that form the system shall be equal to or greater than the system DP.
- c) In the case of SCSSVs and other hydraulically actuated downhole completion equipment, water depth, downhole setting depth, and XT-rated working pressure should be used as input when establishing the appropriate system DP class.

NOTE 2 SCSSV and downhole equipment functional pressure requirements are defined as absolute pressure values in recognition that downhole valve performance normally correlates with downhole process pressure, which is also defined in absolute pressure terms. However, this is not universal, as some SCSSVs have operating pressures that are not linked with downhole process pressure.

- d) Sizing of pressure relief devices shall be in accordance with API 520 and API 521.
- e) A system pressure-relieving device, normally a system pressure-relief valve, shall be fitted at the HPU with a set pressure no higher than the system DP.
- f) The system pressure-relieving device shall limit the HPU maximum relieving pressure to no higher than 110 % of system DP.

Table 2—Pressure Relations

Typical Design-pressure Classes			Hydrostatic Test Pressure		
MPa	bar	psi	MPa	bar	psi
10.3	103	1500	15.5	155	2250
20.7	207	3000	31.1	311	4500
34.5	345	5000	51.8	518	7500
51.7	517	7500	77.6	776	11,250
69.0	690	10,000	103.5	1035	15,000
103.5	1035	15,000	155.0	1550	22,500
137.9	1379	20,000	172.5	1725	25,000
172.4	1724	25,000	215.5	2155	31,250

- g) The system MOP should be set no higher than 5 % below the lowest pressure-relieving device reset pressure.

NOTE 3 The purpose is to ensure that the relieving device fully seals after operation. The specific pressure-relieving device operating characteristics define the reset pressure, the resulting margin, and, consequently, the MOP.

NOTE 4 Example: This means that a system with a 10,000 psi DP class can only be operated at approximately 9000 psi operating pressure depending on the HPU relief valve characteristics (considering additional margin due to valve hysteresis).

- h) The system MOP shall be set such that the highest subsea hydraulic differential pressure resulting from control fluid/seawater static head differences does not exceed the system DP.
- i) The selected SCSSV hydraulic supply MOP shall not overpressurize the SCSSV during well life.

NOTE 5 The maximum and minimum recommended SCSSV hydraulic operating pressure limits are defined by the SCSSV manufacturer. Provision of an operator-controlled, variable SCSSV hydraulic pressure facility at the HPU can mitigate SCSSV overpressurization over well life. This adjustment will affect all wells being fed from the same supply.

- j) The hydraulic system shall provide sufficient system capacity (see Figure 3) to supply control fluid at a pressure and average flow rate required to actuate subsea valves. The operator should specify time interval requirements for the sequential opening of wells.
- k) Local subsea transient hydraulic supply differential pressure (referenced against the relevant DCV and actuator return side pressures) experienced during valve or choke actuation shall not be lower than the Min OP. Min OP shall not be lower than the higher of:
- 1) 150 % of the highest delatching pressure of any local, latched open DCV;
 - 2) 110 % of the highest start-to-close pressure of any spring return actuator.

NOTE 6 Hydraulic system capacity (see Figure 3) is often limited by the actuator start-to-close pressure. Actuators exhibiting a lower start-to-close pressure while still conforming to other API 17D performance requirements will improve hydraulic system performance.

- l) Measures should be taken to ensure the return system is not pressurized beyond its DP. If a closed hydraulic system is used, return-line accumulation should be considered to reduce local return-side transient pressure increases.

4.3.2.3 External Hydrostatic Pressure

In some specific subsea operational scenarios (e.g. depressurized hydraulic circuits), external hydrostatic pressure can be greater than internal hydraulic pressure, leading to potential equipment collapse and/or seal damage. External pressure-loading scenarios shall be identified and evaluated in relation to seal, self-sealing coupling, umbilical core, and distribution flying lead core designs.

4.3.2.4 Hydraulic Control Fluid

Selection of hydraulic control fluid shall consider the maximum and minimum temperature and pressure to which the hydraulic fluid can be exposed in the well. The driver for the maximum fluid temperature is likely to be the flowing temperature at the SCSSV. All parts and components in the system that come into contact with the hydraulic control fluid shall be compatible with the selected fluid. Refer to 8.2.3 and Annex C.

The effect of pressure and temperature on fluid viscosity and bulk modulus, which may be significant, shall be addressed.

Control-fluid resistance to hydrate formation in case of gas ingress into control lines shall be evaluated.

4.3.2.5 System Cleanliness

The specified system cleanliness level shall be clearly identified in the manufacturer's written system specification and shall be demonstrated during the testing of the system. Achieving and maintaining fluid cleanliness from component manufacture through life of field shall be part of the overall systems approach to design, manufacture, test, and operation.

Typical system cleanliness requirements are in accordance with SAE AS 4059, Class 6, or ISO 4406, Class -/15/12.

NOTE For the purposes of this provision, SAE AS 4059, Class 6, is the equivalent of ISO 4406, Class -/15/12.

Only particles larger than 5 μm /6 $\mu\text{m(c)}$ shall be counted.

All control fluids introduced into the system shall meet the selected cleanliness requirements. Provisions shall be made to maintain cleanliness (e.g. filters) and to take fluid samples.

Methods for circulation and flushing out seawater and solid-particle contamination should be considered for the lifetime of the system.

The subsea hydraulic system shall be designed to tolerate some contamination by seawater and solid particles. In addition, the components within the hydraulic system shall be tolerant to seawater ingress and the potential corrosion that it can cause. Vulnerable parts (e.g. DCV pilot stages) shall be protected by filters or suitable screens.

Equipment cleanliness shall be verified prior to acceptance by extracting fluid samples from the system in conformance with ISO 4021 and analyzing the samples using a particle counting technique in conformance with one of the following:

- ISO 4407 hydraulic fluid power: use of optical microscope with image analysis software;
- ISO 11500 hydraulic fluid power: automatic particle counter calibrated per ISO 11171;
- ISO 21018-3 hydraulic fluid power: use of the filter blockage technique;
- the instrument manufacturer's written specifications.

System cleanliness verification shall require that two successive samples meet the required acceptance criteria.

It shall be considered that valve actuator seals and wear bands can self-generate small wear particles in operation; therefore, equipment post-acceptance fluid cleanliness requirements for the smaller particles downstream of an integrated SCM may be reduced accordingly [typically to SAE AS 4059, Class 10, for particles in the range 5 μm /6 $\mu\text{m(c)}$ to 25 μm /21 $\mu\text{m(c)}$ inclusive, or ISO 4406, class -/19/16].

4.3.2.6 Volume and Pressure Compensation

The potential for ingress of seawater during deployment and use shall be minimized. The sea chest shall be sized for the maximum required fluid volume, with a 25 % margin if the sea chest is being topped up during operation of the system (looped circuit). If the sea chests are isolated from the system, a minimum margin of 100 % is required (unlooped circuit). Compensators for the hydraulic system that are used for installation purposes only and do not compensate for actuator displacement volume should be sized based on the storage temperature limits in Table 1 and the coefficient of thermal expansion of the fluid, compressibility of the fluid, and volume of air due to underfilling, if relevant. A minimum margin of 25 % of maximum volume change shall be added to the net compensator volume.

As a minimum, the following situations shall be reviewed:

- compensation of the SCM itself, for retrieval or deployment, when it is not connected to the XT or manifold;
- the prevention of hydraulic lock during shutdown;
- the effect of ROV manual override, with and without external connections;
- fluid shrinkage during cooldown of the well, including but not limited to the lines to the SCSSV and downhole flow control devices;
- fluid expansion during warm-up of the well, including but not limited to the lines to the SCSSV and downhole flow control devices;
- looped circuit valves effectively functioning as nonlooped circuit valves during a hydraulic vent if the hydraulic pressure generated by the valve actuator latches the controlling DCV in its open position;
- the effects of pressure transients during valve stroking, which can lead to both excessively high or low (subambient) pressures in the compensation circuit and actuator spring chambers.

The pressure compensator maximum calculated fluid volume should be considered for the following situations, both individually and in worst-case combinations:

- pressure-compensation effects imposed during subsea retrieval or deployment of individual equipment items (e.g. an individual SCM);
- pressure-compensation effects imposed during subsea retrieval and deployment of equipment combinations (e.g. an SCM or subsea XT assembly).

Enclosure fluid fill volume compensation systems shall be designed with compensator volume and enclosure filling and handling procedures to meet compensation demand as follows:

- during transport and storage, the demand due to storage temperature limits in Table 1, combined with allowance for possible trapped air and losses to any hydraulic compensation within the enclosure;
- during deployment, the demand based on temperature change due to maximum possible pre-deployment storage temperature (see Table 1) and minimum local subsea temperature, combined with compressibility effects based on depth, allowance for possible trapped air, and losses to any hydraulic compensation within the enclosure.

Care should be taken to ensure that combinations of individual pressure-compensation systems do not adversely interact with each other. Specifically, a hydraulic system pressure compensator should operate independently of an associated enclosure fluid fill volume compensation system. If it is not possible to avoid interactions, the design should be checked to ensure that the compensation system thermal relief valves lift in the correct sequence.

The use of pressure-compensation systems should be considered to prevent hydraulic lock when subsea mating or demating of hydraulic couplings during all intermediate stages of subsea system infrastructure construction.

Relative density differences between seawater and internally constrained fluid volumes (e.g. hydraulic control fluids, lubricants, insulating dielectric fluids) can provide a driving force, resulting in significant and continuous fluid-transfer mechanisms. These effects should be carefully considered with respect to all potential leakage paths.

Suitable methods of avoiding continuous fluid transfer mechanisms caused by differential fluid densities should be used as appropriate (e.g. antisiphon techniques, U-tubes).

The return system filling procedure and compensation system performance should be verified by a physical "one-off" test.

Before unit deployment, it shall be verified that all air is removed from the entire hydraulic system including the return system for example by cycling the hydraulic system. It shall also be verified that compensated enclosures and associated compensation systems are completely filled with fluid.

Subsea valve actuator compensation systems shall be designed with an active compensation volume sized on the basis of the combined and accumulated effects of the following items.

- a) A base volume equivalent to the totalized spring chamber swept volume changes between the valve open and closed positions of all actuators connected to the compensation circuit.
- b) An additional volume equal to either of:
 - 25 % of the base volume if the compensation circuit is being topped up during operation of the system (looped hydraulic circuits);
 - 100 % of the base volume if the compensation circuit is isolated from the supply (unlooped hydraulic circuits).

If the compensation circuit serves multiple valves with differing hydraulic circuit configurations, then the volume allowance is established based on pro rata swept volumes using the above sizing criteria.

- c) The required compensator volume, with 25 % margin, calculated from temperature effects on the fluid during installation is considered as a one-off volume. An additional volume equal to the volumetric change of the combined compensator system volume (including spring chamber) caused by a change in ambient temperature and pressure from the API 17F upper storage temperature to the specified subsea ambient pressure and temperature. A high temperature excursion to the maximum specified storage temperature followed by deployment to the maximum rated water depth and minimum specified ambient water temperature results in the maximum compensation fluid volume change. The effects of pressure and temperature shall be calculated using the overall spring chamber fluid-filled volume, which is normally significantly higher than the swept volume change.

Tubing runs and fittings shall be sized to conform to the following operating performance requirements for individual valve closure, with calculated peak transient hydraulic flowrates in the system and most unfavorable compensation fluid physical characteristics in testing and operation.

- a) A pressure drop between compensator and actuator spring chamber of not more than 0.8 bar (12 psi).

NOTE Background for 0.8 bar (12 psi) pressure limit is to avoid pulling vacuum [low pressure (LP)] in the return circuit during workshop testing.

- b) For looped hydraulic circuits only, a pressure drop between the primary vent to sea check valve and the actuator spring chambers of not more than 50 % of the primary relief valve nominal set pressure.

Fittings used at tubing/equipment interfaces often present significant flow restrictions that can dominate tubing flow losses.

A hydraulic analysis shall be conducted, demonstrating that the requirements listed above are met by the proposed compensation system design.

The maximum useable bladder volume for a compensator to fulfill the requirements above shall be a bladder's internal volume in its natural unpressurised state. Bladders will tend to acquire this shape over time accepting that vent to sea relief valves will not maintain an internal pressure indefinitely.

4.3.2.7 Vibration and Pressure Pulses

Design of the hydraulic system should consider water hammer, high-pressure (HP) pulses, and vibration on lines, valves, and couplers. This shall include external sources (e.g. chokes). If high cyclic pressure loads are identified, the design and manufacturing should be reviewed to mitigate associated risks.

4.3.3 Electrical Power System

Subsea control system voltages shall be selected to allow the use of API 17E specified cables. Manufacturer and purchaser may agree to deploy telecoms coaxial power and communication systems with voltages up to 15 kV direct current (DC).

Unless otherwise agreed between the manufacturer and the purchaser, the electrical power for the surface control equipment of an electrohydraulic or electrical control system, its associated interfaces, and the subsea equipment shall be supplied from an uninterruptible power supply (UPS) to ensure system power quality and sufficient time to manage a controlled field shutdown.

Compatibility between the vendor electrical utilities used for testing and those that are available offshore shall be verified.

To minimize the number of conductors in the control umbilical, signal multiplexing and combining power and signal on the same pair of wires may be considered. Possible increased voltage stress on umbilical or distribution wires caused by single insulation failures shall be considered unless otherwise agreed between the manufacturer and the purchaser.

The electrical power distribution system voltage rating shall allow for operation with one earth fault. The operational duration will be dependent on system architecture. Subsea electronic components shall be procured to industrial grade or better whenever possible. The design of the subsea electrical distribution system shall consider the possibility of retrieving failed portions of the distribution network while the redundant and operational parts are in operation.

Live connection or disconnection of subsea electrical power connectors should not be required during normal operation/maintenance and during contingency fault-finding/recovery of the subsea electrical power system equipment.

Topside equipment shall be designed to facilitate modular replacement, repair, and expansion without requiring the total shutdown of the SPCS.

4.3.4 Communication System

A reliable and suitable communication system, based on a qualified design or an industry standard, shall be used for supervision, remote control, shutdown, and data transfer.

The communication system shall transport the defined data signals with high reliability and shall have sufficient capacity to handle the required traffic. There can be control system operations where a large amount of data is generated subsea (e.g. fast scan of an intelligent well system during well startup). In these instances, it may not be possible or appropriate, due to data rate limitations, to relay these data to topside in real time. Temporary storage of the acquired data subsea is acceptable (with suitable time-stamping), provided the stored data are subsequently relayed topside, as required.

Each message shall have a cyclic redundancy check (or a similar type) that reduces the possibility for faulty messages to be received and interpreted as correct. The application layers/protocols used shall have methods for handling lost messages.

Electrical and optical communication performance shall meet a frame-loss rate of less than 0.1 %.

The communications status of each device within the subsea communication system should be monitored.

The status of each communications path within the communications system should be monitored.

The subsea communications shall be prioritized according to functional criticality.

4.3.5 Optical Communication System

The fiber-optic communication system shall be modular, unless otherwise agreed between the manufacturer and the purchaser, and it should be based on a network using internet protocol (IP) over Ethernet.

A backup communications system may be realized, either by means of an electrical system or backup fibers within the umbilical. Lower-speed copper backup communications (if implemented) shall ensure that essential process data update times are not compromised or unacceptably degraded by nonessential data communications.

Configurations with direct fiber-optic connections to the subsea nodes may also be implemented.

Unused umbilical fibers shall be looped in protective caps and outgoing optical flying leads to allow for verification of umbilical fiber integrity from the topside facility.

In jumpers, flying leads and terminations, and everywhere where bending is not necessarily very well controlled, the ITU-T G.652.d should be used.

All fibers and connectors shall be compatible with optical bands used in the actual system (C, L, S Band). Commissioning and testing shall be performed at communication wavelength. There shall, unless otherwise agreed, be a 10 dB margin for a frame loss rate of < 0.1 % at 80 km (50 mi). This margin includes attenuation due to connectors, fiber splices, and fiber aging. A dedicated margin assessment shall be performed for distances longer than 80 km (50 mi). The assessment shall either include nominal loss figures for connectors, splices, and fiber aging in addition to a system margin or include worst-case scenario for all losses and aging with a reduced system margin.

NOTE The central component of a fiber-optic communication distribution system is normally a communication distribution unit (CDU) that incorporates an optical interface with the host facility and provides multiple IP over Ethernet interfaces to the subsea nodes (e.g. the SCM and other devices). The CDU often also acts as a power distribution unit to distribute, and potentially isolate, electrical power to the connected subsea nodes.

4.3.6 Redundancy

The level of redundancy depends on the actual field development, the control system uptime availability target, and the reliability of equipment used. Unless otherwise agreed between the manufacturer and the purchaser, the following guidelines are applicable.

- As design intent, the level of redundancy shall prevent or minimize the loss of subsea production caused by a single-component failure or common cause failure.
- If redundant components are used, the reliability of the method for switching from the primary to the backup component should be evaluated. Active redundancy, which enables a seamless transfer to a secondary system in the event of a primary system failure, shall be implemented.
- Unless otherwise agreed between the manufacturer and the purchaser, the subsea electrical distribution system design shall be redundant or include spares that can be configured to replace failed circuits. Facilities should be provided to enable routine monitoring of spare-line integrity.
- Unless otherwise agreed between the manufacturer and the purchaser, the subsea hydraulic distribution system shall be redundant or include spares that can be configured to replace failed lines in either LP or HP service.
- The number of spares in the umbilical should be specified based on the redundancy needed and the relative impact on umbilical design.
- Redundancy of instruments shall be based on the criticality and retrievability of the sensors.
- The level of redundancy throughout the system is influenced by the complexity and reliability. An analysis of the expected benefit from redundancy should be performed for all critical parts of the system.

NOTE A common cause failure occurs when several failures have the same origin. Common cause failures are either common event failures, where the cause is a single external event, or common mode failures, where two systems fail in the same way for the same reason.

In design, field layouts should be adopted that enable fault finding and proactive diagnostics that minimize the failure risk of other wells, well groups, or fields.

The following levels of redundancy shall be applied, unless otherwise agreed between the manufacturer and the purchaser.

- Host facility power supplies (non-UPS)—Dual redundant power supplies from the host facility to dual redundant subsea control system UPSs, each rated for 100 % of full load. The supplies may be nonsynchronous.
- Host facility UPS feeds—Dual redundant power supply feeds from the host facility UPS to the EPU, each rated for 100 % of full load. The supplies may be nonsynchronous.
- MCS input power supplies—Dual redundant input power supplies from UPS, allowing all MCS components to offer dual redundant configuration.
- Single failure or associated repair work (including software modifications) in redundant topside equipment shall not have greater consequence than loss of redundancy on power or communication to the subsea wells.

- Umbilical cores—Dual redundant electrical power circuits, electrical communication channels, optical communication channels, hydraulic power supplies, and key chemical injection supplies that are considered to be operationally required (e.g. specific hydrate inhibition requirements).
- Dual redundant subsea electronics modules (SEMs) shall be used to improve system availability.
- Additional levels of communications redundancy may be achieved in a networked communications system by routing through redundant channels.
- Subsea electrical fault isolation—Any subsea fault on one of the active dual redundant electrical power or communication channels should not affect operation of the remaining redundant channel. There should be no common cause failures (excluding catastrophic umbilical failure) associated with the electrical and power systems that will affect the remaining redundant channel, i.e. no shared splitters/connectors.
- Subsea hydraulic fault isolation—Any subsea fault on one of the active dual redundant hydraulic supplies should not affect operation of the remaining redundant supply.
- Dual redundant services (e.g. electrical power supplies, electrical communication channels, and/or optical communication channels) should not be terminated in any single subsea connector.

The purpose of the redundancy requirements in the subsea control system is to ensure high technical availability of the subsea production or process system. Redundancy requirements do not necessarily mean redundancy by duality, but the requirements may be fulfilled by alternative sensors (e.g. two pressure transducers over a flow control valve as backup for differential pressure measurement over V-cone) or alternative operations.

For communications systems with backup communications channels, changeover methods between primary and backup channels should be provided. Availability of the backup communications channel should be monitored while operating on the primary channel.

Discrepancies between redundant monitoring systems should be alarmed.

Redundancy within the shutdown system shall be developed applying the following minimum criteria.

- There shall be no single point failure that will prevent a well successfully shutting in on demand.
- Consideration shall be given to common mode and common cause failure within the systems design, manufacture, and installation. Measures should be taken to mitigate the effect of this, such as alternative batches being used for valves performing the same duty on an XT, independent design reviews, and alternate subsuppliers for critical components.

4.3.7 Reliability

Required subsea control system availability should be optimized to result in maximum benefit. Special consideration should be given to the reliability of components that are difficult to repair or replace.

Reliability for units and availability for the total SPCS for the lifetime of the field shall be documented prior to fabrication.

Unless otherwise agreed between the manufacturer and the purchaser, minimum required reliability, mean time to repair, and availability targets for subsea equipment shall be stated for each project. The demonstration of these targets should be part of equipment acceptance criteria. Tests (such as accelerated lifetime tests) or documented performance in operation (may be combined with documented production yield) shall be used to validate that reliability and expected lifetime are in accordance with specifications.

New designs shall also be validated by reliability calculations. Internationally recognized standard databases should be used for electronic component reliability.

A reliability, availability, and maintainability (RAM) analysis should be performed and form the basis for the sparing and maintenance philosophy, including the following:

- 1) description of failure modes;
- 2) consequence of equipment failure;
- 3) reliability and failure data: mean time between failure and mean time to repair for each equipment component;
- 4) full description of preventative, predictive, and scheduled maintenance practices;
- 5) full listing of equipment classification (critical, spare, etc.);
- 6) availability analysis justified by the equipment sparing plan.

Critical sensor systems located on subsea XTs or manifolds shall have component reliability or availability obtained by redundancy that is optimum, relative to the need for the sensor data and the risk of subsea intervention.

Reliability figures for critical components and assemblies shall be documented by field data or alternatively justified by calculations or tests.

The manufacturer shall use a failure reporting analysis and corrective action system, including searchable product test results and searchable failure data from the complete product life cycle.

To increase the reliability of subsea equipment, automated testing for printed circuit board assemblies (PCBAs) and subassemblies should be considered.

Refer to API 17N for additional information on reliability processes.

4.4 Functional Requirements

4.4.1 General Performance Requirements

Control system equipment that is built to this standard shall perform in a manner that is efficient and safe and that protects the environment. System performance requirements for the control system shall conform to:

- applicable regulatory authority requirements;
- operator-specified requirements.

4.4.2 Shutdown Philosophy

4.4.2.1 General

Subsea control systems shall be designed to render the production system in a safe status on loss of communications; it shall be possible to shut down hydrocarbon production by venting the hydraulic system. This may be achieved at the subsea location by de-energizing electrically held hydraulic control valve(s) or depressurizing the topside hydraulic power supply.

The system shutdown philosophy shall be developed applying the following minimum criteria.

- a) In the event of a shutdown, the primary means to command the valves to the defined safe state shall be from the SPCS via the normal communication architecture.
- b) For electrically actuated well isolation valves, in the event that the communication system is unavailable, then the loss of electrical power via the host system shall be available as the contingency method to initiate valve actuation to defined safe state. Configurable timers may be used to achieve a defined closure sequence across an XT or subsea piece of equipment. The target PFD for this function shall be defined according to the operator's safety analysis and local regulatory requirements. Where a safety function is identified, this shall be specified, designed, and built according to IEC 61511, following a full safety life cycle approach. If the surface elements used to initiate the contingency power loss condition of the valves are defined as part of a safety function (e.g. ESD), they shall be considered safety critical and conform to IEC 61508.
- c) The in-service testing and maintenance of this contingency electrical shutdown function shall be dependent on the defined PFD and/or local regulatory requirements.
- d) Diagnostic features relevant for any safety function(s) shall be compliant with IEC 61508 and evaluated as part of safety analyses.
- e) Failure of the primary SPCS means to initiate actuation to the safe state shall not prevent the contingent electrical power loss-initiated closure. This shall be confirmed through recognized analyses, e.g. failure mode, effects, and criticality analysis (FMECA) and qualification (failure mode) testing.

On return of electrical power and communication, actuators shall remain in their fail-safe position until restarted by the operator after the trip condition is cleared. There shall be no single-component failure that prevents the closure of the SCSSV and the designated subsea barrier valves. Specific cases that should be reviewed are as follows:

- locking mechanism failure or inadvertent operation that results in disconnection of a hydraulic interface;
- empty sea chest preventing subsea valve closure by generation of a hydraulic lock, particularly when a closing actuator can generate sufficient hydraulic function line pressure to latch open its controlling DCV and render a local looped hydraulic circuit inoperative;
- hydraulic supply shuttle valves with a blocked mid-position, or situations where one of the input supply lines is left in an isolated condition with locked-in pressure.

4.4.2.2 Requirements for “Energize to Trip” Systems

Systems incorporating subsea electrical energy storage and an “energize to trip” (non-spring) shutdown, requiring functional safety compliant operation of valves, shall additionally apply the following minimum criteria.

- a) The battery system shall be designed, built, and tested according to IEC 61508 with a target PFD defined according to the operator's safety analysis and local regulatory requirements.
- b) A partial stroke function test shall be provided. The function test shall be configurable with a percentage movement along with a time limited back stop to mitigate the chance of unwanted excess valve movement. The impact on valve seals of partial stroke testing shall be validated and demonstrated.
- c) Loss of power (communication is available) does not require valves to actuate to a defined safe state providing there is sufficient battery charge to complete actuation of the valve and local requirements permit. Critical failures modes of the system shall be established by performing FMECA/failure mode, effects, and diagnostic analysis. The acceptable response of the system to failures shall be tested during qualification testing of the completed unit with target hardware and software. Critical failures will depend on the details of a system design. Some examples are as follows:

- failure to detect a dangerous situation (loss of power, communication, battery level) and to actively start up the safety function (e.g. safety relays);
 - failure by transmitting the electric energy (such as failure in internal or external cable, connectors, wiring, etc.);
 - failure by converting the electric energy in mechanical movement (wear out of electric motor parts or mechanical gear boxes);
 - failure in any software system that may cause the loss of the safety function, e.g. freezing of the execution of a critical function of the firmware within the processor; such software modules are safety relevant and shall fulfill the requirements specified in IEC 61508-3, including firmware updates, monitoring systems, and communication systems;
 - failure of the battery monitoring system preventing the charge of the battery to be reliably determined;
 - loss of ability to charge the batteries;
 - reduction in performance of the battery below an acceptable limit;
 - unknown valve position.
- d) If a critical failure is detected by the system, this shall be immediately alarmed to the SPCS and no further valve command shall be executed except to command the valve to its defined safe state. The system may, after a configurable delay, automatically be brought to its defined safe state by the SPCS upon detection of a critical state.
- e) Subsea systems with local power storage shall provide updated status from subsea valves and critical instrumentation following a shutdown trigger (loss of main charging supply from topside). This may be stored subsea if communications to topside is lost and for as long as local power storage permits.
- f) For non-spring return solutions, these shall be considered safety critical and conform to IEC 61508. Two useable charge levels shall be established for each system, a low level and low-low critical level. Valve operations within these charge levels will be restricted as follows: if the charge falls below the low level, no further valve actuations shall be permitted, except to the defined safe state.
- g) If the charge falls below the low-low critical level, the valve shall automatically initiate actuation to the defined safe state. This automatic action may be performed by the SPCS.

4.4.3 Valve Response Time

4.4.3.1 Subsea Valve Closing-time Requirement Using Primary Control Mode

The subsea control system, in combination with all other elements of the shutdown system, shall complete closure of SCSSVs and designated subsea barrier valves within the maximum response time specified by the operator and in compliance with applicable regulatory authority requirements.

4.4.3.2 Requirement for Subsea Valve Contingency Closure Control Mode

Contingency methods that render the production system in a safe state by closing the SCSSV and designated subsea barrier valves, and that are functionally independent of the primary subsea control system, shall be provided in compliance with operator and regulatory authority requirements.

Individual components or subsystems in the subsea control system that are part of the contingency closure system (e.g. HPU hydraulic vent valves, SCM electrically held-open DCVs) shall comply with applicable contingency closure system specifications.

The primary subsea control system shall ensure that SCSSVs and designated subsea barrier valves that are closed by contingency closure control mode are prevented from automatically reopening on reinstatement of the appropriate hydraulic and/or electrical supplies.

4.4.3.3 Subsea Valve Closing-time Requirement Using Contingency Closure Control Mode

Individual subsea control system components or subsystems that are part of the contingency closure system (e.g. HPU hydraulic vent valves, SCM electrically held-open DCVs) shall operate individually in a time that, combined with all other elements of the contingency closure system, allows closure of SCSSVs and designated subsea barrier valves to be completed within the maximum response time specified by the operator and in compliance with applicable regulatory authority requirements.

4.4.3.4 Failure of Valve Actuator Hydraulic Boost System

If designated subsea barrier valve actuators are fitted with a hydraulic boost system, failure of the boost system shall not prevent valve closure within the maximum response time specified by the operator and in compliance with applicable regulatory authority requirements.

4.4.3.5 Prediction and Verification of Subsea Valve Response Times

Subsea valve closure response times shall be predicted for the full control system before fabrication. Unless otherwise agreed between the manufacturer and the purchaser, one of the following methods shall be used to verify that the response times meet the objectives.

- Run a control system simulation using a previously calibrated model for an identical umbilical material, allowing for new variables (e.g. control path length, operating pressure) and end-device characteristics.
- Measure the response time directly by using a similar system configuration and equipment. Justify the predicted response time by calculations and experience.

In addition, subsea valve response times and contingency closure response times should be demonstrated and verified against analysis after installation to confirm that the measured response times are within the required limits.

4.4.4 Functional Considerations

4.4.4.1 Barrier Valve Tests and Diagnostics

The subsea control system shall support the performance of regulatory mandated barrier valve tests on the subsea equipment. The control system shall provide the capability to facilitate diagnostics of the failure conditions.

NOTE Regulatory requirements can include testing of high-integrity pressure protection system barrier valves and designated subsea barrier valves.

4.4.4.2 Interlocks (Permissive Logic)

The following interlock functions (i.e. permissive logic that needs to be satisfied before the action can initiate) should be considered.

- Prevent the SCSSV from opening unless the production master valve or production wing valve (PWV) is closed.
- Prevent the operator from inadvertently commanding the SCSSV closed against flow.
- Prevent the operator from inadvertently commanding annulus barrier valves, production barrier valves, and crossover valves simultaneously open.
- Prevent the PWV from opening unless the choke is at the preset position.

4.4.4.3 SCSSV or Intelligent Well Completion Seal Failure

Backflow of well fluids into the subsea control system caused by SCSSV or IWCS seal failure shall not impair the ability of the subsea control system to execute closure of the designated subsea barrier valves.

The potential for gas hydrate formation on vent-to-sea relief valves that results from SCSSV or IWCS seal failure shall be considered. If appropriate, suitable measures should be taken to avoid compromising well control.

The impact of hydrocarbon ingress on SCM performance that results from an SCSSV or IWCS seal failure shall also be considered. If appropriate, suitable measures should be taken to avoid compromising well operations.

In the case of SCSSV and IWCS downhole device hydraulic actuation, the hydraulic system design shall address the following environmental and operational issues associated with potential gas leakage past the devices into the hydraulic function line(s).

- The provision of downhole function line isolation facilities should be considered.
- SCSSV, IWCS, and LP XT valves shall not share hydraulic SCM return circuits or vent-to-sea ports.

4.4.4.4 Actuation Indication

The subsea control system shall provide a surface indication of the actuation of a selected function. As appropriate to the hardware, such indication may be through the use of visual flow indicators, pressure transducers, pressure gauges, position-indication sensors, flow sensors, or pressure sensors.

4.4.4.5 Protection of SCSSV

Under commanded-closure conditions, the design of the production control system shall protect the SCSSV from slam or creep closure on a flowing stream. Any such provision shall not affect the ability of the SPCS to close the SCSSV in shutdown conditions.

4.4.4.6 Flushing of SCSSV Hydraulic Circuit

Provisions for flushing the hydraulic circuit from the control module to the SCSSV during installation and in the operational phase shall be considered as part of front-end engineering.

4.4.4.7 Safety Isolation During Workover

The subsea control system shall be capable of being positively disabled from the operation of XT control functions while a workover control system is in use on that XT.

4.4.4.8 Control Fluid Venting and Leakage

External venting and leakage of control fluids shall not exceed local regulatory requirements. Internal leakage shall not exceed the control component manufacturer's written specifications.

For closed hydraulic systems, the return system shall be sized for the maximum internal leakage.

4.4.4.9 Load Capability

Product designs shall be capable of sustaining rated loads without degradation, exceeding the allowable stresses, or impairment of other performance requirements.

4.4.4.10 Subsea Processing System and Closed-loop Control

Subsea processing systems are defined as systems containing one or more of the following elements:

- a) separation;
- b) boosting;
- c) gas compression;
- d) antisurge control;
- e) active chemical dosing;
- f) magnetic bearing control;
- g) active choke control.

A subsea processing installation may comprise one or several closed control loops along with shutdown functions to maintain the control and safety of a particular piece of equipment. A study shall be completed to identify and describe the control loops, shutdown functions, and determine their required safety integrity level. A strategy shall be developed addressing whether such control loops should be closed subsea or topsides.

Shutdown functions and control loops shall be segregated and use different instrument hardware such that a dangerous failure of either system will not prevent the other from operating. Logical segregation of safety functions and basic process control functions onto common data transport networks is permitted provided this complies with IEC 61508/IEC 61511 requirements.

Dynamic performance and response requirements for all active control loops shall be established. A subsea processing system may have multiple active control functions that are time critical.

The control system shall meet all requirements driven from the respective time constants. In addition to level, flow, and pressure control, control of antisurge valves can in certain applications be a time-critical control loop.

Control loops can be closed through application software at host facility or through application software locally within the subsea hardware.

Unless otherwise agreed between the manufacturer and the purchaser, the process control and the production control communication systems shall be identical in technology and topology type if supplied by the same contractor.

The digital security of the process control network shall be considered and measure taken to ensure that the cybersecurity requirements are considered within the design and configuration of the system.

The subsea control system shall have a defined fail-safe state for all control loops. System response in case of communication loss shall be defined as per system analysis.

Processing control system shall include embedded system health monitoring tools (tools to monitor system communications loading, memory use, CPU loading, etc.).

Diagnostic utilities that identify faults and failures as defined by the chosen system analysis methods (FMECA, HAZOP, HAZID, RAM, etc.) to ensure a fully operable system shall be implemented.

The subsea control system shall be designed such that active control parameters can be tuned from the distributed control system (DCS) to optimize control performance based on operational experience.

Control loop performance monitoring applications may be used to remotely diagnose and optimize performance of controls loops. Control loop performance data shall be shared with the host facilities control system to facilitate the use of such applications.

Subsea production control and process control should share one HPU.

The production control system and the process control system should use different conduits for supply of hydraulic power (may be in the same umbilical), unless analyses demonstrate that pressure fluctuations are within acceptable limits.

Sensors shall use subsea instrumentation interface standardization (SIIS) interface as defined in 7.5.

Sensors shall be considered that will enable early warning of impending failure of subsea rotary machinery (pumps and compressors). Machinery protection must align with the principles of API 670, considering the particular application to subsea.

The process control design should use redundant equipment such that no single point failure shall impact the availability of the system especially for power, communications, control function processing, and I/O cards.

Segregation between the production control system and the processing control system shall be considered. Where common equipment is shared, the impact of failures shall be understood and impact considered within the design. Consideration should also be given to the segregation of processing equipment performing parallel operations to minimize common failure point within the design.

The production control system and the processing control system shall use different optical fibers for communication unless analyses demonstrate acceptable performance in combined communications (fibers may be located in the same optical bundle).

Safe operating limits shall be defined for the processing equipment and suitable alarms set to provide early warning of a potential issue to operators.

4.5 Design Requirements

4.5.1 General Requirements

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.

Vulnerable areas for connection (e.g. electrical connectors, hydraulic couplers, and stab plates) should be furnished with necessary protection equipment to protect the equipment while it is unmated and in service and to prevent calcareous buildup and marine growth.

Special safety considerations (with respect to personnel) shall be paid to electrical components that are deliberately electrically isolated from their supporting equipment during surface testing programs to mitigate against potentially hazardous internal ground faults.

Equipment design shall mitigate potential overpressurization of filled or partially filled retrievable equipment when it is recovered from subsea.

4.5.2 Design Methods

4.5.2.1 Pressure-containing Vessels

All pressure-containing vessels used for applications in excess of 0.1 MPa (15 psi) shall meet the requirements of the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1; BS EN 14359; ISO 10945; or any other agreed-upon pressure vessel or accumulator code or standard.

NOTE For the purposes of this provision, BS 7201-2 is the equivalent of ISO 10945.

4.5.2.2 Electrical Devices

All electrically driven motors, motor starters, and other electrical devices shall conform to the requirements of an appropriate approved electrical code for the equipment location.

4.5.2.3 Interconnecting Tubing

All tubing runs shall be installed with sufficient and appropriate clamps to prevent vibration-induced fatigue failure. Interconnecting control tubing shall meet the requirements of ASME B31.3 or other agreed-upon piping code or standard.

A positive means of preventing tubing fitting back-off shall be provided at interconnecting hydraulic supply or actuator function line tubing interfaces.

4.5.2.4 Components Containing Software and Configuration Data

Software and firmware used in production, test, and installation equipment shall be developed, acquired, supplied, configured, tested, maintained, and supported in conformance with recognized and verifiable standards. The minimum requirements shall be as described in ISO 9001/API Q1 and ISO/IEC 90003.

Configuration data associated with the software development shall also be maintained and controlled using a documented configuration management system.

Planning of software development and configuration activities, in all phases of the project, shall include progress monitoring and shall identify all interdependencies with internal and external interfaces, engineering, production, testing, and delivery of other equipment.

The documentation, including functional descriptions, shall at any stage in the development be auditable and reflect the actual software.

4.5.3 Condition Monitoring

All data available in the SPCS shall be made available for remote trending.

Unless otherwise agreed between the manufacturer and the purchaser, SPCS data shall be individually evaluated for inclusion in external condition-based maintenance applications.

During system testing and operation, valve signatures shall be recorded, unless otherwise agreed between the manufacturer and the purchaser.

NOTE The large quantity of status parameters and measurements generated by the SPCS can potentially provide valuable diagnostic information about the system and can play an essential role in condition monitoring, fault detection, and failure analysis.

4.5.4 Design Analysis

4.5.4.1 General

Analyses shall be performed on the proposed subsea control system for the purpose of validating compliance with system requirements (e.g. performance characteristics, performance requirements, component reliability, system availability, system fault tolerance).

Analysis work shall include the following:

- hydraulic and electrical power requirements for valve operations;
- hydraulic system operation and response time analysis;
- electrical power distribution analysis;
- communication analysis;
- failure mode effects and criticality analysis;
- reliability, availability, maintainability analysis;
- safety assessment analysis;
- mechanical and thermal analysis;
- structural (static) analysis.

4.5.4.2 Hydraulic Systems

A simulation of the hydraulic system shall be created and an analysis made, such that the required opening and closing time requirements for the system can be verified. The simulation shall model project-specific control fluid physical properties.

The hydraulic analysis or demonstration by other means shall establish the following:

- time to prime the hydraulic system from a depressurized state;
- opening and closing response times of the process valves under conditions of absence of any bore-pressure assistance, minimum and maximum process pressure;
- time for the pressure to recover following a process valve opening;
- time to carry out a sequence of valve openings (e.g. the opening of an XT);
- time to carry out a specified sequence of well open or close operations;
- stability of opened control and process valves to pressure transients caused by the operation of other control and process valves (e.g. unintended control valve delatching or partial closing, process valve partial closing);
- stability of opened downhole control and safety valves to pressure transients caused by the operation of other safety or IWCS valves (e.g. unintended control valve delatching, process valve partial closing);

- response time to close process valves in the event of a common close command (e.g. vent-down at the surface; venting off hydraulic control valves via supply lines), including any DCV latch-open effects caused by closing process valve-generated hydraulic pressures;
- response time and pressure for multiple simultaneous choke operations;
- response time and pressure for continuously energized subsea quick dump valve where used for SCM supply line depressurization; response time and pressure for closed hydraulic systems;
- peak return-line pressure transients that can cause partial opening of closed process valves and damage to hydraulic components with limited return-pressure capability;
- impact that the failure of subsea accumulation and return-line boost pressure systems (assist closing systems) have upon the safe operation and closure of the process valves;
- impact of the loss of subsea accumulator precharge;
- extent of control fluid total loss rate;
- hydrostatic conditions that can give rise to line collapse, seawater ingress, etc., caused by differential hydrostatic pressures resulting from differential heads and differential fluid densities.

XT actuator hydraulic systems should be configured as looped hydraulic circuits to exhaust control fluid to sea (for an open hydraulic system) or to the umbilical return line (for a closed hydraulic system) during the actuator opening stroke.

The specific SCSSV manufacturer should define the maximum and minimum recommended SCSSV hydraulic supply pressure limits to the SPCS manufacturer, and these limits shall be addressed in the system hydraulic analysis.

4.5.4.3 Electrical Control Power Systems

The subsea electrical power distribution analysis shall determine whether all elements of the subsea control system will operate within their specified limits with regard to voltage range and power handling, including appropriate margins.

The electrical control power analysis or demonstration by other means shall establish the following:

- minimum and maximum subsea electrical loads (e.g. predicted variations in SEM loading, including SEM infrastructure, communications system load variations, instrumentation load variations, and transient loads associated with valve and choke control);
- minimum and maximum subsea consumer demand, taking into account phased installation, start-up, and specified future expansion;
- minimum and maximum umbilical lengths, including allowances for final installed lengths (as-built);
- operation of system with maximum design case fault tolerance (e.g. for redundant systems; operation on a single channel, including the impact of shared loads);
- variations in umbilical characteristics (resistance, inductance, capacitance, conductance), including allowances for manufacturing tolerances and the impact of final installed conditions (e.g. increased capacitance for free flooding cables, the effects of temperature);

- minimum and maximum topside supply voltages resulting from supply output voltage regulation specification and regulation caused by supply cabling impedance;
- UPS supply requirements.

NOTE The analysis can require multiple runs using differing control system design elements to iterate to an acceptable solution. These design elements can include topside and subsea transformer turns, ratio variations, electrical flying lead (EFL) cross-sectional area variations, and tighter control of minimum and maximum load cases through system operational restrictions. In some instances, changes to umbilical characteristics can be necessary to produce a viable system.

4.5.4.4 Electrical Actuator Power Systems

Design analysis shall be performed to demonstrate adequate system sizing of the electrical actuator power systems, including energy storage units to accommodate valve operations that satisfy all relevant operational requirements. This analysis shall at a minimum include the following:

- power load profiles based on specific project requirements;
- the low threshold is defined as the battery power required to perform two full XT closures (close open-close), with an appropriate margin, and shall be validated by adequate testing; the low-low threshold is defined as the battery power required to perform one full XT closure, with an appropriate margin, and shall be validated by adequate testing;
- end-of-life capacity;
- maximum battery cell temperature under worst-case load and charge conditions; battery cycle life at a depth of discharge (DoD) of 50 % enabling comparison of different solutions and an end of charge (EoC) worst case to be considered; battery charging time for normal operation with defined DoD and EoC;
- demonstrable fault-tolerant design voltage at actuator for maximum and minimum load;
- the minimum stored power for specified subsea valve operation, if local battery power is used;
- opening and closing response times of the process valves under conditions of minimum and maximum process pressure;
- time to recover following a process valve stroking;
- time to conduct a sequence of valve openings (e.g. the opening of an XT);
- time to conduct a specified sequence of well open or close operations;
- stability of opened downhole control and safety valves to transients caused by other operations;
- response time to close the process valves in the event of a common close command;
- response time for multiple simultaneous choke operations.

4.5.4.5 Communication Systems Analysis

4.5.4.5.1 General

The electrical and optical communication system analysis or demonstration by other means shall establish the following: