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Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 6: Subsea production control systems

*Industries du pétrole et du gaz naturel — Conception et exploitation des
systèmes de production immergés —*

Partie 6: Commandes pour équipements immergés



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13628-6 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

This second edition cancels and replaces the first edition (ISO 13628-6:2000) which has been technically revised.

ISO 13628 consists of the following parts, under the general title *Petroleum and natural gas industries — Design and operation of subsea production systems*:

- *Part 1: General requirements and recommendations*
- *Part 2: Unbonded flexible pipe systems for subsea and marine applications*
- *Part 3: Through flowline (TFL) systems*
- *Part 4: Subsea wellhead and tree equipment*
- *Part 5: Subsea umbilicals*
- *Part 6: Subsea production control systems*
- *Part 7: Completion/workover riser systems*
- *Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems*
- *Part 9: Remotely Operated Tools (ROT) intervention systems*
- *Part 10: Specification for bonded flexible pipe*
- *Part 11: Flexible pipe systems for subsea and marine applications*

Part 12 on dynamic production risers is in preparation.

Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 6: Subsea production control systems

1 Scope

This part of ISO 13628 is applicable to design, fabrication, testing, installation and operation of subsea production control systems.

This part of ISO 13628 covers surface control system equipment, subsea-installed control system equipment and control fluids. This equipment is utilized for control of subsea production of oil and gas and for subsea water and gas injection services. Where applicable, this part of ISO 13628 can be used for equipment on multiple-well applications.

This part of ISO 13628 establishes design standards for systems, subsystems, components and operating fluids in order to provide for the safe and functional control of subsea production equipment.

This part of ISO 13628 contains various types of information related to subsea production control systems. They are

- informative data that provide an overview of the architecture and general functionality of control systems for the purpose of introduction and information;
- basic prescriptive data that shall be adhered to by all types of control system;
- selective prescriptive data that are control-system-type sensitive and shall be adhered to only when they are relevant;
- optional data or requirements that need be adopted only when considered necessary either by the purchaser or the vendor.

In view of the diverse nature of the data provided, control system purchasers and specifiers are advised to select from this part of ISO 13628 only the provisions needed for the application at hand. Failure to adopt a selective approach to the provisions contained herein can lead to overspecification and higher purchase costs.

Rework and repair of used equipment are beyond the scope of this part of ISO 13628.

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.

ISO 3722, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods*

ISO 4406:1999 *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 7498 (all parts), *Information processing systems — Open Systems Interconnection — Basic Reference Model*

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

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

ISO 10423, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

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

ISO/TR 10949, *Hydraulic fluid power — Component cleanliness — Guidelines for achieving and controlling cleanliness of components from manufacture to installation*

ISO 13628-4, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment*

ISO 13628-5, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 5: Subsea umbilicals*

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*

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*

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/TS 16431, *Hydraulic fluid power — Assembled systems — Verification of cleanliness*

ANSI/ASME B31.3, *Process Piping*

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

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

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

ASTM D445, *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)*

ASTM D471, *Standard Test Method for Rubber Property — Effect of Liquids*

ASTM D665:2003, *Standard Test Method for Rust Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water*

ASTM D892, *Standard Test Method for Foaming Characteristics of Lubricating Oils*

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

ASTM D1298, *Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

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

ASTM G1:2003, *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*

BS 7201-1, *Hydraulic fluid power — Gas loaded accumulators — Specification for seamless steel accumulator bodies above 0,5 l water capacity*

DIN 41612-2, *Special contacts for multi two-part connectors; concentric contacts (type C)*

IEC 61892 (all parts), *Electrical installations of ships and of mobile and fixed offshore units*

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

Internet RFC 793, *The 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>

IP 34, *Determination of flash point Pensky-Martens closed cup method*

IP 135:2005, *Determination of rust-preventing characteristics of steam-turbine oil in the presence of water*

3 Terms and definitions

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

3.1

boost

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

3.2

commanded closure

closure of the underwater safety valve and possibly other valves depending on the control system design

NOTE Such commands can originate manually, automatically or as part of an ESD.

3.3

control path

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

3.4

design pressure

maximum pressure for which the system or component was designed for continuous usage

3.5

design life

specified operational life of system after pre-delivery test

3.6

diagnostic data

data provided to monitor the condition of the downhole equipment

NOTE Can include the ability to make (engineering) adjustments.

3.7

direct hydraulic control

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

NOTE Upon venting of the pressure at the surface, the control fluid is returned through the umbilical to the surface due to the action of the restoring spring in the valve actuator. Subsea functions may be ganged together to reduce the number of umbilical lines.

3.8

downstream

away from a component in the direction of flow

3.9

electrohydraulic control

control method wherein communication signals are conducted to the subsea system and used to open or close electrically-controlled hydraulic control valves

NOTE Hydraulic fluid is locally sourced and acts on the associated subsea valve actuator. "Locally sourced" may mean locally stored pressurized fluid or fluid supplied by a hydraulic umbilical line. With electrohydraulic control systems, data telemetry (readback) is readily available at high speed. Multiplexing of the communication signals reduces the number of conductors in the umbilical.

3.10

expert operation

operating the IWCS with other control commands or other methods than used for normal operation

NOTE Typically used by IWCS supplier or other skilled resource to read IWCS diagnostic data and make (engineering) adjustments to IWCS equipment.

3.11

hydrostatic test pressure

maximum test pressure at a level greater than the design pressure (rated working pressure)

3.12**intelligent well**

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

3.13**intelligent well control system**

control system used to operate an intelligent well

3.14**normal operation**

operating the system to perform the intended basic functionality

3.15**offset**

horizontal component of control path length

3.16**proof pressure**

maximum test pressure at a level greater than the design pressure

3.17**response time**

sum of the signal time and the shift time

3.18**running tool**

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

NOTE An example is the subsea control-module running tool.

3.19**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

NOTE Of primary interest is the time to fully stroke, on a subsea tree, a master or wing valve that has been designated as the underwater safety valve.

3.20**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)

3.21**subsea production control system**

control system operating a subsea production system during production operations

3.22**surface safety valve**

safety device that is located in the production bore of the well tubing above the wellhead (platform well), or at the point of subsea well production embarkation onto a platform, and that will automatically close upon loss of hydraulic pressure

3.23**umbilical**

combination of electric cables, hoses or steel tubes, either on their own or in combination (or with fibre optic cables), cabled together for flexibility and over-sheathed and/or armoured for mechanical strength and typically supplying power and hydraulics, communication and chemicals to a subsea system

3.24

underwater safety valve

safety valve assembly that is declared to be the USV and which will automatically close upon loss of power to that actuator

3.25

upstream

away from a component against the direction of flow

3.26

well data

data provided from the downhole equipment for reservoir description, flow calculations and routine production monitoring

NOTE Typically, these include sensor readings and valve positions.

3.27

β

filtration ratio

4 Abbreviated terms

ANSI	American National Standards Institute
AC	alternating current
API	American Petroleum Institute
AS	Aerospace Standard
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BER	bit error rate
capex	capital expenditure
CB	centre of buoyancy
CISPR	Comité International Spécial des Perturbations Radioelectrique (International Special Committee on Radio-Interference)
CIU	chemical injection unit
CIV	chemical injection valve
CPS	combined power and signal
CW	clockwise
DC	direct current
DCS	distributed control system
DCV	directional control valve
DH	direct hydraulic
EPU	electrical power unit
EM	electromagnetic
EMC	electromagnetic compatibility
ESD	emergency shutdown
ESS	environmental stress screening
ETH	ethernet
EUT	equipment under test

EXT	extended
FAT	factory acceptance test
GND	ground
HF	high frequency
HIPPS	high integrity pipeline protection system
HP	high pressure
HPU	hydraulic power unit
HRC	hardness Rockwell C
HV	high voltage
IEC	International Electrotechnical Commission
I/O	input/output
IP	Institute of Petroleum
iSEM	intelligent well subsea electronics module
ISM	industrial, scientific and medical
ITE	information technology equipment
IWCS	intelligent well control system
IWE	intelligent well equipment
LF	low frequency
LP	low pressure
MCS	master control station
MIL-STD	Military Standard
mo	month
MV	manifold valve
OPC	object linking and embedding (OLE) for process control
Opex	operational expenditure
OREDA	offshore reliability data
OSI	open system interconnection
PH	piloted hydraulic
PMV	production master valve
PSD	process shutdown
PTFE	polytetrafluoroethylene
PWV	production wing valve
RET	return
RMS	root mean square
ROV	remotely operated vehicle
RPC	remote procedure call
RX	radio receiver
SCM	subsea control module
SCSSV	surface-controlled subsurface safety valve
SEM	subsea electronic module
TAN	total acid number
TBD	to be decided
TBN	total base number
TCP	transmission control protocol

THD	total harmonic distortion
TX	radio transmitter
UPS	uninterruptible power supply
USV	underwater safety valve
VAC	volts alternating current
VDC	volts direct current
wk	week
yr	year

5 System requirements

5.1 General

In 5.2 to 5.6 are described the activities of specifying organisations. Reference should be made to Annex A for types and selection of control system, and to Annex B for typical control and monitoring functions.

5.2 Concept development

During front-end engineering, possible impact on control system functionality and infrastructure related to the following items shall be considered:

- flexibility with respect to production scenarios;
- optimization with respect to operation;
- optimization with respect to cost-effective installation;
- optimization with respect to phased production development;
- flow assurance;
- project execution time;
- life cycle cost [component cost (capex), installation cost (opex), operation/maintenance/intervention cost (opex)].

Operational philosophy, installation sequences and possible operational challenges shall be evaluated during front-end engineering.

Reference should be made to Annex D for operational considerations with respect to flowline pressure exposure.

5.3 Production control system functionality requirement

5.3.1 General

The subsea production control system shall allow for flexibility and optimization. The basic system design shall to a maximum extent allow for a full range of functionality with use of existing infrastructure.

The following elements shall be considered during system engineering:

- intelligent well application;
- flexibility with respect to electrical load situations (power and communication);
- robustness of hydraulic system;
- prevention of seawater ingress in hydraulic system;

- seawater ingress 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.

5.3.2 Intelligent well application

If an intelligent well completion is clearly defined as a current or future requirement by front-end engineering efforts, the control system will provide valve functionality, data retrieval, computational support and communication pathways without the need for changing the subsea umbilical system and the associated distribution system. Subsea control modules may be expected to be retrieved and retrofitted to accommodate the introduction of smart well systems at a future date.

Automatic shutdown functionality is not required for the downhole intelligent well functions.

5.3.3 Flexibility with respect to electrical load situations (power and communication)

The system should be built to function properly within a large range of electrical load variations to allow for flexibility regarding new wells. Load flexibility can help overcome electrical distribution system failures by connecting more wells to the same cable.

5.3.4 Robustness of hydraulic system

The hydraulic system shall be robust and maintain acceptable pressure values in the SCM during all modes of operation.

Actuation of valve actuators shall not cause alarms or unintended valve movement due to low supply pressure in the SCM. The pressure should not drop below 150 % of the highest latching pressure of any DCV.

5.3.5 Seawater ingress in hydraulic system

The hydraulic system shall be designed to minimize seawater ingress in all operational scenarios, including installation and retrieval of individual units. If seawater ingress prevention cannot be guaranteed or if there is a credible risk of seawater ingress, SCM fluid-wetted components should be considered along with procedures to flush out contaminated fluid.

5.3.6 Subsea intervention

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

5.3.7 Increased scope with respect to number of wells

The system shall allow for flexibility with respect to number of wells tied into the system. Operational and criticality analysis should represent the practical limitations with respect to number of wells rather than mechanical limitations.

5.3.8 Increased scope with respect to number of umbilicals

System design, when defined as a future requirement by front-end engineering, shall allow for additional umbilical systems to be connected. A philosophy covering both serial and parallel connections should be outlined.

5.3.9 Interface toward subsea separation/subsea boosting system

The system design when defined as a future requirement by front-end engineering shall allow for possible connection of a subsea separation or boosting system without extensive marine operations or modifications related to an existing system. Possible impact on production control system shall be described at an outline level during system design.

5.3.10 Subsea chemical injection

Flow-assurance issues shall be considered during front-end engineering. The system shall 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, plan for possible subsea chemical injection system add on, reconfiguration of lines, etc. Possible impact on production control system shall be described at an outline level during system design.

5.3.11 Downhole instrumentation system interfaces

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

5.3.12 Downhole chemical injection

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

5.4 General requirements

5.4.1 General

The functional building blocks of a subsea production control system typically include the following. These building blocks may be integrated in the same physical units:

a) hydraulic power unit (HPU):

The HPU provides a stable and clean supply of hydraulic fluid to the remotely operated subsea valves. The fluid is supplied via the controls' umbilical, the subsea hydraulic distribution system, and the SCMs (if included in system design) to operate subsea valve actuators.

b) chemical injection unit (CIU):

The CIU provides single and/or mixed "cocktail" chemicals at constant regulated pressure or metered volume. The fluid is supplied via the hydraulic umbilical and the subsea hydraulic distribution system to the injection points of the subsea production system.

c) master control station (MCS):

The MCS may be the central control "node" containing application software required to control and monitor the subsea production system and associated topside equipment such as the HPU and EPU.

d) distributed control system (DCS):

The DCS can perform the same functions as an MCS, but with a decentralized configuration.

e) electrical power unit (EPU):

The EPU supplies electrical power at the desired voltage and frequency to the subsea users. Power transmission is performed via the electrical umbilical and the subsea electrical distribution system.

f) modem unit:

This unit modulates and demodulates communication signals for transmission to and from the applicable subsea users.

g) uninterruptible power supply (UPS):

The UPS is typically provided to ensure safe and reliable electrical power to the subsea production control system.

h) umbilical:

The umbilical(s) transfer(s), as required, electrical power and communication signals, hydraulic power, and/or chemicals to the subsea components of the subsea production system. Communication signals may be transmitted via power cable (signal on power), signal cable or fibre optic.

i) subsea control module (SCM):

In a piloted-hydraulic, electrohydraulic or electric control system, the SCM is the unit that, upon command from the MCS, directs hydraulic fluid to operate subsea valves. In an electrohydraulic or electric system, the SCM also gathers information from the subsea control system equipment and transmits the information to the topside facility.

j) subsea distribution systems:

Distribution systems distribute electrical, hydraulic and chemical supplies and electrical/optical communications signals from the umbilical termination(s) to the subsea trees, manifold valves, injection points, and the control modules of the subsea production control system.

k) subsea and downhole sensors:

Sensors located in the SCMs, on subsea trees or manifolds, on the seabed or downhole provide data to help monitor operation of the subsea production system.

l) control fluids:

Oil- or water-glycol based liquids are used to transmit, control and distribute hydraulic signals and energy from the surface HPU to the subsea control system.

m) control buoy:

Moored-buoy-housing generation, communication and chemical injection (optional) equipment is connected to the subsea components of the subsea production system via an electrical/fibre optic/hydraulic control umbilical. The buoy can communicate with the surface production facility via umbilical, acoustic, radio or satellite links or a combination thereof.

n) flying lead:

Flying lead(s) transfer(s) electrical power and communications signals, hydraulic power, and/or chemicals to the subsea components of the subsea production system. Signals may be transmitted via combined signal and power cable, separate signal and power cable, or separate fibre optic signal and power cable.

This part of ISO 13628 covers all systems, both hydraulic and electrohydraulic. Only the relevant subclauses should be used.

5.4.2 Service condition

5.4.2.1 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, corrosion, marine growth, tidal forces, illumination and hazardous-area classifications. For the subsea environment, this includes corrosion, ambient pressure and temperature, marine growth and fouling, fishing activity or marine operations, currents, seafloor composition and maintenance considerations. Suitability to the likely storage environment should be considered. This can include ultra-violet radiation, ozone, ice, sand, wind, humidity or temperature extremes.

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

5.4.2.2 Pressure ratings

5.4.2.2.1 General

Specialized conditions shall also be considered, such as pressure rating changes in system and component interfaces (such as subsea control module to receiver plate, umbilical to tree-mounted terminations) and pressurizing with temporary plugs and caps installed. The effects of external loads (i.e. bending moments, tension), ambient hydrostatic loads and fatigue shall be considered.

In order to preserve the existing installed base of designed, qualified and field-proven systems and equipment with a safe field-operations history, such systems and equipment should be exempted from the working- and design-pressure rating subclauses in this part of ISO 13628, and accepted for use within projects/systems specifying compliance with this edition of this part of ISO 13628. Where applicable to the preceding, exceptions to this part of ISO 13628 shall be identified early in the development process and addressed on a case-by-case basis.

The maximum working pressure of the system shall not exceed the design pressure of the components that are used to build the system.

Provisions shall be made to include a system pressure-relieving device, normally a system pressure relief valve, to ensure that surge pressures in the system do not exceed the design pressure of the system components by more than 10 %.

When setting the system pressure-controlling device, normally a pressure regulator, a minimum of 5 % of the design pressure shall be left as a margin between the maximum working pressure of the system (as set by the system pressure-controlling device) and the reseal pressure of the system pressure-relieving device. This is to prevent overlapping of the two pressures with excessive pump operation as a result.

Proof pressure shall be a minimum of 1,5 times design pressure.

5.4.2.2.2 Hydraulic control components

It is recommended that hydraulic components have design pressures according to Table 1. Hydraulic components for the SCSSV circuit shall have a design pressure in accordance with the design pressures of the SCSSV.

Table 1 — Pressure relations

Recommended design-pressure classes	Minimum proof pressure
MPa (psi)	MPa (psi)
11,3 (1 639)	17,0 (2 465)
22,8 (3 307)	34,2 (4 960)
37,9 (5 497)	56,9 (8 252)
56,9 (8 252)	85,3 (12 372)
75,9 (11 000)	113,8 (16 520)
113,9 (16 520)	170,8 (24 772)

5.4.2.2.3 Other equipment

The design pressure of other equipment such as running, retrieval and test tools shall comply with manufacturer's written specifications.

5.4.2.3 Temperature ratings (host facility equipment)

5.4.2.3.1 Without controlled environment

Surface-installed equipment covered by this part of ISO 13628 and not installed in a controlled environment shall be designed, tested, operated and stored in accordance with the temperature ratings listed in Table 2.

Table 2 — Temperature rating — Surface-installed equipment without controlled environment

	Electronics		System	
	°C	(°F)	°C	(°F)
Design				
a) Standard	0 to 40	(32 to 104)	0 to 40	(32 to 104)
b) Extended	– 18 to 70	(0 to 158)	– 18 to 40	(0 to 104)
Operate				
a) Standard	0 to 40	(32 to 104)	0 to 40	(32 to 104)
b) Extended	– 5 to 40	(23 to 104)	– 5 to 40	(23 to 104)
Store	– 18 to 50	(0 to 122)	– 18 to 50	(0 to 122)
Temperatures relate to environment, not individual components.				

Equipment shall be marked in accordance with 12.1.2.

5.4.2.3.2 Controlled environment

Surface-installed equipment covered by this part of ISO 13628, and installed in a controlled environment, shall be designed, tested, operated and stored in accordance with temperature ratings compatible with the specified controlled environment.

Packaged assemblies or components that are restricted for use in a controlled environment shall be appropriately marked in accordance with the provision of 12.1.3.

5.4.2.4 Temperature ratings (subsea-installed equipment)

Subsea-installed equipment covered by this part of ISO 13628 shall be designed, tested, operated and stored in accordance with the temperature ratings listed in Table 3.

Table 3 — Temperature rating — Subsea-installed equipment

	Electronics		System	
	°C	(°F)	°C	(°F)
Design				
a) Standard	– 10 to 70	(14 to 158)	0 to 40	(32 to 104)
b) Extended	– 18 to 70	(0 to 158)	– 18 to 40	(0 to 104)
Test				
a) Standard	– 10 to 40	(14 to 104)	0 to 40	(32 to 104)
b) Extended	– 18 to 40	(0 to 104)	– 18 to 40	(0 to 104)
Operate				
a) Standard	0 to 40	(32 to 104)	0 to 40	(32 to 104)
b) Extended	– 5 to 40	(23 to 104)	– 5 to 40	(23 to 104)
Store	– 18 to 50	(0 to 122)	– 18 to 50	(0 to 122)
Temperatures in Table 3 relate to environment, not individual components. Subsea sensors that monitor produced or injected fluid may operate outside the ranges given. They shall be rated accordingly.				

Equipment shall be marked in accordance with 12.1.2.

5.4.2.5 Electromagnetic compatibility

The design shall conform to the applicable local regulations regarding EMC for the environment in which the equipment is used. For EMC, surface equipment comes within the scope of IEC 61892 (all relevant parts) which cites IEC 60533^[22]. For subsea equipment, each application needs to be considered with regard to its installed environment but guidance should be taken from the appropriate sections of IEC 61000-2^[27]. Annex F of this part of ISO 13628 gives definitions for a subsea environment and guidance on the selection of tests, limits and severity levels that can be used in order to provide a presumption of compliance. Consideration should also be given to IEC 61000-1-2^[28], particularly for HIPPS.

5.4.2.6 Storage/test 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, then the manufacturer should be contacted to determine if special storage or surface testing procedures are recommended. Manufacturers shall document any such special storage or surface testing considerations, such as exposure to fluctuations in ultra violet, ozone, ice sand, wind, humidity, or temperature extremes.

5.4.2.7 External hydrostatic pressure

In subsea applications, external hydrostatic pressure can be higher than internal system pressure. This external loading situation shall be considered, especially relative to seal design, self-sealing couplings and one-atmosphere enclosures. Umbilical and distribution flying-lead collapse during installation and in service shall also be considered.

5.4.2.8 Fluid compatibility

Components shall be selected considering compatibility with both control fluid and chemical injection fluid. In addition, compatibility with process fluid, cleaners, preservers, seawater, brines, diesel and corrosion inhibitors shall be considered.

5.4.3 Hydraulic system

5.4.3.1 Hydraulic control fluid

Selection of hydraulic control fluid shall consider the maximum 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 shall be compatible with the selected fluid. Reference should be made to Annex C.

The handling and topside safety and environmental implications should be considered carefully in the selection of the control fluid and control fluid distribution system.

5.4.3.2 Cleanliness

The hydraulic fluid-wetted portion of the control system shall be prepared to a cleanliness level as defined in AS 4059^[51]. The selected 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 should be part of the overall systems approach to design, manufacture, test and operation.

Typical cleanliness levels are ISO 4406, Class 15/12.

Note For the purposes of this provision, AS 4059^[51], Class 6B-F is the equivalent of ISO 4406, Class 15/12.

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 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 should 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 with very low fluid consumption (e.g. DCV pilot stages) shall be protected by filters or suitable screens.

System cleanliness should be verified in accordance with ISO/TS 16431.

All parties who can influence fluid cleanliness, including drilling and topside construction personnel, normally unfamiliar with subsea practices, should be made aware of the importance of fluid cleanliness and that working procedures to achieve, test and maintain cleanliness are to the required standard.

5.4.3.3 Seawater ingress and compensation

The potential to ingress of seawater during deployment and use shall be minimized. Recommended measures include removal of residual air, flushing immediately after deployment, and pressure compensation of hydraulic system.

The seachest/compensator shall be sized for the maximum required fluid volume, with a 25 % margin if the seachest/compensator is being topped up during operation of the system (looped circuit). If the seachests/compensators are isolated from the system, a minimum margin of 100 % is required (non-looped circuit).

As a minimum, the following situations shall be reviewed:

- compensation of the SCM itself, for retrieval or deployment, when not connected to the christmas tree;
- prevention of hydraulic lock during emergency shutdown;
- the effect of ROV manual over-ride, with- and without external connections;
- fluid shrinkage during cool-down (SCSSV line).

5.4.3.4 Overpressure protection

System pressure-relief (safety) valve settings shall not exceed design pressure.

The setting of the primary relieving device shall not be greater than the design pressure.

5.4.3.5 Vibration and pressure pulses

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

5.4.4 Electrical system

The electrical power for the surface control equipment of an electrohydraulic control system, its associated interfaces, and the subsea equipment should be supplied from an UPS to ensure continued operation in the absence of primary power for a minimum period of 30 min.

Typically, the UPS system should include isolation and regulation to ensure a clean constant supply of electrical power. In the case of communication on power, the UPS shall have a THD figure of better than 3 % with no more than 60 % of the THD concentrated in the third harmonic.

In order to minimize the number of conductors in the control umbilical, signal multiplexing and combining power and signal on the same pair of wires should be considered. Possible increased voltage stress on umbilical or distribution wires caused by single insulation failures should be considered. For subsea assemblies, electrical components of high reliability shall be used. Components shall be procured to industrial grade or better wherever possible. The electronic control system supplier shall be able to provide a quality assurance system or test documentation to demonstrate component and system reliability levels appropriate to the system application. Typically, this should demonstrate failure probabilities acceptable for the design life of the control system.

The design of the subsea electrical distribution system shall consider the possibility of retrieving failed portions of the distribution network whilst the redundant and operational parts are in operation.

With respect to “live disconnect” of subsea wet-mate connectors, consideration should be given to arcing damage that can occur in the event of slow separation speed. Electrical distribution systems should be designed such that “live disconnect” is not required during normal operation, maintenance or, if possible, during failure mode operation or recovery periods.

Topside equipment should be designed to facilitate modular replacement.

5.4.5 Redundancy

The level of redundancy depends on the actual field development, control system uptime availability target and reliability of equipment used. Generally the following guidelines are applicable.

- a) As a design intent, the level of redundancy should prevent or minimize the loss of subsea production due to a single-component failure or common-mode failure.
- b) Redundancy is most important if component replacement is difficult, or if significant production availability or operating capability is lost through single-component failure.
- c) 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, should be implemented if practical.
- d) The subsea electrical distribution system design should 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.
- e) Consideration should be given to providing completely segregated redundant electrical systems. The subsea hydraulic distribution system should be redundant or should include spares that can be configured to replace failed lines in either LP or HP service.
- f) The subsea chemical-distribution system and supply line should have redundancy consistent with the importance of the treatment chemical.
- g) The number of spares in the umbilical should be specified based on the redundancy needed and relative impact on umbilical design, e.g. spares which fill space in a given cross-section add less cost than those which lead to a diameter increase.
- h) Redundancy of instruments should be based on criticality and retrievability of the sensors.
- i) 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.

5.4.6 Reliability

Required reliability of the subsea control system should be optimized to result in maximum benefit. The use of high-reliability components should be compared against redundant components of more standard quality. Special consideration should be given to the reliability of components that are difficult to repair or replace.

Minimum required reliability, mean time to repair and availability targets for subsea equipment should be stated for each project.

The demonstration of these targets should be part of equipment acceptance criteria.

Critical sensor systems located on subsea trees or manifolds should have component reliability, or reliability obtained by redundancy, that is optimum relative to the need for the sensor data and the risk of subsea intervention. This is most important for sensors that trigger safety or shutdown responses.

Reliability figures for critical components and assemblies should preferably be documented by field data or alternatively justified by calculations, tests or an accepted industry data base (such as OREDA)^[53].

5.5 Functional requirements

5.5.1 General performance requirements

Control system equipment built to this part of ISO 13628 should perform in a manner which is efficient, safe and protects the environment. Performance requirements for the control system as a whole should

- provide for individual or multiple operation of all remotely controlled subsea valves;

- provide sufficient data-readback information to operate the system safely and to react promptly to conditions requiring PSDs;
- provide ESD capability that ensures the subsea system will shutdown production safely within the time specified by this part of ISO 13628 or by applicable regulatory authorities for all production scenarios, including simultaneous drilling, completion and workover operations.

5.5.2 Operating pressure

The control system shall be capable of supplying control fluid at a pressure which is sufficient to open subsea valves under the worst case set by valve manufacturer specifications. The minimum working pressure shall be at least 10 % greater than the minimum opening pressure specified by the manufacturer for the worst-case condition of the actual installation. The decrease in operating pressure while a subsea valve is being actuated should not reach a value at which any of the other previously actuated subsea valves change commanded state.

Pressure required to operate SCSSV is higher than for wellhead control. As the pressure required to open an SCSSV is a function of the tubing pressure, which is itself variable over time as the well depletes, the value of the SCSSV hydraulic pressure shall be selected to ensure that the SCSSV is not over-pressured at the end of well life. Having an operator-variable SCSSV hydraulic pressure at the HPU mitigates against SCSSV over-pressurizations over well life.

5.5.3 Fail-safe philosophy

Subsea control systems shall be designed to render the production system to a fail-safe status upon loss of hydraulic power. Typically, this is achieved by closure of a USV. Such closure can be achieved by either de-energization of electrical circuits or depressurizing of the hydraulic power supply. If an all-electric-type control system is used, the system shall be fail-safe upon loss of electric power.

There should be no subsea control system component failure that prevents the fail-safe closure of the SCSSV and the designated USV.

5.5.4 Response time

5.5.4.1 Valve closing

5.5.4.1.1 General

The primary constraint on control system response time is set by the requirement to execute promptly a shutdown of the subsea production upon command from the surface facilities. Such shutdowns are associated with discharging a supply of combustible materials to the surface facilities, and/or reducing pollution of the environment in the event of a loss in containment integrity of the subsea system. If closure of a valve is the means by which a downstream segment of piping is protected against overpressure, the response time shall be less than that which would allow the segment to be over-pressured due to continued flow.

5.5.4.1.2 Requirement for contingency closure control mode

All control systems for which malfunction or failure of the primary control system do not necessarily cause the USVs to return to a fail-safe position, and, as such, can potentially allow flow to continue indefinitely, shall be equipped with a contingency closure control mode that can execute the necessary valve closures. If such contingency closure control mode involves bleeding off supply hydraulic pressure, the system shall reset in such a manner as to prevent the automatic reopening of the closed valves when supply pressure is restored. The SCSSVs should be the last valves to close.

5.5.4.1.3 USV closing-time requirement using primary control mode

Upon receipt of a commanded closure, the subsea control system shall complete a closure of the designated USV using the primary control mode with the maximum response time not to exceed 10 min. For multiple-well installations, the USVs on all flowing wells shall close within the designated 10 min time allowance.

5.5.4.1.4 USV closing-time requirement using contingency closure control mode

In the event that a subsea control system failure has necessitated a valve closing operation in a contingency closure control mode that is not in compliance with the 10 min closure-time limitation, the contingency closure control mode shall still execute the closure in a manner that meets the general requirements stated in 5.5.4.1.1.

5.5.4.1.5 Shift time limitation

The shift time portion of the overall response time for a single USV shall be 3 min or less. This shift time limitation may be waived if flow in the subsea well associated with the respective USV has already been stopped by other valves or flow control devices that have previously been closed or that are simultaneously responding to the commanded closure.

5.5.4.1.6 Failure of boost system

Failure of the boost system shall not prevent the fail-safe closure of the USV under the loss of hydraulic pressure.

5.5.4.1.7 Relationship of surface and riser safety system response requirements to subsea control-system response requirements

The response time of an SSV or riser valve following a commanded closure is established by regional regulations for the protection of the surface facility. The response time of these surface and riser safety devices is independent of the requirements for subsea control system response. As such, this is not a part of this performance specification, but should be considered in a total system safety evaluation.

5.5.4.2 Valve opening

If equalization of pressure across the USV is not possible prior to opening, the USV shall be constrained to a shift time not to exceed 3 min. This requirement may be waived if there is another valve or flow-control device in the flowstream that can be closed such that the USV can be opened without encountering a prolonged differential pressure.

5.5.4.3 Demonstration of response time

One of the following four methods shall be used to demonstrate that the response time projected for the control system meets the objectives (prior to installation).

- a) Run a control system simulation using perfectly elastic umbilical volumetric data and valve operator data, typically available from the respective manufacturers. This approach typically results in the most conservative calculated response times.
- b) Run a control system simulation using viscoelastic umbilical volumetric data, based on measurements made on at least 30 m (100 ft) of sample material of pressure and volume versus time. Combine with manufacturer's valve operator data.
- c) Run a control system simulation using a previously calibrated model for an identical umbilical material, allowing for new variables such as control path length, operating pressure, and end device characteristics.
- d) Measure response time directly using actual equipment.

5.5.5 Functional considerations

5.5.5.1 Leak tests and diagnostics

The subsea control system shall be capable of performing required diagnostics and regulatory-mandated leak tests on the subsea equipment. Such leak tests include leak-testing of barrier valves in the HIPPS system, the SCSSV and leak-testing of the designated USV. In the event of leak-test failure, the control system should provide capability to facilitate diagnostics of the failure conditions.

5.5.5.2 Interlocks

The following interlock functions should be evaluated:

- prevent SCSSV from opening unless PMV or PWV is closed;
- prevent SCSSV from closing unless PMV or PWV is closed;
- prevent the cross-over valve from opening unless PMV is closed;
- prevent the PWV from opening unless choke is at preset position.

5.5.5.3 SCSSV or intelligent well completion seal failure

Backflow of well fluids into the subsea control system due to seal failure in the SCSSV or IWCS shall not impair the ability of the subsea control system to execute the fail-safe closure of the USV.

5.5.5.4 Actuation indication

The production control system shall provide a surface indication of the actuation of a selected hydraulic 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.

5.5.5.5 Protection of SCSSV

Under commanded-closure conditions, the design of the production control system should protect the SCSSV from slam or creep closure on a flowing stream, through operational procedure or introduction of a delay following the closure of the valves downstream of the SCSSV. Any such provision should not impact the ability of the subsea production control system to close the SCSSV in shutdown conditions.

5.5.5.6 Flushing of SCSSV hydraulic circuit

Provisions for flushing the hydraulic circuit from control module to SCSSV during installation and in the operational phase shall be considered as part of front-end engineering. This function can be implemented by using a dedicated flushing valve in the SCM. Flushing operations shall not result in HP system pressure drop which can affect other wells.

5.5.5.7 Safety isolation during workover

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

5.5.5.8 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. Margins for leakage increase shall be allowed.

Internal leakage shall not threaten the safe operation of the isolation valves particularly the ability to shut-in.

For closed-loop systems, the return system shall be designed for the maximum leakage.

5.5.5.9 Load capability

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

5.6 Design requirements

5.6.1 General design 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 such as electrical connectors, hydraulic couplers and stabplates shall be furnished with necessary protection equipment in order to protect the equipment when being unmated and in service and to prevent calcareous build-up and marine growth.

Early in the project, the manufacturer and purchaser should clearly establish utility interface requirements.

5.6.2 Design methods

5.6.2.1 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, or BS 7201-1 or ISO 10945, or any other agreed-upon pressure vessel or accumulator code or standard.

Note For the purposes of this provision, BS 7201-2^[17] is the equivalent of ISO 10945.

5.6.2.2 Electrical devices

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

5.6.2.3 Interconnecting tubing

Vibration-induced fatigue failure of the subsea tubing system shall be considered. All tubing runs shall be installed with sufficient and appropriate clamps. Interconnecting tubing shall meet the requirements of ANSI/ASME B31.3 or any other agreed upon piping code or standard.

5.6.3 Design analysis

5.6.3.1 General

The following analyses shall be performed during detailed design of the production control system for the purpose of establishing system requirements (e.g. performance characteristics, requirements, etc.), and only if they are relevant to the type of control system:

- hydraulic system operation and response time analysis;
- electrical power distribution analysis;

- electrical communication analysis;
- optical communication analysis;
- communication data rate analysis;
- failure mode effects and criticality analysis;
- reliability, availability, maintainability analysis;
- safety assessment analysis (if applicable).

Further the following analyses should also be considered during detailed design:

- a) reliability, availability and maintainability analysis;
- b) failure mode effect and criticality analysis;
- c) structural (static) analysis.

A simulation of the control system shall be created, and analysis made, such that the required opening and closing time requirements for the system can be verified. The response time of the control system shall be simulated in the absence of any bore-pressure assistance to the closure of the valve. The simulation shall properly account for response-time degradation due to use of high density gradient and high viscosity control fluids. Effects of a boost-pressure supply acting to assist the prompt closure of the valve operator may be included in the analysis. However, this does not relieve the supplier from providing a system that meets the requirements of this part of ISO 13628 without the use of a boost system.

5.6.3.2 Hydraulic systems

Hydraulic system analyses should ensure that the hydraulic system performance in the various modes of operation is safe and operationally acceptable. The areas of hydraulic performance that should be addressed are the following:

- time to prime the hydraulic system from a depressurized state;
- opening and closing response times of the process valves under conditions of 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, such as the opening of a tree (neglecting choke valve operation);
- stability of opened control and process valves to pressure transients caused by operation of other control and process valves (sympathetic control valve delatching, process valve partial closing, etc.);
- stability of opened downhole control and safety valves to pressure transients caused by operation of other safety or IWCS valves (sympathetic control valve delatching, process valve partial closing, etc.);
- response time to close process valves in the event of a common close command, such as an ESD vent-down at the surface, venting off hydraulic control valves via supply lines;
- response time and pressure for multiple simultaneous choke operations;
- response time and pressure for subsea quick dump;
- response and pressure for closed-loop 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 failure of subsea accumulation and return-line boost pressure systems (assist closing systems) has upon the safe operation and closure of the process valves;
- impact of loss of subsea accumulator pre-charge;
- 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;
- chemical system flow analysis that should establish that a specified supply of well-treatment, start-up and shut-down chemicals is achieved under the range of wellhead flowing and shut-in process pressures.

5.6.3.3 Electrical power systems

The electrical power distribution analysis should establish the following:

- voltage at SEM for maximum and minimum SEM power loads;
- voltages at SEM at maximum and minimum numbers of SCM on the subsea electrical distribution line;
- voltages at SEM at minimum and maximum umbilical lengths;
- voltages at SEM at redundant and non-redundant power distribution, if applicable;
- voltages at SEM at cable parameters for dry and wet umbilical insulations, if applicable;
- voltages at SEM at the limits of cable parameters such as inductance, capacitance, resistance and conductance (noting that some parameters may change when subsea);
- SEM component stress levels that should be maintained within acceptable limits for normal and degraded modes of operation;
- minimum and maximum subsea power requirements;
- maximum current load;
- power factors for full range of control system operating conditions.

5.6.3.4 Electrical communication systems

The electrical communication analysis should establish the following:

- signal voltage in SEM and topside at minimum and maximum umbilical lengths;
- signal voltage in SEM and topside at maximum and minimum numbers of SCM on the subsea electrical distribution;
- signal voltages in SEM and topside at worst-case cable transmission line parameters, such as inductance, capacitance, resistance and conductance (noting that some parameters can change when subsea and are also subject to discrepancies between calculated and manufactured values);
- interference from the subsea and topside power supplies or other sources of electromagnetic energy in the signal frequency band;

- power frequency components in subsea and topside receivers;
- signal voltage in SEM and topside at cable parameters for dry and wet umbilical insulations;
- BER and signal-to-noise in SEM and topside at minimum and maximum umbilical lengths;
- acceptable amplitude variation within the frequency band required by the modem system at minimum and maximum numbers of SCM on the subsea electrical distribution;
- subsea communication data transfer response time for downlink commands and uplink data transfer. The response time shall be calculated for the maximum number of data points and maximum number of SEM connected to one line and include communication load from possible other users like IWCS.

In the case where IWCS share the same communication link as the production control system, special consideration shall be made to communication system operation during critical functions like PSD to ensure the safety integrity level specified is maintained.

5.6.4 Design review

Control-system design documentation shall be reviewed and verified by a qualified individual other than the individual who created the original design.

The design verification of the subsea components shall be sufficiently rigorous to reflect the importance and cost of repair if it should fail. Such verification of design shall include all life phases such as installation, operation and recovery.

5.6.5 Control system design documentation

5.6.5.1 Manufacturer's engineering data records

Engineering data records shall include required analyses listed in 5.6.3, other design analyses performed by the manufacturer and FAT procedures and records.

5.6.5.2 Installation, operating and maintenance manual

The installation, operating and maintenance manual should incorporate information on the following:

a) installation procedures:

The manufacturer shall write procedures that prepare the equipment for installation and commissioning in a manner which is effective and minimizes the risk of damage. The procedures shall cover the testing of control modules, control umbilicals and connections just prior to, during, and immediately following installation.

b) operating procedures:

Operating procedures shall be prepared for use by field personnel and service technicians, and should include adequate schematics and block diagrams. They shall define the following:

1) general description and features:

This portion shall describe the function of each major component of the system and define its capabilities and interfaces with other components.

2) general function and shutdown philosophy:

This information shall include block diagrams, panel logic and schematics that represent the control system. Sensor-initiated inputs and outputs should be included. The interface between the operating circuits on host facilities, instrument and emergency utilities, such as air, water and electricity, shall

be included. The nature and purpose of all signals to and from the surface-facility fire and safety systems, motor control centre, and supervisory controls shall be identified. The approximate time required for shutdown actions to occur should be noted.

3) system checkout:

The system checkout shall be based on FAT and integrated tests described in Clause 11. The purpose of the procedure is to verify the correct function of all shutdown inputs and safety devices, and to verify the correct setting of all control system adjustments. The procedure should be written to allow testing to the fullest possible extent without interrupting well production. Where mechanical or electrical overrides are required, their active status shall be clearly indicated. A document should be prepared that collects all the set points and allowable ranges for the process variables. This document can be updated as needed and attached to the procedures.

The system checkout shall include a test and documentation of the safety shutdown system.

c) maintenance procedures:

The manufacturer shall furnish suitable instructions concerning field assembly and maintenance of the equipment. Instructions for periodic checks and/or replacement of control system surface equipment should be included.

5.6.5.3 Manufacturer's data record book

The manufacturer shall collect data record information for the supplied equipment, including subcontractor supplied equipment as required by the customer. The following should be included:

- general assembly drawings with list of materials;
- electrical schematics;
- hydraulic schematics;
- interface drawings;
- material certificates with appropriate test reports;
- component data sheets, including performance specifications;
- load test reports;
- welding procedures;
- certificates of conformance.

6 Surface equipment

6.1 General

The purpose of Clause 6 is to set forth additional requirements that are specific to the surface-installed equipment that is part of a subsea production control system. All such surface-installed equipment shall be designed to perform in accordance with these additional requirements.

All host facility-based production control system equipment shall be built and documented according to specifications applicable for the host facility where the equipment will be located. Relevant standards and installation specifications shall be a part of the contractual documentation for the specific project.

The functional requirements for the surface equipment typically include all or some of the following:

- supply and conditioning of electric and/or hydraulic power for the subsea equipment;
- communication with the subsea equipment;
- control and monitoring of subsea equipment;
- communication with the host process equipment;
- ESD/PSD;
- chemical injection;
- recording and storing data;
- communication with drilling rig for rig-initiated shutdown.

6.4.1 Master control station (MCS)

6.4.1.1 The MCS is the unit that controls and monitors the subsea production system. It can range in complexity from a manual hydraulic panel to an automated computer system. As an automated computer system, it can be configured in three possible ways:

- fully integrated with the host DCS;
- as a stand-alone terminal being the primary interface for control of the subsea system;
- as a stand-alone terminal with interface to both the DCS and subsea equipment. The host DCS is the primary operator's interface for control of the subsea system. The MCS is secondary, but able to perform subsea control should the DCS or the link to the DCS fail.

6.4.1.2 The MCS shall be designed to include the following capabilities to

- operate safely in the sited environment;
- respond to the host safety systems;
- provide effective operational interface;
- display and warn of out-of-limit (fault) conditions;
- display operating status;
- provide a shutdown capability.

6.4.1.3 The MCS may optionally provide the following additional capabilities:

- sequenced operation of valves;
- software interlocks;
- process-control interconnections with host facility;
- data collection, storage, analysis and presentation;
- remote communication to offsite control centre;
- interface with remote shutdown system on drilling or workover vessel;
- rate of change of pressure analogue(s) for rudimentary leak detection;
- hydrate detection by pressure/temperature curve comparison;
- flowrate control by detection of choke position and pressure sensors up- and downstream of choke.

6.4.1.4 The application software should be simple. Start-up operations after shutdown situations should be under the complete control of the operator, having the appropriate level of access, with a minimum number of inherent interlocks.

The MCS or DCS shall provide the operator interface and automated functions for the production control system, as appropriate to the selected configuration.

The MCS should be installed in a safe area.

If a dual redundant configuration is used, transfer to the secondary or hot standby controller shall be bumpless with no loss of data or control.

The MCS should allow for post-installation expansion, both of hardware and software. The level of expandability of the MCS shall be defined during the equipment specification phase. The MCS shall be capable of post-installation modification and upgrading of software.

6.4.2 Electrical power unit (EPU)

For electrohydraulic systems, an EPU may be installed as a separate system, or may be combined with the modem unit or the MCS.

The EPU, which is normally powered from the UPS, supplies electrical power to the subsea wells via the control umbilical. The EPU should include safety devices which ensure that, under electrical fault conditions, the equipment and personnel are protected from electrical hazard.

If redundant power conductors are provided in the umbilical, the output voltage of the EPU should be individually adjustable for each channel of each umbilical power pair. Each pair should be galvanically segregated from the rest of the system. The design shall allow for individual pair connection/disconnection.

The design should allow easy access to individual power systems for maintenance and repair.

The following EPU parameters should be monitored by the MCS or DCS:

- input voltage;
- input current;
- umbilical voltages/currents (optional for communication lines);

- overvoltage and overcurrent alarms;
- line insulation (optional).

The EPU shall be designed to operate safely in the sited environment.

6.4.3 Modem unit

Modems, filters and isolation transformers are typically included in the unit.

The modem unit may either be connected to an MCS, dedicated to the production control system or, alternatively, may interface directly with the host facility DCS via a communication interface unit (part of the DCS).

In either configuration, the communications protocol shall provide a mean of ensuring the security of the data being transferred.

If redundant communication paths are provided, the redundant elements shall not share common hardware, such as modems or power supplies. It shall be possible to switch communications easily between the redundant paths. This feature should, preferably, be automatic with the status of the communication links being announced to the control system operator.

The surface-to-surface communications link should employ an industry standard communication protocol.

The following modem unit parameters should be monitored by the MCS or DCS:

- input voltage;
- input current;
- umbilical voltages/currents;
- line insulation (optional).

The modem unit shall be designed to operate safely in the sited environment.

6.4.4 Uninterruptible power supply (UPS) (optional)

The UPS shall supply electrical power to the EPU, modem unit and the MCS.

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

The UPS battery back-up shall be capable of running the system for at least 30 min after loss of host-facility power.

The following parameters should be monitored by the MCS:

- input voltage;
- input current;
- UPS output frequency;
- UPS bypass mode;

- UPS on-line mode;
- UPS failure.

6.4.5 Hydraulic power unit (HPU)

6.4.5.1 General

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

The HPU shall include provisions for obtaining and maintaining the specified cleanliness requirement, such as drainage or circulation and filtration capability, should the fluid become contaminated. Output fluid from the HPU shall satisfy a cleanliness requirement according to manufacturer's written specification, as defined in ISO 4406.

Note For the purposes of this provision, AS 4059^[51] is the equivalent of ISO 4406.

Proper fluid sampling points shall be included to enable safe fluid sampling from the active part of the HPU hydraulic system.

HPUs shall be capable of being maintained without depressurizing the system.

HPUs should not have automatic filter bypasses that enable unfiltered fluid to pass around a filter blockage.

Redundancy should be provided on key components such as pumps and filters.

The same type (style) of tubing fitting should be used for each pressure class throughout the system.

The HPU shall be designed to operate safely in the sited environment.

The design should allow maintainable components within the unit to be isolated for servicing or replacement without interrupting the normal operation.

Electrical equipment in the HPU shall be designed to an ingress protection rating appropriate for the sited environment

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

6.4.5.2 Accumulators

The accumulators shall comply with ASME Boiler and Pressure Vessel Code, Section VIII, or BS 7201-1 and ISO 10945 or any other agreed pressure vessel or accumulator code or standard.

Note For the purposes of this provision, BS 7201-2^[17] is the equivalent of ISO 10945.

All surface-located accumulator systems shall have a pressure-relieving device to prevent over-pressurization. This applies both to the gas side in the form of fusible plugs or burst discs, and the hydraulic side in the form of safety relief valves.

Nitrogen pre-charge pressure should be significantly lower than normal hydraulic operating pressure to maximize stored energy in case of a supply pump failure.

Accumulator capacity shall be in accordance with the following criteria (the one criteria giving the greatest volume shall be used):

- allow all valves on one subsea tree to be opened and closed without requiring recharge of the accumulators; to maintain sufficient subsea pressure to keep process valves open, if a failure of the HPU pumps occurs, for a period of 12 h neglecting all other methods of fluid energy storage, such as umbilical line expansion and subsea accumulation;
- prevent short pump-run cycles, which would be detrimental to the life and reliability of the pumps;

- a minimum HPU accumulation of two 37 l (1,3 ft³) accumulators for the common LP header, and two 10 l (0,35 ft³) accumulators for the common HP header.

Failure of one accumulator (if more than one is used) shall not impair more than 50 % of the surface system capacity. Under such failure conditions, available pressure shall not drop below the minimum level required to maintain system operations.

Visual indication of low nitrogen pressure should be considered.

6.4.5.3 Pumps

Control devices shall be incorporated to shut off pumps upon occurrence of low fluid level in the supply reservoir.

Control devices shall be incorporated to cycle pump(s) on and off to maintain pressure within operating limits.

Pumps shall be fitted with isolation valves, a pressure-relief valve and a non-return valve at each pump discharge line.

The pressure-relieving device shall be installed at the output of all high-pressure pumps upstream of any blocking or isolation valves.

Anti-condensation heaters should be considered for electrical motors.

6.4.5.4 Reservoirs

The main reservoir should have a minimum capacity of 1,5 times the volume required to pressure charge the system including surface and subsea accumulators, umbilical and all valve operators and one full open and close cycle of chokes. However, if the main reservoir has a capacity equal to or greater than 2 000 l (70,6 ft³), a spare capacity of 750 l (26,5 ft³) is acceptable. The reservoir(s) should be sized, or alternative disposal means provided, to accommodate drainage of all subsea valve operator, accumulator and umbilical fluid in case of a total system depressurization. Provision shall be made for the reservoir to overflow to a designated line in the event of overfilling.

The hydraulic fluid reservoirs should be equipped with visual level indicators. Calibration of level transmitters should be possible without draining of tanks.

The reservoir(s) should be fitted with an inspection/access hatch and tank-fill breather or pressure-relief mechanism.

The hydraulic fluid tanks should be designed to minimize build-up of contamination and facilitate flushing.

Fluid reservoirs shall be made from non-corrosive material and should be equipped with circulating pumps and filters. Sample points shall be located no higher than pump suction ports, taking samples from the active part of the reservoir.

Consideration should be given to the use of two fluid reservoirs, one used for the transport of new fluid, return fluid from subsea (if implemented) and return fluid from depressurization of the system; the other, used for supplying clean fluid to the subsea system.

6.4.5.5 Control and monitoring

The HPU is typically controlled locally, but may be controlled and monitored from the MCS. Consideration should be given to the response time of the control loop.

If primary control is from the MCS, provision shall be made for local control. A local control panel shall be fitted with all the necessary gauges, switches, valving and indicators to enable operator control and monitoring. Provision for setting pumps in manual mode shall be provided.

If the facilities provide for ESD capability, then the HPU and control panel, if applicable, shall incorporate devices to bleed-off system-control pressure upon execution of ESD.

Should an ESD that requires hydraulic-pressure bleed-off occur, inadvertent reset of any HPU/ESD circuit shall be prevented while ESD conditions are still present.

The HPU parameters monitored may include the following:

- non-regulated supply pressure(s);
- regulated supply pressure(s);
- fluid levels;
- pump status;
- delivery flowrates;
- return flow;
- filter status;
- ESD indicators.

Monitoring of filter clogging should be provided preferably using remote indication measures that provide operator alarms.

Hydraulic fluid leak detection with the HPU should be considered. This information is valuable in identifying and diagnosing subsea problems.

6.4.6 Chemical injection unit (CIU)

6.4.6.1 General

In 6.4.6 are addressed surface facilities for the supply of well-treatment chemicals to the subsea production system via the production control system. Excluded from these requirements are storage and handling of the chemicals.

6.4.6.2 General requirements

The CIU shall supply filtered and regulated or metered chemical injection fluid(s) to the subsea installation. The CIU supply pressure is typically sufficient to deliver fluid into the wellbore, subsea tree, or other delivery points at a pressure in excess of the shut-in pressure.

For treatment chemicals that are delivered in specific rates, the CIU system should provide a means to vary and set the rate to meet the specified delivery rate. The topside unit is always the source of pressure, but might not incorporate flow control elements.

The CIU should contain provisions for obtaining and maintaining the specified cleanliness requirement. Output fluid from the CIU shall satisfy a cleanliness requirement according to manufacturer's written specification, as defined in ISO 4406.

Note For the purposes of this provision, AS 4059^[51] is the equivalent of ISO 4406.

The use of redundancy should be considered for critical components such as pumps, filters and flow-rate control devices.

Any accumulators used in the CIU shall comply with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, and BS 7201-1 and ISO 10945, or any other agreed pressure vessel or accumulator code or standard.

Note For the purposes of this provision, BS 7201-2^[17] is the equivalent of ISO 10945.

All accumulator systems shall have a pressure-relieving device to prevent over-pressurization. This applies to both the gas side in the form of fusible plugs or burst discs, and the hydraulic side in the form of safety relief valves.

The CIU shall be designed to operate safely in the sited environment. Special consideration shall be given to toxicity and flammability typical of the injection chemicals.

The design should allow maintainable components within the unit to be isolated for servicing or replacement without interrupting the normal operation.

The layout of the CIU should allow easy and safe access to all components for maintenance and repair.

6.4.6.3 Chemical injection pumps

Control devices shall be incorporated to shut off chemical injection pumps upon occurrence of low fluid level in the supply reservoir.

Chemical injection pumps shall be fitted with isolation valves, a pressure-relief valve and a non-return valve at each pump discharge line.

The pressure-relief device shall be installed at the output of all high-pressure pumps upstream of any blocking or isolation valves.

Pump selection should give consideration to chemical injection fluid.

6.4.6.4 Reservoirs

The chemical injection fluid reservoirs, if integral with the CIU, shall be equipped with visual level indicators. Calibration of level transmitters, if supplied, should be possible without draining the reservoir.

The chemical injection fluid reservoirs, if integral with the CIU, should be designed to minimize build-up of contamination and facilitate flushing.

To prevent undesirable contact between air and chemicals, a bladder tank or a blanket protection system should be considered.

Fluid reservoirs shall be made from non-corrosive material. Sample points shall be located no higher than pump suction ports for taking samples from the active part of the reservoir.

6.4.6.5 Control and monitoring

The CIU is typically controlled locally, but may be controlled and monitored from the MCS.

If primary control is from the MCS, provision shall be made for local control. A local control panel shall be fitted with all the necessary gauges, switches, valving and indicators to enable operator control and monitoring. Provision for setting pumps in manual mode shall be provided.

The CIU and control panel shall incorporate devices to terminate injection upon execution of an ESD/PSD.

The CIU parameters monitored may include

— non-regulated supply pressure(s);

- regulated supply pressure(s);
- fluid levels;
- pump status;
- return flow (if applicable);
- filter status;
- delivery flowrate.

Monitoring of filter clogging should be provided, preferably using remote indication measures that provide operator alarms.

6.4.6.6 Fluid compatibility of components and materials

All surfaces and seal materials in contact with the chemical injection fluids shall be verified to be compatible.

Some treatment chemicals require anaerobic conditions to prevent oxidation. Bladder tanks or variable volume tanks should be used if such chemicals are selected.

6.4.7 Hydraulic control fluid

6.4.7.1 General

The fluid in a subsea control system is intended to transmit both signals and power from one point in the system to another. The fluid may be either oil-based or water-based.

All control fluids shall provide inhibitors to prevent corrosion, biological growth and to tolerate a degree of seawater ingress without having a significant effect upon performance and characteristics.

The fluid is expected to remain in some parts of the system for the life of the project. Since most projects have a life of 10 years to 20 years, the long-term stability of the fluid is extremely important.

Reference should be made to Annex C for detailed information on control fluid specifications and testing.

6.4.7.2 Design

Any water-based hydraulic fluid shall be an aqueous solution (not emulsion) of its components. The fluid shall retain its properties and remain a homogeneous solution, within the temperature range, from manufacture through field-life operation.

Any oil-based hydraulic fluid shall be a homogeneous miscible solution of its components. It shall retain its properties and remain stable as a solution, within the temperature range, from manufacture through field-life operation.

6.4.7.3 Fluid compatibility

Hydraulic fluid compatibility with drilling brines such as zinc bromide, calcium bromide, zinc chlorine and calcium chloride shall be considered.