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

**Part 7:
Completion/workover riser systems**

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

*Partie 7: Systèmes de liaison surface/fond de mer pour
complétion/reconditionnement*



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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 13628-7 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

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 Tool (ROT) intervention systems*
- *Part 10: Specification for bonded flexible pipe*
- *Part 11: Flexible pipe systems for subsea and marine applications*

Introduction

This part of ISO 13628 has been prepared to provide general requirements, recommendations and overall guidance for the user to the various areas requiring consideration during development of subsea production system. The functional requirements defined in this part of ISO 13628 allow alternatives in order to suit specific field requirements.

This part of ISO 13628 constitutes the overall C/WO riser system standard. Functional requirements for components comprising the system and detailed requirements for riser pipe and connector design and analysis are included herein.

This part of ISO 13628 was developed on the basis of API RP 17G:1995, and other relevant documents on subsea production systems.

It is necessary that the users of this part of ISO 13628 be aware that further or different requirements might be needed for individual applications. This part of ISO 13628 is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application.

This is probably particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the vendor's responsibility to identify any variations from this part of ISO 13628 and provide details.

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

Part 7: Completion/workover riser systems

1 Scope

This part of ISO 13628 gives requirements and recommendations for the design, analysis, materials, fabrication, testing and operation of subsea completion/workover (C/WO) riser systems run from a floating vessel.

It is applicable to all new C/WO riser systems and may be applied to modifications, operation of existing systems and reuse at different locations and with different floating vessels.

This part of ISO 13628 is intended to serve as a common reference for designers, manufacturers and operators/users, thereby reducing the need for company specifications.

This part of ISO 13628 is limited to risers, manufactured from low alloy carbon steels. Risers fabricated from special materials such as titanium, composite materials and flexible pipes are beyond the scope of this part of ISO 13628.

Specific equipment covered by this part of ISO 13628 is listed as follows:

- riser joints;
- connectors;
- workover control systems;
- surface flow trees;
- surface tree tension frames;
- lower workover riser packages;
- lubricator valves;
- retainer valves;
- subsea test trees;
- shear subs;
- tubing hanger orientation systems;
- swivels;
- annulus circulation hoses;

- riser spiders;
- umbilical clamps;
- handling and test tools;
- tree cap running tools.

Associated equipment not covered by this part of ISO 13628 is listed below:

- tubing hangers;
- internal and external tree caps;
- tubing hanger running tools;
- surface coiled tubing units;
- surface wireline units;
- surface tree kill and production jumpers.

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 148, *Steel — Charpy impact test (V-notch)*

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 783, *Metallic materials — Tensile testing at elevated temperature*

ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs*

ISO 898-2, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 3183 (all parts), *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

ISO 4885, *Ferrous products — Heat treatment — Vocabulary*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 9327-1, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 1: General requirements*

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

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 10423:2003, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

ISO 10432, *Petroleum and natural gas industries — Downhole equipment — Subsurface safety valve equipment*

ISO 10474, *Steel and steel products — Inspection documents*

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

ISO 11960:2001, *Petroleum and natural gas industries — Steel pipes for use as casing or tubing for wells*

ISO 11961, *Petroleum and natural gas industries — Steel pipes for use as drill pipe — Specification*

ISO 13533:2001, *Petroleum and natural gas industries — Drilling and production equipment — Drill-through equipment*

ISO 13535, *Petroleum and natural gas industries — Drilling and production equipment — Hoisting equipment*

ISO 13628-2, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 2: Unbonded flexible pipe systems for subsea and marine applications*

ISO 13628-4:1999, *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 13628-6:2000, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 6: Subsea production control systems*

ISO 14693, *Petroleum and natural gas industries — Drilling and well-servicing equipment*

ISO 15156-1, *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production — Part 1: General principles for selection of cracking-resistant materials*

ISO 15156-2:2003, *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons*

ISO 15156-3, *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 15579, *Metallic materials — Tensile testing at low temperature*

API ¹⁾ Spec 7 ²⁾, *Rotary Drill Stem Elements*

API Spec 16C, *Specification for Choke and Kill Systems*

API RP 17B, *Recommended Practice for Flexible Pipe*

1) American Petroleum Institute, 1220 L Street, North West Washington, DC 20005-4070, USA.

2) For the purposes of this part of ISO 13628, API Spec 7 will be replaced by ISO 10424-1 and ISO 10424-2 when they become publicly available.

ASME ³⁾, *Boiler and pressure vessel code, Section VIII:2001, Rules for construction of pressure vessels, Division 1*

ASME, *Boiler and pressure vessel code, Section IX:2001, Welding and brazing qualification*

ASTM A193, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service*

ASTM A194, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service*

ASTM A320, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service*

ASTM ⁴⁾ A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A508, *Standard Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels*

BS ⁵⁾ 7201, *Hydro-pneumatic accumulators for fluid power purposes — Part 1: Specification for seamless steel accumulator bodies above 0,5 l water capacity*

EN ⁶⁾ 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 288 (all parts), *Specification and approval of welding procedures for metallic materials*

EN 1418, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials*

IEC ⁷⁾ 60089-0, *Electrical apparatus for explosive gas atmospheres — Part 0: General Requirements, Fourth Edition*

MSS ⁸⁾ SP-25, *Standard Marking Systems for Valves, Fittings, Flanges and Unions*

SAE ⁹⁾ AS 4059, *Aerospace fluid power — Cleanliness classification for hydraulic systems*

3 Terms, definitions, abbreviated terms and symbols

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

3.1 Terms and definitions

3.1.1

accidental load

load(s) which are imposed on the C/WO riser system under abnormal and unplanned conditions

EXAMPLES Loss of vessel station-keeping and heave compensator lock-up.

3) ASME International, Three Park Avenue, New York, NY 10016-5990, USA.

4) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

5) British Standards Institution, 389 Chiswick High Road, London W4 4AL, UK.

6) European Committee for Standardization, 36 rue de Stassart, B-1050, Brussels, Belgium.

7) International Electrotechnical Commission, IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

8) Manufactures Standardization Society of the Valve & Fitting Industry, 127 Park Street, N.E., Vienna, VA 22180, USA.

9) SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

3.1.2**agreement**

unless otherwise indicated, “by agreement” means “by agreement between manufacturer and purchaser at the time of enquiry and order”

3.1.3**apparent weight****weight in water****wet weight****net lift****submerged weight****effective weight**

submerged weight including content minus buoyancy

3.1.4**attachment weld**

fillet or full penetration weld used for attachment of components to pipe or coupling

3.1.5**auxiliary line**

conduit (excluding choke and kill lines) attached to the outside of the riser main pipe

EXAMPLES Hydraulic supply line and annulus circulation line.

3.1.6**ball joint**

ball and socket assembly having a central through-passage equal to or greater than the riser internal diameter

NOTE This can be positioned in the riser string to reduce local bending stresses.

3.1.7**barrier**

one or several barrier elements that are designed to prevent unintended flow of formation fluid

3.1.8**barrier element**

device that, alone, cannot prevent flow from one side to the other side of itself

3.1.9**bearing stress**

average normal stress on the contact surfaces of mating surfaces

3.1.10**blow-out preventer****BOP**

device installed at the wellhead to contain well-bore pressure either in the annular space between the casing and the tubulars or in an open hole during drilling, completion, testing or workover

3.1.11**BOP stack**

assembly of well control equipment including BOPs, spools, valves, hydraulic connectors, and nipples that connect to the subsea wellhead

NOTE As commonly used, this term sometimes includes the LMRP.

3.1.12

BOP adapter joint

BOP spanner joint

tubing hanger orientation joint

specialized C/WO riser joint used when the C/WO riser is deployed inside a drilling riser and subsea BOP to install and retrieve an orientated subsea tubing hanger

3.1.13

BOP stack

assembly of well control equipment including BOPs, spools, valves, hydraulic connectors and nipples that connects to the subsea wellhead

NOTE As commonly used, this term sometimes includes the LMRP.

3.1.14

buoyancy module

structure of low-mass material, usually foamed polymers strapped or clamped to the exterior of riser joints, to reduce the submerged mass of the riser

3.1.15

calculation

use of analytical-based formulas or numerical-based methods, e.g. finite element method or boundary element method, to investigate the structural safety of a component/system

3.1.16

Charpy V-notch test

test to indicate fracture toughness in terms of energy absorbed or lateral expansion or fracture appearance

3.1.17

choke-and-kill line

external conduits, arranged laterally along the riser pipe, and used to circulate fluids into and out of the wellbore to control well pressure

3.1.18

connector

mechanical device used to connect adjacent components in the riser system to create a structural joint resisting applied loads and preventing leakage

EXAMPLES Threaded types, including (i) one male fitting (pin), one female fitting (integral box) and seal ring(s), or (ii) two pins, a coupling and seal sea ring(s); flanged types, including two flanges, bolts and a gasket/seal ring; clamped hub types, including hubs, clamps, bolts and seal ring(s); dog-type connectors.

3.1.19

control module

assembly of subsea control equipment for piloted or sequential hydraulic or electrohydraulic operations from surface

NOTE Can be configured as a riser control module used for operation of landing strings in tubing hanger mode or as a workover control module in tree mode for operation of the lower workover package.

3.1.20

completion riser

temporary riser that is designed to run inside a BOP and drilling riser to allow for well completion

NOTE Completion operations are performed within the drilling riser. A completion riser can also be used for open-sea workover operations.

3.1.21**completion/workover riser****C/WO riser**

temporary riser used for completion or workover operations

3.1.22**component**

part of the pressure-containing equipment, which can be considered as an individual item for the calculation

NOTE Includes structural components like pipes, connectors, stress joints, tension joints, landing blocks, slick joints, tubing hanger orientation joints, adapter joints, etc.

3.1.23**corrosion allowance**

amount of wall thickness added to the pipe or component to allow for corrosion, scaling, abrasion, erosion, wear and all forms of material loss

3.1.24**crack tip opening displacement****CTOD**

measure of crack severity that can be compared against a critical value at the onset of crack propagation

3.1.25**design basis**

set of project-specific design data and functional requirements that are not specified or are left open in the general standard

3.1.26**design check**

assessment of a component for a load case by means of an application rule

3.1.27**design criteria**

quantitative formulations which describe each failure mode the conditions shall fulfil

3.1.28**design factor**

factor (usage factor) used in working stress design

3.1.29**design life**

period for which a riser can be used for its intended purpose with anticipated maintenance but without substantial repair or replacement being necessary including storage and working periods

NOTE The design life includes the entire period from start of manufacture to condemnation of the C/WO riser system or part of the system.

3.1.30**design load**

combination of load effects

3.1.31**design material strength**

stress used for structural strength calculation

3.1.32**design pressure**

maximum difference between internal pressure and external pressure that is unlikely to be exceeded during the life of the riser, referred to a specified reference height

NOTE Design pressure is often named maximum allowable pressure or rated working pressure or maximum allowable.

EXAMPLE Design pressure is the maximum pressure considering shut-in pressure at the wellhead (seabed) or at the top of the riser with subsea valves open, maximum well fracturing pressure, maximum well injection pressure, maximum surge pressure or maximum well kill pressure.

**3.1.33
designer**

individual or organization that takes the responsibility for the design of C/WO riser systems conforming with requirements of this part of ISO 13628

**3.1.34
drift**

cylindrical mandrel for verifying drift diameter of individual and assembled equipment

**3.1.35
meter**

minimum diameter that allows for the passage of the drift

**3.1.36
drift-off**

unintended lateral movement of a dynamically positioned vessel off its intended location relative to the wellhead, generally caused by loss of station-keeping control or propulsion

**3.1.37
drill pipe riser**

single string of drill pipe with an attached hydraulic control umbilical and annulus umbilical

**3.1.38
drilling riser**

system used with floating drilling vessel for guiding the drill string and circulating fluids between the drilling vessel and the subsea BOP

**3.1.39
drive-off**

unintended movement of a dynamically positioned vessel off location driven by the vessel's main propulsion or station-keeping thrusters

**3.1.40
dynamic positioning**

computerized means of maintaining a vessel on location by selectively activating thrusters

**3.1.41
effective tension**

axial tension calculated at any point along a riser by considering only the top tension and the apparent weight of the riser and its contents (tension positive)

NOTE Global buckling and geometric stiffness is governed by the effective tension.

**3.1.42
emergency disconnect package**

subsea equipment package that typically forms part of the lower workover riser package and provides a disconnection point between the riser and subsea equipment

NOTE This equipment is used when it is required to disconnect the riser from the well, typically in case of a vessel drift-off or other emergency that could move the vessel away from the well location.

3.1.43

emergency quick-disconnect

automatic activation of an emergency shutdown followed by an automatic disconnect of the riser

3.1.44

emergency shutdown

controlled sequence of events that ensures that the well is secured against accidental release of hydrocarbons into the environment, i.e. closing of barrier elements

3.1.45

environmental loads

loads due to the environment

EXAMPLES Waves, current and wind.

3.1.46

environmental seal

outermost pressure-containing seal at a connector interface

NOTE This seal normally separates a pressurized medium from the surrounding environment.

3.1.47

fabricator

individual or organization that takes the responsibility for the fabrication of CWO riser systems conforming with the requirements of this part of ISO 13628

3.1.48

factory acceptance test

FAT

test conducted by the manufacturer to verify that the manufacture of a specific assembly meets all intended functional and operational requirements

3.1.49

fail-safe

term applied to equipment or a system so designed that, in the event of failure or malfunction of any part of the system, devices are automatically activated to stabilize or secure the safety of the operation

3.1.50

failure

event causing an undesirable condition, e.g. loss of component or system function, or deterioration of functional capability to such an extent that the safety of the unit, personnel or environment is significantly reduced

EXAMPLE Structural failure (excessive yielding, buckling, rupture, leakage) or operational limitations (slick joint protection length, clearance).

3.1.51

false rotary

component that sits on the drilling rotary and provides a slip profile for single, dual or triple tubing strings

NOTE This allows the workover control system umbilical to feed into the drilling riser without interfering with the slips.

3.1.52

fatigue analysis

conventional stress-life fatigue analysis using material S-N curves and specified fatigue design factors

3.1.53

fatigue crack growth analysis

analysis of crack growth from assumed initial defect size under the action of cyclic loading

NOTE Used to determine fabrication inspection requirements and in-service inspection plans.

3.1.54

finite element analysis

numerical method for analysing dynamic and static response, by dividing the structure into small continuous elements with the given material properties

NOTE The analysis can be local or global.

3.1.55

flex joint

laminated metal and elastomer assembly, having a central through-passage equal to or greater in diameter than the interfacing pipe or tubing bore, that is positioned in the riser string to reduce the local bending stresses

3.1.56

floating vessel

buoyant installation that is floating and positioned relative to the sea bottom by station-keeping systems

NOTE The following types of station-keeping systems are normally considered: catenary mooring systems and dynamic positioning systems based on thrusters. Combination of station-keeping systems can be considered.

EXAMPLE Semi-submersible drilling vessels and drill ships.

3.1.57

fluid

gases, liquids and vapour in pure phases as well as mixtures thereof

3.1.58

fractile

p -fractile (or percentile) and the corresponding fractile value X_p is defined as $F(X_p) = p$, where F is the distribution function for X_p

3.1.59

fracture mechanics assessment

assessment and analysis where critical defect sizes under design loads are identified to determine the crack growth life, i.e. leak or fracture

3.1.60

frequency domain

dynamic analysis method based on the assumption that any applied irregular process is a superposition of fundamental, regular processes

NOTE Frequency domain analysis is usually associated with linear systems.

3.1.61

functional load

load caused by the physical existence of the riser system and by the operation and handling of the system, excluding pressure loads

3.1.62

galling

cold welding of contacting material surfaces followed by tearing of the materials during further sliding/rotation

NOTE Galling results from the sliding of metallic surfaces that are under high bearing forces. Galling can generally be attributed to insufficient lubrication between the surfaces. The purpose of the lubrication medium is to minimize the metal-to-metal contact and allow efficient sliding of the surfaces. Other ways to prevent galling are to reduce the bearing forces or reduce the sliding distance.

3.1.63**gasket**

deformable material (or combination of materials) intended to be clamped between flanges to prevent leakage of fluid

3.1.64**gimbal**

device that interfaces with the spider and the riser joint and enables the riser to rotate about the horizontal axis, thereby reducing the bending moments, which can otherwise occur due to vessel roll/pitch motions

3.1.65**global analysis**

analysis of the complete riser string from the sea floor (wellhead) to top drive including tensioner joint, utilizing beam element

NOTE Bending moments and effective tension distributions along the riser string due to functional loads, vessel motions and environmental loads are determined by global analysis.

3.1.66**global buckling**

elastic Euler buckling

3.1.67**grip length**

combined thickness of all the elements clamped together by the bolts and nuts, including washers, gaskets and joint members

3.1.68**gross structural discontinuity**

structural or material discontinuity which affects the stress or strain distribution across the entire wall thickness over a region of significant area

EXAMPLE End-to-pipe junction, connector-to-pipe junction, the junction of two pipes of different diameters, thickness or material, or a stiffener-to-pipe junction.

3.1.69**hang-off**

riser when disconnected from seabed

NOTE Hang-off is usually differentiated from disconnected. Disconnected is normally the condition directly after disconnecting the riser. Hang-off is normally associated with the riser suspended from the rotary table.

3.1.70**heat-affected zone**

region around a weld that has been affected by welding

3.1.71**heave**

floating vessel motion in the vertical direction

3.1.72**horizontal tree**

subsea tree with production and annulus bore valves located external to the tree, where the tubing hanger or dummy tubing hanger is installed after the tree

3.1.73**hydraulic connector**

mechanical connector that is activated hydraulically

3.1.74

hydrodynamic loads

flow-induced loads caused by the relative motion between the riser and the surrounding water

3.1.75

integral riser

integral style C/WO riser is a riser in which the pressure-containing conduits are mounted into a common assembly or joint

NOTE 1 An integral riser is typically classified as either jacketed or non-jacketed. The integral riser joint allows the production and annulus lines to be made up simultaneously.

NOTE 2 A jacketed C/WO riser can also contain hydraulic control lines inside the structural housing. This type of riser is typically used in applications where high tensile or bending loads are anticipated.

3.1.76

jumper

short piece of flexible pipe

3.1.77

landing string

all the equipment of the riser above the tubing hanger that is contained wholly or partly within the BOP stack and up to the first standard riser joint

NOTE For live well operations, the landing string typically consists of a tubing hanger running tool, subsea test tree, shear sub, retainer valve and lubricator valve. For killed well operations, the landing string typically consists of a tubing hanger running tool and tubing hanger orientation joint or slick joint.

3.1.78

leak-tight

leakage that is acceptable for a particular component

NOTE See 6.4.11.5.

3.1.79

lifting device

tool dedicated for lifting

3.1.80

limit analysis

method used to compute the resistance of a component made of ideally (rigid) plastic material

3.1.81

load

physical influence which causes stress and/or strains in the riser system

3.1.82

load case

combination of simultaneously acting loads

3.1.83

local buckling

buckling mode implying deformations of the cross-section

NOTE This can e.g. be due to external pressure (hoop buckling) or moment (wrinkling) or a combination thereof.

3.1.84

load effect

effect of a single load or combination of loads on the structure, such as stress, strain, deformation, displacement, motion, etc.

3.1.85**low-frequency vessel motion**

motion response at frequencies below wave frequencies typically with periods ranging from 30 s to 300 s

3.1.86**lower marine riser package****LMRP**

upper section of a two-section subsea BOP stack consisting of the hydraulic connector, annular BOP, ball/flex joint, riser adapter, jumper hoses for the choke, kill and auxiliary lines and subsea control modules

NOTE The LMRP interfaces with the BOP stack.

3.1.87**lower riser package**

subsea equipment package which forms part of the lower workover riser package and typically consists of a WCT-BOP and tree running tool

3.1.88**lower workover riser package**

lowermost equipment package in the riser string when configured for subsea tree installation/workover and including any equipment between the riser stress joint and the subsea tree, and typically consisting of a lower riser package and emergency disconnect package

NOTE The lower workover riser package permits well control and ensures a safe operating status whilst performing coiled tubing/wireline and well servicing operations.

3.1.89**lubricator valve**

valve assembly typically situated below the surface tree and used to isolate the reservoir from the environment when deploying long wireline/coiled tubing tool assemblies

3.1.90**maintenance**

total set of activities performed during the service life of the riser to preserve its function

3.1.91**make-up tool**

tool to facilitate the make-up of the riser joint connectors

3.1.92**manufacturer**

individual or organization that is normally responsible for the design and manufacture of the C/WO riser and its conformance with this part of ISO 13628

NOTE The manufacturer can subcontract one or more of the above-mentioned tasks under its responsibility.

3.1.93**manufacturing procedure specification**

document prepared by the manufacturer to demonstrate how the specified properties can be achieved and verified through the proposed manufacturing route

3.1.94**mean static offset**

<of vessel> mean static offset includes static offset due to steady forces from current, wind and wave, offset due to low-frequency motions and active positioning of the vessel

3.1.95**mill/FAT test pressure**

hydrostatic test pressure applied to riser components upon completion of manufacture and fabrication to test the riser components for strength and/or tightness

3.1.96

nominal value

dimensions as specified on the drawings and specifications

3.1.97

non-integral riser

riser which is made up of independent production and annulus strings or bores

NOTE This type of riser is normally run with joints slightly staggered to allow conventional tubing or drill pipe-handling tools to be used for make-up of joints. Clamping the tubular members as they are assembled provides ease of handling and some structural stiffening. A non-integral C/WO riser can be grouped into two types: a drill pipe riser and a tubing riser.

3.1.98

notch stress range

sum of the primary stress range plus the secondary stress range plus the peak stress range, forming the total stress range (see Annex C), as applied to fatigue assessment of unwelded parts

3.1.99

operating envelope

limited range of parameters in which operations will result in safe and acceptable equipment performance

3.1.100

operating mode

condition that arises from the use and application of the equipment or riser system

NOTE Typical operating modes are racking of riser components, running/retrieval, landing/connecting, overpull to verify lockdown, system pressure testing, normal operation, surface shut-in, subsea shut-in, disconnecting, hang-off, overpull to retrieve tubing hanger, failure of dynamic positioning system, failure of tensioner system and failure of anchors or anchor lines.

3.1.101

out-of-roundness

deviation of the circumference from a circle

NOTE This can be an ovalization, i.e. an elliptic cross-section, or a local out-of-roundness, e.g. flattening. The numerical definition of out-of-roundness and ovalization is the same.

3.1.102

ovalization

deviation of the circumference from a circle which has the form of an elliptic cross-section

3.1.103

qualified personnel

individuals with characteristics or abilities gained through theory and training and/or experience as measured against the manufacturer's established requirements

3.1.104

peak stress

part of stress, which is additive to the respective primary and secondary stresses, to form the total stress

NOTE Peak stresses do not cause any noticeable distortion and are only important to fatigue and brittle fracture in conjunction with primary and secondary stresses.

3.1.105

pitch

nominal distance between two adjacent threads roots or crests

3.1.106**primary load**

load which is independent of structural deformation in the riser and induces an internal force that is necessary to satisfy the laws of static equilibrium

NOTE The internal force acts as long as the load is applied, and does not diminish when yielding occurs.

EXAMPLE Internal pressure, external hydrostatic pressure, self-weight, contents and buoyancy of the riser.

3.1.107**primary stress**

stress that satisfies the laws of equilibrium of pressure, external force and moment (i.e. load effects)

NOTE 1 Regarding the mechanical behaviour of a structure, the basic characteristic of this type of stress is that in case of (non-admissible) increment of external load, the deformations upon full plasticification of the section considerably increases without being self-limiting.

NOTE 2 Regarding primary stress, distinction is made between membrane stress and bending stress with respect to their distribution across the cross-section governing the load-carrying behaviour. Primary membrane stress is defined as the average value of the respective stress components distributed over the section governing the load-carrying behaviour. Primary bending stress is defined as primary stress distributed linearly across the considered section and proportional to the distance from the neutral axis.

NOTE 3 Regarding the distribution of membrane stress along the wall, distinction is made between general primary membrane stress and local primary membrane stress. Membrane stress due to gross structural discontinuities (e.g. integral attachments) is considered as local.

3.1.108**process shutdown**

controlled sequence of events that ensures that the well is secured against accidental release of hydrocarbons to the environment

3.1.109**prying**

magnification of an external load by a pseudo-lever action when the load is an eccentric tensile load

3.1.110**pup joint**

joint of pipe or tubing shorter than standard length

3.1.111**purchaser**

organization that buys the C/WO riser system on behalf of the user and/or operator or for its own use

3.1.112**ratcheting**

progressive inelastic deformation or strain which can occur in a component that is subjected to variations of mechanical stress, thermal stress, or both (thermal stress ratcheting is partly or wholly caused by thermal stress)

NOTE Ratcheting results in a plastic deformation, which increases by about the same amount at each cycle and quickly leads to an unacceptable value.

3.1.113**re-entry spool**

uppermost part of a subsea tree to which the C/WO riser is attached to gain vertical well access or the uppermost part of a lower workover riser package to which an emergency disconnect package connector is attached to provide a single disconnect point

3.1.114

resistance

mechanical property of a component, a cross-section, or a member of the structure, e.g. bending resistance, local buckling resistance

3.1.115

response amplitude operator

RAO

relationship between wave surface elevation amplitude and the vessel response amplitude, and the phase lag between the two

3.1.116

retainer valve

valve assembly in the C/WO riser used to retain fluid within the riser and hence preventing its escape to the environment during a riser disconnect operation

NOTE Typically located just above the disconnect point.

3.1.117

return period

average period of time between occurrences of a given event

NOTE The inverse of the return period is the statistical probability of such an event occurring in any given year.

3.1.118

riser disconnect

operation of unlatching a riser connector

EXAMPLE Disconnecting the emergency disconnect package from the lower riser package and/or disconnecting the riser from the subsea test tree.

3.1.119

riser joint

joint consisting of a tubular member(s) midsection, with riser connectors at the ends

NOTE Riser joints are typically provided in 9,14 m to 15,24 m (30 ft to 50 ft) lengths. Shorter joints, pup joints, can also be provided to ensure proper space-out while running the subsea tree, tubing hanger, or during workover operations.

3.1.120

riser model

structural model, established from the tabulated data of the riser, to describe the actual riser, and used in a global analysis of the riser system

3.1.121

riser pipe

seamless pipe which forms the principal conduit of the riser joint

EXAMPLE The riser pipe is the conduit for containing the production fluid flow from the well to the surface tree.

3.1.122

riser system

comprises the riser and all integrated components including subsea and surface equipment

EXAMPLE In tubing hanger mode, the system includes all components from tubing hanger to the top drive; in tree mode, the system includes all components from the wellhead to the top drive.

3.1.123

rotary table

device used to apply torque to the drill string during drilling and normally located in the centre of the drill floor

NOTE Can be rotated and can support wear bushing or spider.

3.1.124**running tool**

specialized tool used to run equipment in a well

EXAMPLE Wireline running tool or various types of tubing-type running tools.

3.1.125**wave scatter diagram**

table listing occurrence of sea-states in terms of significant wave height and wave peak period or mean upcrossing period

3.1.126**seal**

barrier to prevent the passage of fluids

3.1.127**seamless pipe**

tubular product made without a welded seam, manufactured in a hot-forming process using an extrusion or drawing process that can be followed by cold sizing or cold finishing to produce the desired shape, dimensions and properties

3.1.128**secondary load**

load induced by structural deformation (or the prevention thereof) in the riser which is necessary to satisfy the laws of compatibility of strain and deformation

NOTE The internal forces induced by a secondary load diminish when yielding occurs. Secondary loads do not have to be taken into account where they do not affect the resistance of the member/component to resist other loads. Preload of bolts in flanges is an example. During make-up of a flange, the torque/tension applied by the tool on the bolts is primary, but after make-up, the residual bolt preload is secondary.

EXAMPLE An example of a secondary load is the bending caused in the C/WO riser during operation within the drilling riser due to flex joint/ball joint angles. Bending moments that exceed yield, in this case, do not generally cause excessive yielding and failure. Other examples are differential temperature in restrained sections and residual stresses after welding.

3.1.129**secondary stress**

stress developed by constraint due to a geometrical discontinuity, by the use of materials of different elastic moduli under external load, by constraint due to differential thermal expansion, or by assembly load (preload) that does not impair the sealing performance of a connector

NOTE 1 Only stresses that are distributed linearly across the thickness are considered secondary stresses. For non-linearly distributed stresses, the secondary stresses are those of the equivalent linear distribution.

NOTE 2 With respect to the mechanical behaviour of the structure, the basic characteristic of secondary stresses is that they lead to plastic deformation when equalizing different local distortions in the case of excess of the yield strength. Characteristic for a secondary stress is that it is self-limiting, i.e. local flow deformation leads to a limitation of the stress.

NOTE 3 Secondary stresses can be of the membrane or bending type.

NOTE 4 Bending stresses caused by gross structural discontinuities and acting across the wall thickness of the pipe are classified as secondary stresses.

3.1.130**secure status**

establishment of two independent barriers between the reservoir and the environment

3.1.131

service life

duration of time in which the equipment performs under the specified design conditions, i.e. time in active operation excluding storage periods

NOTE The service life is normally a small fraction of the design life.

3.1.132

shearing valve

gate valve or ball valve designed to shear wireline or coiled tubing and that can seal the bore

3.1.133

slick joint

special riser joint designed to prevent damage to the riser and control umbilical where they pass through the rotary table

NOTE Usually included in C/WO risers and is sometimes named "cased wear joint".

3.1.134

S-N curve

graphical presentation of the dependence of fatigue life, N , on fatigue strength, S

NOTE It is also known as the Wöhler curve.

3.1.135

sour service

service conditions with H_2S content exceeding the minimum specified by ISO 15156 (all parts) at the design pressure

3.1.136

specified minimum yield strength

minimum yield strength at room temperature prescribed by the specification or standard under which the material is purchased

3.1.137

spider

device having retractable jaws or dogs used to support the riser on the uppermost connector support shoulder during running of the riser

NOTE The handling spider sits either on the rotary bushing or in the rotary table. It provides a hang-off point for the integral C/WO riser. Some spiders will lock to the rotary via the kelly drive pinholes in the master bushing. With the pins engaged, the spider can resist torque. For non-integral risers, tubing slips and false rotaries are used in lieu of the spider.

3.1.138

splash zone

part of the riser subjected to repeated wetting and drying by seawater

3.1.139

stab

mating box and pin assembly that provides pressure-tight engagement of two pipe joints

NOTE An external mechanism is normally used to keep the box and pin engaged. For example, riser joint annulus stabs can be retained in the stab mode by the make-up of the riser coupling.

3.1.140

stab sub

male half of sealing mechanism between component interfaces

NOTE Stab subs can use elastomeric or metal seals or both.

3.1.141**strength**

mechanical property of a material, usually given in units of stress

3.1.142**stress concentration factor****SCF**

local peak alternating stress in a component (including welds) divided by the nominal alternating stress in the pipe wall at the location of the component

NOTE This factor is used to account for the increase in the stresses caused by geometric stress amplifiers, which occur in the riser component.

3.1.143**stress intensity factor**

(fracture mechanics) factor used to define the local conditions of stress and strain around a crack tip in terms of global parameters such as of loads, geometry and crack size

3.1.144**stress joint**

specialized riser joint designed with a tapered cross-section, in order to control curvature and reduce local bending stresses

NOTE It is the lowermost riser joint in the riser string when configured for workover.

3.1.145**stress range**

difference between stress maximum and stress minimum in a stress cycle

3.1.146**stroke**

total upward and downward vertical movements of the riser relative to the vessel, i.e. travel of the riser tensioner, draw works and slick joint

NOTE It includes effects from environmental loads, functional loads (i.e. top tension, temperature and mean static vessel offset) and pressure.

3.1.147**subsea test tree**

assembly of valves positioned above the tubing hanger running tool located inside the subsea BOP and equivalent to the lower workover riser package

NOTE It is used to secure the well and provides a disconnect point for the C/WO riser. The subsea test tree can be configured for operation on horizontal or vertical trees.

3.1.148**subsea tree**

assembly of valves attached to the uppermost connection of the subsea wellhead and used to control well production

3.1.149**subsea wellhead**

wellhead assembly used during drilling and completion operations that has provisions to lock and seal to a subsea BOP stack and to the subsea tree

3.1.150**surface tree**

device which provides flow control of the production and/or annulus bores during both tubing hanger installation and subsea tree installation/workover operations

NOTE It can also have provisions to support the mass of the C/WO riser system.

3.1.151

surface tree adapter joint

crossover from the standard riser joint connector to the connection at the bottom of the surface tree

NOTE Its bore configuration is consistent with the standard riser joint. This speciality joint is usually made up to the surface tree prior to installation.

3.1.152

support shoulder

shoulder or projection on the external surface of a connector or the riser component for supporting the riser system or well control equipment during riser running operations

3.1.153

surge

vessel motion along the fore/aft axis

3.1.154

surge pressure

pressure produced by sudden changes in the velocity of the moving stream of fluids inside the riser

3.1.155

sway

vessel motion along the port/starboard axis

3.1.156

system pressure test

field hydrostatic leak-tightness pressure test of the complete riser system performed after installation and before start of operation

3.1.157

system test pressure

test pressure applied to the riser during system field pressure test of the C/WO riser system performed after installation and before start of operation

3.1.158

minimum design metal temperature

lowest metal temperature likely to be reached in operation, normally taken as the lowest fluid temperature to which the riser will be exposed in service

3.1.159

room temperature

any temperature between 4 °C and 40 °C (40 °F and 104 °F), i.e. temperature corresponding to the test conditions of the material

3.1.160

tension joint

special riser joint that provides a means for tensioning the C/WO riser with the floating vessel's tensioning system during open-sea workover mode

NOTE When in use, the tension joint is located below the slick joint, which has a provision for attaching the tensioner unit to the riser.

3.1.161

tension ring

attachment point on the tension joint for the floating vessel tensioning lines

3.1.162

tensioner system

device that applies a close to constant tension to the riser string while compensating for the relative vertical motion (stroke) between the floating vessel and the top of the deployed riser string

3.1.163**time domain**

timewise, incremental simulation of riser response

NOTE Offers the capability of modelling hydrodynamic and structural non-linearity.

3.1.164**top tensioned riser**

vertical or nearly vertical riser supported by top tension in combination with boundary conditions that allow for relative riser/vessel motions in vertical direction and constrained to follow the horizontal vessel motion at one or several locations

3.1.165**tree running tool**

device used to run and land the subsea tree on the subsea wellhead

3.1.166**tubing**

pipe used in wells to conduct fluid from the well's producing formation into the subsea tree

3.1.167**tubing hanger**

component used to support the downhole completion tubing string

NOTE It is also typically used to seal and contain the completion annulus from the environment.

3.1.168**tubing hanger running tool**

device used to run, land and lock the tubing hanger inside the wellhead, tubing spool, or subsea tree

3.1.169**tubing riser**

riser which consists of one or more individual strings of production tubing and a hydraulic control umbilical

NOTE If multiple tubing strings are used, they can be left either independent of each other, or secured together using some type of clamping device. The hydraulic control umbilical is normally clamped or strapped to one of the tubing strings as it is run.

3.1.170**umbilical**

flexible hose consisting of a group of electrical cables, optical fibre cables, hoses, pipes, either on their own or with combinations of each other, cabled together for flexibility and oversheathed and/or armoured for mechanical strength, used to transmit fluid/electrical signals to and from a power source to a remote station

3.1.171**umbilical clamp**

clamp used to attach the umbilical(s) to the riser joints

3.1.172**user and/or operator**

organization that uses and/or operates the C/WO riser system

3.1.173**verification**

examination to confirm that an activity, a product or a service is in accordance with specified requirements

3.1.174**vessel mean offset**

offset created by steady forces from current, wind and waves

3.1.175

vessel offset

total offset of the vessel, taking into account the vessel mean offset, wave frequency motions and low-frequency wind and wave motions

3.1.176

vertical tree

subsea tree with either multiple or concentric bores and production valves located in the vertical bore of the tree, where the tubing hanger is installed before the tree

3.1.177

vortex-induced vibration

in-line and transverse oscillation of a riser caused by current-induced periodic shedding of vortices

3.1.178

wave frequency motion

motion of the vessel at the frequencies of incident waves

3.1.179

wear bushing

bushing to be installed in the rotary table, to provide a smooth lateral support to the workover riser at drill floor level

3.1.180

well completion

well operations including tubing installation, well perforation and test production

3.1.181

wireline/coiled tubing BOP

WCT-BOP

subsea BOP that attaches to the top of a subsea tree to facilitate wireline or coiled tubing intervention

NOTE WCT-BOP rams are designed to shear wireline or coiled tubing and seal the bore, in one operation.

3.1.182

work

all activities to be performed within relevant contract(s) issued by designer, owner, operator, contractor, fabricator or manufacturer

3.1.183

workover riser

jointed riser that provides a conduit from the subsea tree upper connection to the surface and allows for the passage of tools during workover operations of limited duration, and can be retrieved in severe environmental conditions

NOTE Historically, workover operations have normally been performed in open sea (i.e. for vertical tree systems), but can be performed inside a drilling riser, provided sufficient barrier elements are available.

3.2 Abbreviated terms

ASTM	ASTM International
BOP	blow-out preventer
CTOD	crack tip opening displacement
C/WO	completion/workover
EDP	emergency disconnect package
EN	European Standard

FAT	factory acceptance test
FMECA	failure mode, effects and criticality analysis
GPS	global positioning system
HAZOP	hazard and operability
HV	Vickers hardness
IMO	International Maritime Organization
LMRP	lower marine riser package
MPI	magnetic particle inspection
NA	not applicable
NDT	non-destructive testing
OOR	out of roundness
PWHT	post-weld heat treatment
RAO	response amplitude operator
SCF	stress concentration factor
SCSSV	surface controlled subsurface safety valve
SSC	sulfide stress-cracking
UT	ultrasonic testing
WCT-BOP	wireline/coiled tubing BOP

3.3 Symbols

$A_{b,r}$	bolt root area
$A_{b,s}$	bolt stress cross-sectional area
A_c	pipe cross-section area
A_{int}	internal cross-section area of the pipe
A_o	external cross-section area of the pipe giving buoyancy if submerged
A_{TTS}	tensile test specimen cross-section area
A_5	elongation after rupture, expressed in percent; for a tensile test piece with gauge length, $L_0 = 5,65\sqrt{A_{TTS}}$ or $5d_d$
a	crack depth for surface flaws or half depth for embedded crack
a_f	final crack size
a_0	initial crack size
$\bar{a}$	characteristic fatigue strength or intercept of the design S-N curve with the log N axis

$\bar{a}_1$	intercept of the design S-N curve with the log N axis, left part of S-N curve
$\bar{a}_2$	intercept of the design S-N curve with the log N axis, right part of S-N curve
$\bar{a}_{1,thick}$	intercept of the design S-N curve with the log N axis, left part of S-N curve, size corrected
$\bar{a}_{2,thick}$	intercept of the design S-N curve with the log N axis, right part of S-N curve, size corrected
C	constant crack growth-rate parameter
C_f	design condition factor
D_{FAT}	fatigue damage
D_F	design fatigue factor
D_{align}	pipe/connector alignment (line-up tolerance) on diameter
D_{clear}	minimum drift clearance on diameter
D_{drift}	major drift diameter
D_{int}	inside diameter of pipe
$D_{int,min}$	minimum inside diameter of pipe
D_o	specified or nominal pipe outside diameter
$D_{o,max}$	maximum outside diameter at any cross-section
$D_{o,min}$	minimum outside diameter at any cross-section
D_{SN}	accumulated long-term fatigue damage or Miner-Palmgren damage ratio
$D_{SN,ij}$	fatigue damage in the sea-state, j , and wave direction, i
D_{weld}	weld root bead finish (height) on weld root diameter
d	minor drift diameter
d_b	nominal (basic major diameter) bolt diameter
$d_{b,f}$	mean effective bolt diameter
d_{bh}	bolt hole diameter
d_d	tensile test specimen diameter
d_{max}	maximum depth below the surface for a blend
d_n	effective contact diameter of nut-bearing surface
d_{nf}	nut diameter across flats
d_t	effective contact diameter of the threads
E	modulus of elasticity
e	axial misalignment (eccentricity or centre-line mismatch)

e_0	misalignment (eccentricity) inherent in the S-N data
$e_{\text{OOR,max}}$	maximum misalignment resulting from out of roundness
$e_{\text{t,max}}$	maximum misalignment resulting from difference in wall thickness
F_b	pipe burst design factor
F_d	design factor
F_{hb}	pipe hoop buckling (collapse) design factor
$F_{\text{w,c}}$	wave and current forces
$f(S_{\text{a,lm}})$	Weibull probability density function for the stress amplitude, $S_{\text{a,lm}}$
f_m	stress range reduction factor
$f_s(S)$	stress cycles probability density function
f_0	initial pipe ovality
g	acceleration due to gravity
H_s	significant wave height
H_{wrf}	weld root bead finish
h	height difference between the actual location and the internal pressure reference point
I	moment of inertia of section
I_n	n th order response spectral moment
I_{pitch}	pitch of the threads
I_0	zero-order moment of stress spectrum
I_2	second-order moment of stress spectrum
i	summing index
J	polar moment of inertia of section
j	summing index
ΔK	stress intensity factor
K_F	flex-joint rotational stiffness
K_m	geometric stress concentration factor
K_{notch}	notch stress concentration factor
ΔK_{th}	threshold stress intensity factor range below which fatigue crack growth does not occur
k	number of stress range bins (blocks)
k_{cg}	crack growth exponent

k_1	thickness exponent on fatigue strength
L_c	clearance
L_F	calculated fatigue life
L_S	service life
L_{SO}	vessel static offset
L_0	tensile test-specimen gauge length
l_b	bolt clamp length (clear distance between engaged threads)
l_{se}	length of stud engagement
M_{bm}	bending moment
$M_{b,max}$	maximum torque during make-up
$M_{b,nom}$	nominal torque during make-up
ΔM_{bm}	bending moment range
M_c	single load ultimate bending capacity
M_f	bending moment required to bend C/WO riser
M_G	global bending moment acting below marine riser flex-joint
M_{pc}	plastic bending moment capacity of the pipe
M_T	applied torque
m	negative inverse slope of the S-N curve
m_1	negative inverse slope of the S-N curve, left part
m_2	negative inverse slope of the S-N curve, right part
N	number of cycles to failure at constant stress range
N_i	number of cycles to failure at constant stress range S_i in each stress bin (block) i
N_p	design operating cycles to failure
N_1	point of discontinuity on a bilinear S-N curve
$N_{1,a}$	point of discontinuity on a bilinear S-N curve, in air or non-corrosive environment
$N_{1,sw}$	point of discontinuity on a bilinear S-N curve, in seawater with cathodic protection
n_i	number of occurrences in stress range bin i
n_{thr}	number of threads per inch
P_{br}	average bearing stress
P_{bs}	primary bending stress

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P_l	local primary membrane stress
P_m	general membrane primary stress
P_{sh}	primary average shear stress
p_b	burst pressure of the pipe
$p_{b,min}$	minimum pipe burst pressure
p_c	pipe hoop buckling (collapse) pressure
$p_{c,min}$	minimum pipe hoop buckling (collapse) pressure
p_{ec}	single load ultimate pressure capacity due to end cap effect
p_{el}	elastic hoop buckling (collapse) pressure (instability) of pipe cross-section
$p_{el,min}$	minimum elastic hoop buckling (collapse) pressure (instability) of pipe cross-section
p_{FAT}	hydrostatic FAT test pressure
p_{int}	internal pressure at a reference point
$p_{int,d}$	internal design pressure
$p_{int,min}$	minimum hydrostatic internal pressure
$p_{int,o}$	internal operating pressure
$p_{l,int}$	local internal pressure at a specified point
p_o	external pressure at a reference point
p_{od}	external design pressure
$p_{o,min}$	minimum external hydrostatic pressure
p_p	plastic pressure at hoop buckling (collapse) of the pipe cross-section
$p_{p,min}$	minimum plastic pressure at hoop buckling (collapse) of the pipe cross-section
Q_{ms}	secondary membrane stress
Q_s	secondary stress
q_i	probability of wave direction i
q_j	probability of sea-state j
R_a	arithmetical average roughness
$R_{c,test}$	ultimate capacity (resistance)
R_d	design capacity (resistance)
R_m	specified minimum ultimate tensile strength at room temperature
$R_{m/T}$	specified minimum ultimate tensile strength at a specific temperature

R_{nc}	normal operation capacity
$R_{t0,5}$	specified minimum yield strength for 0,5 % total elongation at room temperature
$R_{t0,5/T}$	specified minimum yield strength for 0,5 % total elongation at a specific temperature
$R_{t0,5/T,stud}$	specified minimum yield strength for 0,5 % total elongation at a specific temperature for a stud
$R_{t0,5/T,tapped}$	specified minimum yield strength for 0,5 % total elongation at a specific temperature for tapped hole material
R_{uc}	plastic collapse or ultimate capacity
r	pipe mean radius
r_m	mean section radius
r_s	section radius
S	stress range
$S_{a,lm}$	local stress maxima (amplitude)
S_b	bending component of the primary plus secondary principal stress range
S_d	design load effect
S_{gs}	geometric stress concentration stress range
S_i	constant stress range in each stress block
S_m	membrane (average) component of the primary plus secondary principal stress range
S_{notch}	notch stress range
S_{P+Qs}	primary plus secondary stress range
S_{P+Qs+F}	maximum primary plus secondary plus peak stress range
S_1	stress range at the point of discontinuity (bi-linear S-N curve)
$S_{1,thick}$	stress range with thickness correction
$S_{\sigma\sigma}$	autospectral density of the stress response
$T_{b,max}$	maximum bolt preload (tension) during make-up
$T_{b,min}$	minimum bolt preload (tension) during make-up
$T_{b,nom}$	nominal bolt preload (tension) during make-up
T_c	single load ultimate tension capacity
T_e	effective tension
ΔT_e	cyclic effective tension range
T_{eq}	equivalent effective tension due to bending moment

$T_{e,tot}$	total effective tension from the marine riser and C/WO riser acting at the flex-joint
T_p	wave peak period
T_{pc}	plastic tension capacity of the pipe
T_{tot}	total axial load
T_v	vertical tension component of $T_{e,tot}$
T_w	true wall tension
T_z	wave zero-upcrossing period
t	pipe wall thickness
t_{ca}	corrosion/wear/erosion allowance
Δt_{fab}	is the absolute value of the negative tolerance taken from the material specification/standard
t_n	nominal (specified) pipe wall thickness
Δt_{neg}	percentage negative wall thickness tolerance
$t_{n,max}$	maximum nominal wall thickness
$t_{n,min}$	minimum nominal wall thickness
Δt_{pos}	percentage positive wall thickness tolerance
t_{ref}	reference thickness equal to 25 mm (0,984 in) for welded connections and bolts (stress diameter)
t_1	minimum pipe wall thickness without allowances and fabrication tolerances as appropriate
t_2	pipe wall thickness without allowances
V_c	current velocity
V_{se}	shear force acting at the flex-joint due to environmental loading on the marine riser and BOP
V_{sh}	total shear force acting at the marine riser flex-joint
V_w	wave velocity
w_{BOP}	submerged weight of the BOP and LMRP including bore contents
w_e	effective (apparent) weight
w_p	weight of the pipe
x_{pca}	pipe/connector alignment tolerance
Y	stress intensity correction factor
Y_u	ultimate tensile strength reduction factor at elevated temperature
Y_y	yield strength reduction factor at elevated temperature
Z	pipe plastic section modulus

z	variable in the gamma function
α	Weibull distribution scale parameter
α_{bm}	pipe cross-section slenderness parameter
α_L	linear coefficient of thermal expansion
β	Weibull distribution dimensionless shape parameter
β_{thr}	half-angle of the threads, equal to 30° for UN threads
$\Gamma(\cdot)$	gamma function
$\Gamma(;)$	complementary incomplete gamma function
$\gamma(;)$	incomplete gamma function
Δ_b	bolt transfer loss for tension tool
δ_1	horizontal distance between the flex-joint and point of interest
δ_2	horizontal distance from the BOP centre of gravity to the point of interest
ε	scatter in preload during make-up
ε_{peq}	equivalent plastic strain
ε_t	scatter in applied torque during make-up
θ_{dev}	deviation angle of the BOP and high-pressure wellhead housing vertical axis relative to the global vertical axis
θ_B	marine riser upper ball-joint angle relative to diverter vertical axis
θ_F	marine riser lower flex-joint angle relative to BOP vertical axis
θ_G	global marine riser lower flex-joint angle relative to the global vertical axis
θ_W	main wave direction
μ_n	coefficient of friction between nut and bearing surface
μ_t	coefficient of friction between nut and bolt threads
$\hat{\mu}_{st}$	statistical moment for local maxima
ν	Poisson's ratio
ν_0	average zero-crossing frequency of the stress response
$\nu_{0,S}$	average zero-crossing frequency for the service life
ρ_{int}	density of the internal fluid
ρ_o	density of sea water
σ	stress

σ_{act}	actual average (minimum three specimens) yield strength from test specimens at test temperature
σ_b	bending stress
σ_{br}	average bearing stress
σ_{eq}	von Mises equivalent stress
$\Delta\sigma_{eq}$	equivalent von Mises stress range
σ_{HS}	structural hotspot stress
σ_{int}	stress at inside of section/wall
σ_m	membrane stress
σ_{max}	maximum cyclic principal stress
σ_{mean}	mean cyclic stress
σ_{min}	minimum cyclic principal stress
σ_N	notch stress
σ_o	stress at outside of section/wall
σ_{SD}	standard deviation of the stress response process
$\hat{\sigma}_{st}$	statistical moment for local maxima
σ_u	ultimate tensile strength to be used in design at maximum design temperature
σ_y	yield strength to be used in design at maximum design temperature
$\sigma_1, \sigma_2, \sigma_3$	principal stresses in directions 1, 2 and 3, respectively
$(\Delta\sigma)_1, (\Delta\sigma)_2, (\Delta\sigma)_3$	principal stress ranges in directions 1, 2 and 3, respectively
$(\sigma_{br})_{P+Qs}$	average primary plus secondary bearing stress
$(\sigma_{eq})_P$	primary membrane von Mises stress
$(\sigma_{eq})_{Pm+Qms+Pbs}$	primary membrane plus secondary membrane plus secondary bending von Mises stress
$(\Delta\sigma_{eq})_{P+Qs}$	primary plus secondary von Mises stress range
$(\sigma_{eq})_{PI}$	local primary membrane von Mises stress
$(\sigma_{eq})_{Pm}$	general primary membrane von Mises stress
τ	time
$\tau_{r\theta}$	average shear stress

τ_{ss}	duration of short-term sea-states
$(\tau_{sh})_{Pm}$	average primary shear stress
ϕ_{A5}	ductility reduction factor
ϕ	variable in the gamma function
ω_{SR}	angular frequency of stress response

4 System requirements

4.1 Purpose

Clause 4 specifies system requirements for C/WO riser systems.

4.2 Description of C/WO riser systems

A completion riser is used to run the tubing hanger and tubing through a drilling riser and BOP into the wellbore. A workover riser is typically used in place of a drilling riser to re-enter the well through the subsea tree in open sea, and may also be used to install the subsea tree. A completion and workover riser may be a common system with items added or removed to suit the task being performed.

Both riser types provide communication between the wellbore and the surface equipment. Both resist external loads and pressure loads and accommodate tools for necessary operations. The completion riser is exposed to external loading such as curvature of the drilling riser, especially at the upper and lower joints (flex-joint/ball-joint angles). The workover riser is exposed to ocean environmental loads such as hydrodynamic loads from waves and current in addition to vessel motions.

4.3 System engineering

System engineering shall be performed to ensure that engineering activities are performed in such a manner that the C/WO riser system complies with the provisions of this part of ISO 13628, purchaser's specification(s) and regulatory requirements. System engineering shall as a minimum include the following:

- establishment of a design basis, see 11.3 and Annex F;
- establishment of the system definition, see 4.4;
- system design, see 4.5;
- system review, see 4.6;
- verification, see 4.17.

A typical engineering-process flow chart is shown in Figure 1.

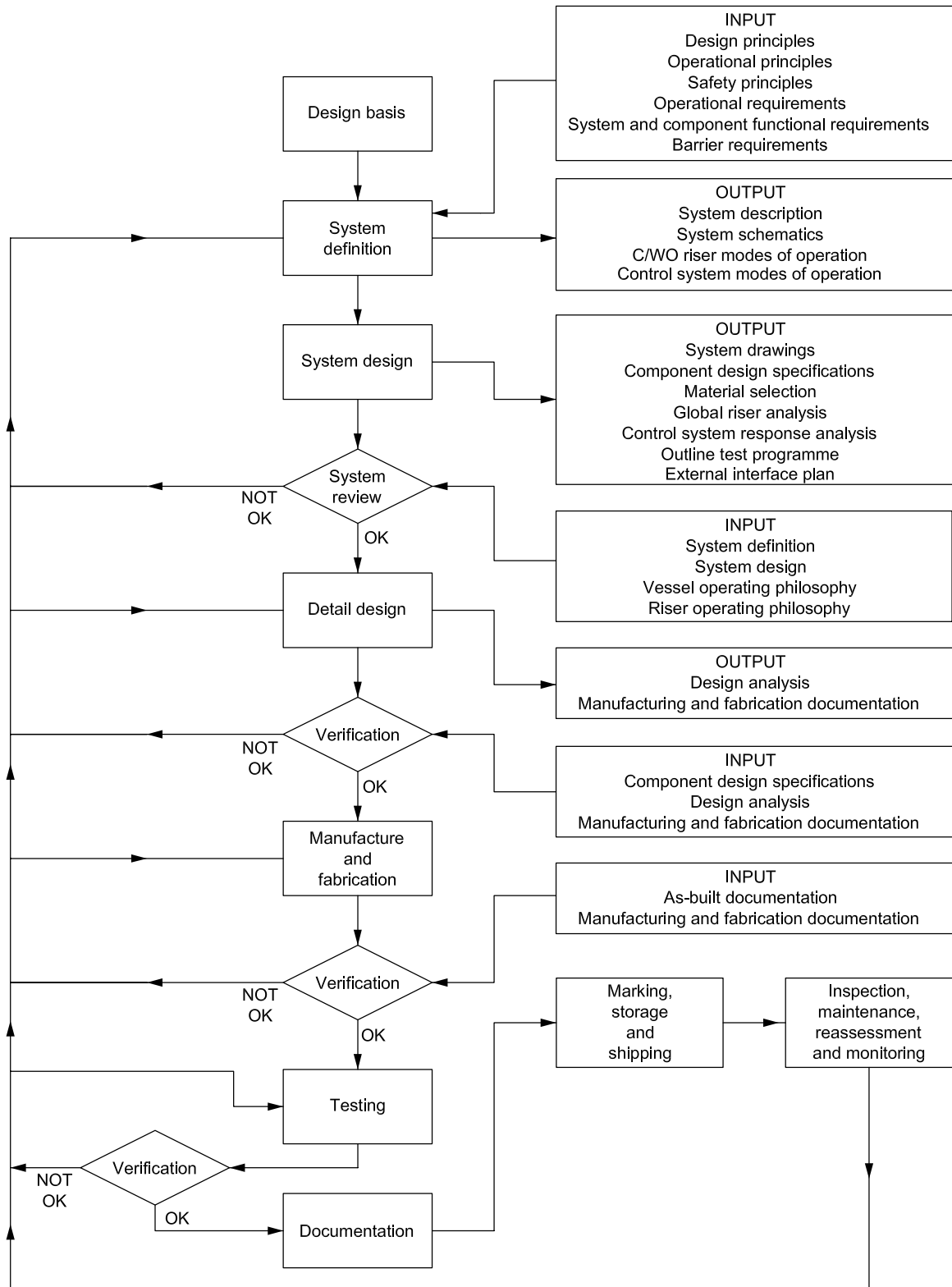


Figure 1 — Typical engineering-process flow chart

4.4 System definition

A system solution shall be defined that meets the following requirements:

- a) regulatory requirements;
- b) barrier requirements; see 4.11;
- c) purchaser specification requirements; see Annex F;
- d) design basis; see 11.3 and Annex F;
- e) design principles, see 4.8;
- f) operational principles; see 4.9;
- g) safety principles; see 4.10;
- h) operational requirements; see 4.13 and Annex B;
- i) system and component functional requirements; see 5.2 and 5.4.

The system definition shall as a minimum be defined in terms of the following:

- system description;
- system schematics;
- riser system modes of operation; see 4.7.1;
- workover control system modes of operation; see 4.7.2.

4.5 System design

System design shall be based on the design basis and the system definition. The system design shall as a minimum be defined in terms of the following:

- system drawings;
- component design specifications;
- material selection; see 6.4.3 and 7.2.1;
- global riser analysis; see Clause 6 and Annex B;
- workover control system analysis including emergency shutdown and disconnect response times; see 5.5.5 and 5.5.6;
- outline test programme;
- external interface plan.

4.6 System review

4.6.1 General

A systematic review or analysis shall be performed according to a clearly defined review basis and shall include the following:

- verification of system compliance;
- risk assessment.

4.6.2 System compliance

A systematic review shall be performed to verify that the C/WO riser system complies with the following:

- regulatory requirements;
- barrier requirements; see 4.11;
- purchaser specification requirements; see Annex F;
- design basis; see 11.3 and Annex F;
- design principles; see 4.8;
- operational principles; see 4.9;
- safety principles; see 4.10;
- operational requirements; see 4.13;
- system and component functional requirements; see 5.2 and 5.4.

4.6.3 Risk assessment

The operator shall specify the extent of the risk assessments and the risk assessment methods. The extent of the assessment or analysis shall reflect the criticality of the C/WO riser system, the criticality of the operations and previous experience with similar systems and operations.

Although the integrity of the C/WO riser system is the primary concern, the risk assessments shall encompass a larger scope, including the subsea well, drilling riser and BOP, surface vessel, environmental conditions and system interfaces at the top and bottom of the C/WO riser.

The purpose of the risk assessments shall be to identify possible critical items, operations or activities, which could cause or aggravate a hazardous condition, and to ensure that effective corrective measures are taken (e.g. either by design or operational procedures).

Quantitative risk analysis may be conducted to provide an estimation of the overall risk to health and safety, environment and assets and typically includes the following:

- hazard identification;
- assessment of probabilities of failure events;
- accident developments;
- consequences and risk assessment.

NOTE It should be noted that legislation in some countries requires risk analysis to be performed, at least at an overall level to identify critical scenarios that might jeopardize the safety and reliability of the C/WO riser system. Other methodologies for identification of potential hazards are failure mode and effect analysis and HAZOP studies.

Conditions that may require system review or risk analysis include:

- new or non-standard operations;
- operations in new areas;
- operations to be performed by new or modified vessel or installation;
- operations using new or modified equipment;
- operations including contractor(s) not familiar with the surface vessel, area or operation;
- operations that are considered hazardous (e.g. high temperature/high pressure, dynamic positioning, simultaneous operations, deep water or cold climate).

4.7 Modes of operation

4.7.1 Riser system

The C/WO riser system is normally used for the following operations:

- a) well completion, i.e. run/retrieve tubing and tubing hanger through the drilling riser and BOP;
- b) run/retrieve the subsea tree;
- c) workover operations to provide wireline/coiled tubing access into the production and/or annulus wellbores.

A typical arrangement for a connected C/WO riser in tree mode is illustrated in Figure 2. In the tubing hanger mode, see Figure 3 for a typical arrangement, the system is used to run the downhole completion through the drilling riser and BOP stack. The typical modes of operation for vertical and horizontal subsea trees are listed in Table 1.

Table 1 — Typical modes of operation

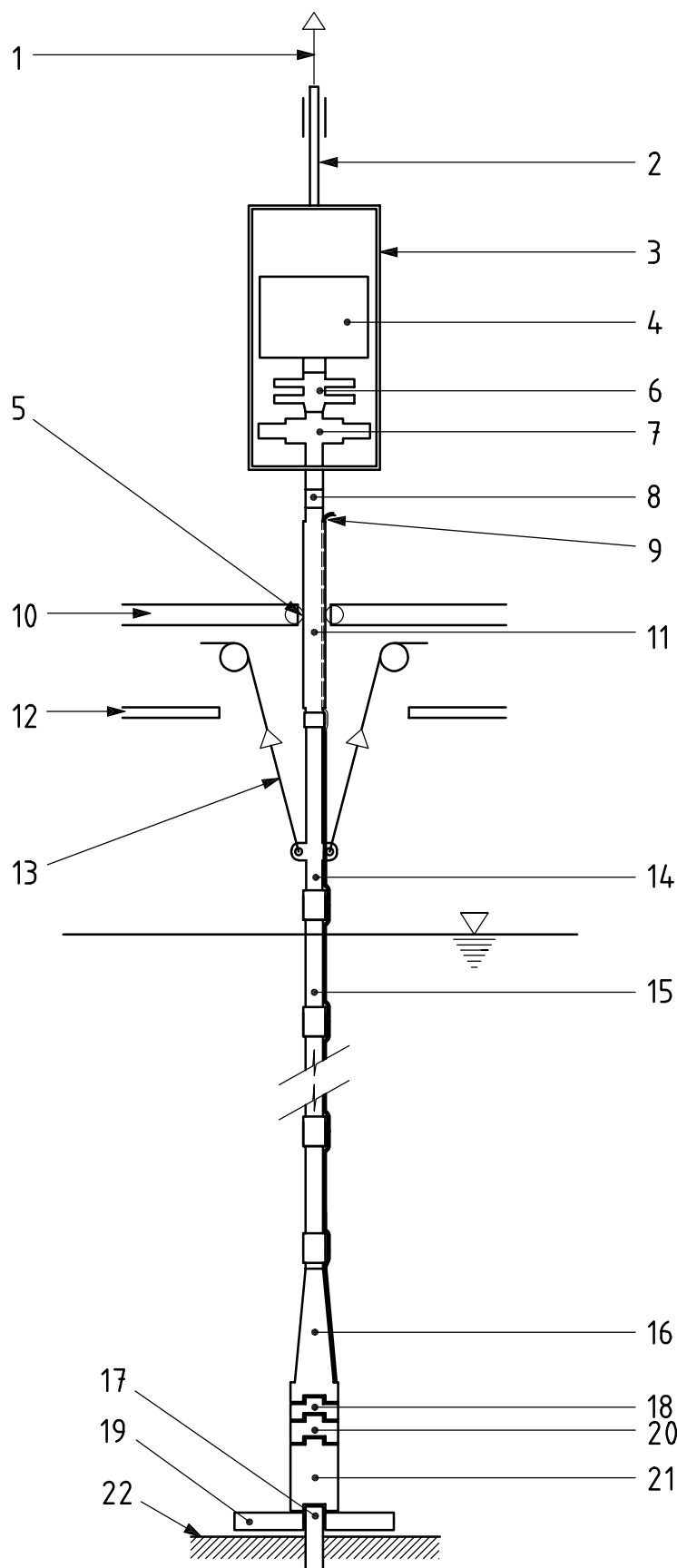
Operation ^a	Tubing hanger mode	Tree mode
Well completion	b + c	c
Well intervention — open sea	NA	b + c
Well intervention — inside drilling riser	b + c	NA
Full workover	b + c	c
^a These modes of operation are typical for horizontal and vertical trees. Other modes of operation may apply for existing and future tree designs. ^b Horizontal tree. ^c Vertical tree.		

Typical schematics for each mode of operation and for both types of subsea trees are shown in Figures 4 to 7.

4.7.2 Workover control system

The modes of operation for the control system shall be defined for each mode of operation (i.e. tubing hanger and tree mode) and subsequent operations. The following shall be defined for each mode:

- automatic shutdown and disconnect sequences including sequenced response times, time delay functions and interlock functions;
- control function failure mode, where applicable (i.e. fail-safe close or fail as is);
- function type (i.e. hydraulic, electrical, pneumatic or chemical injection);
- line number, line size, displaced volume and maximum line pressure;
- instrumentation location and type;
- chemical/methanol injection points, injection pressure and flow rate.



Key

- 1 top drive
- 2 drill sub
- 3 surface-tree tension frame
- 4 coiled tubing injector
- 5 roller bushing
- 6 surface BOP
- 7 surface tree
- 8 surface-tree adapter joint
- 9 umbilical (to hose reel)
- 10 drill floor
- 11 slick (cased wear) joint
- 12 moon pool area
- 13 riser tension wires
- 14 tension joint
- 15 standard riser joints
- 16 stress joint
- 17 wellhead
- 18 emergency disconnect package
- 19 guide base
- 20 lower riser package
- 21 subsea tree
- 22 seabed

Figure 2 — Typical C/WO riser general arrangement — Tree mode

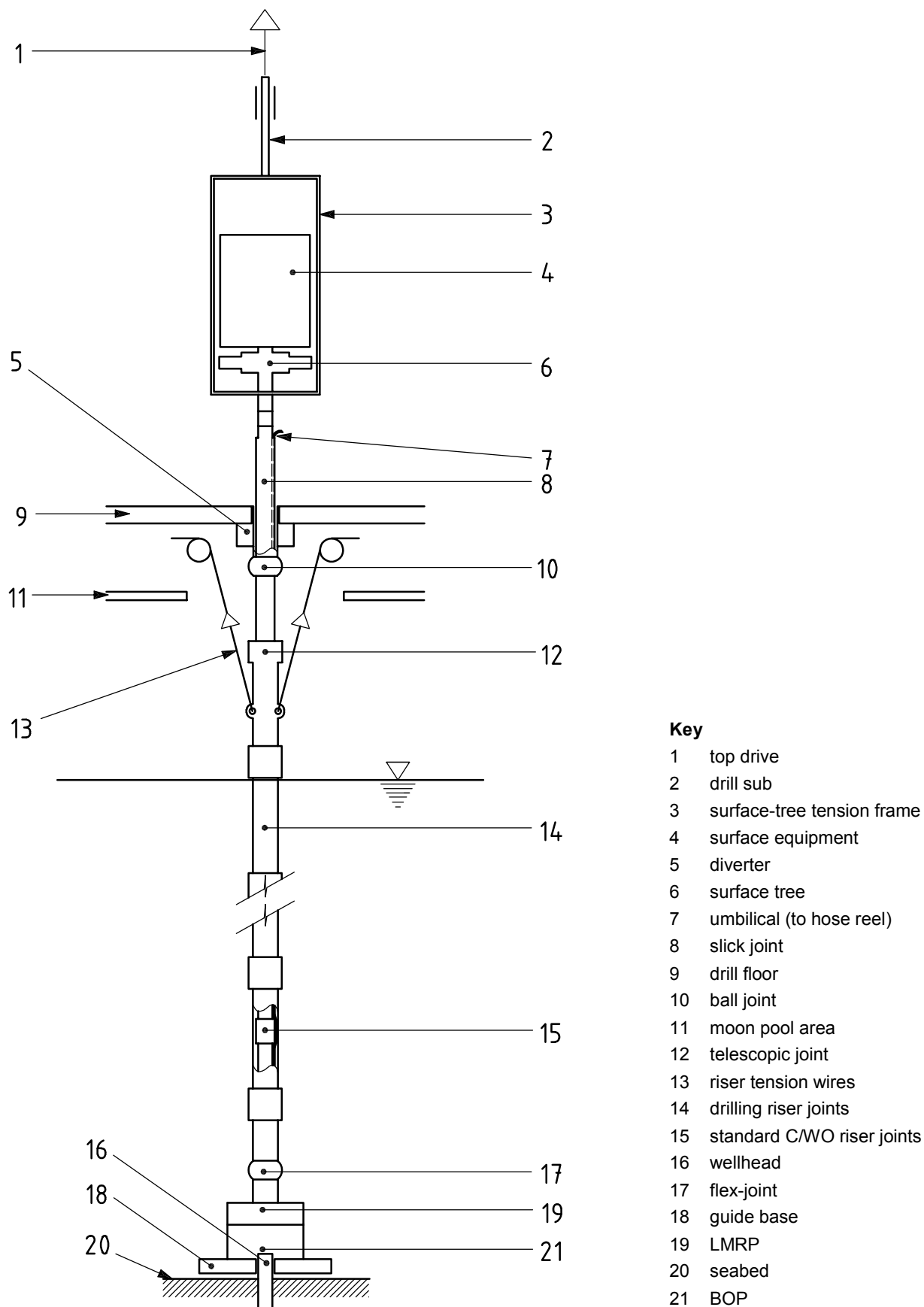
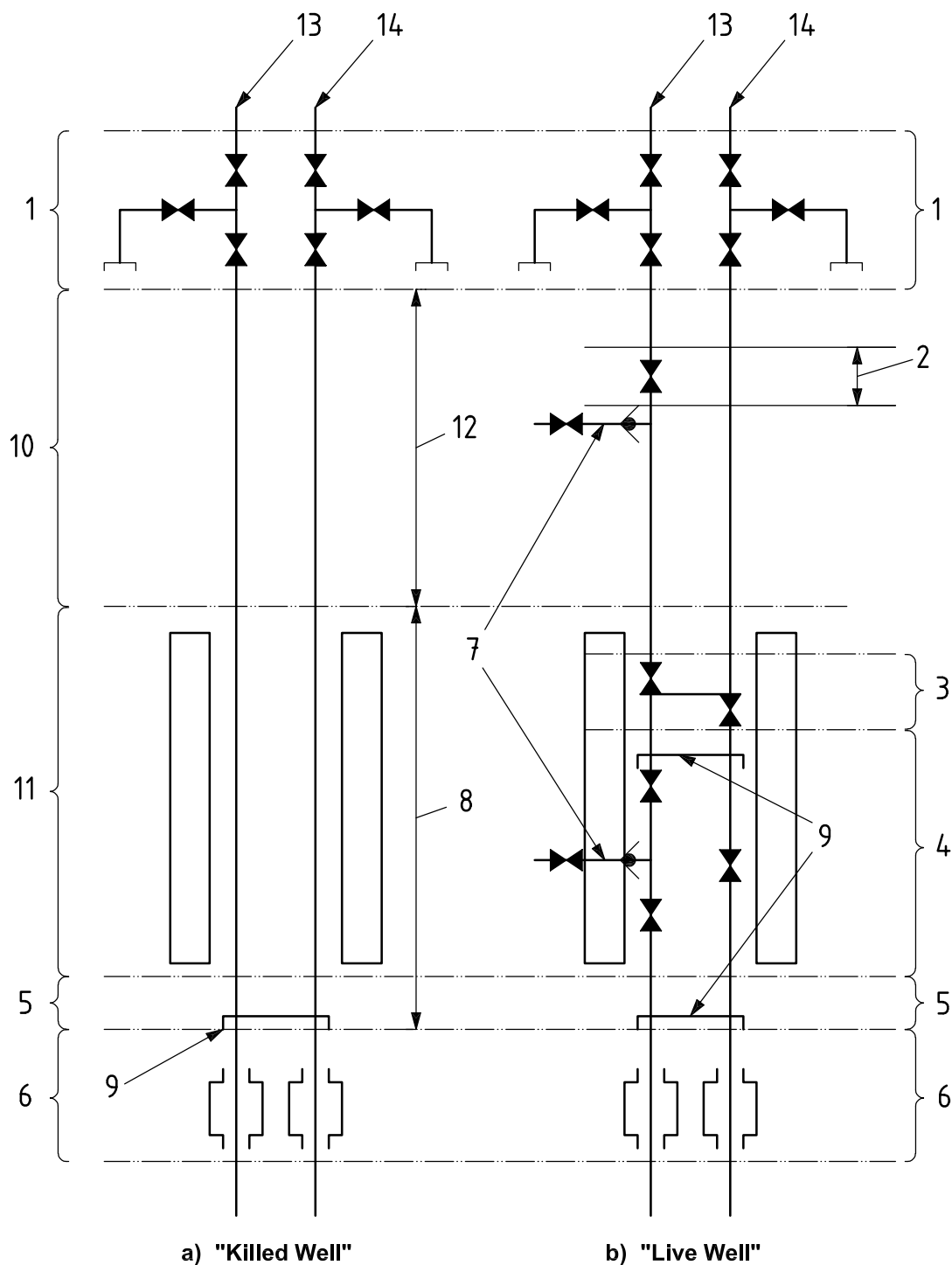


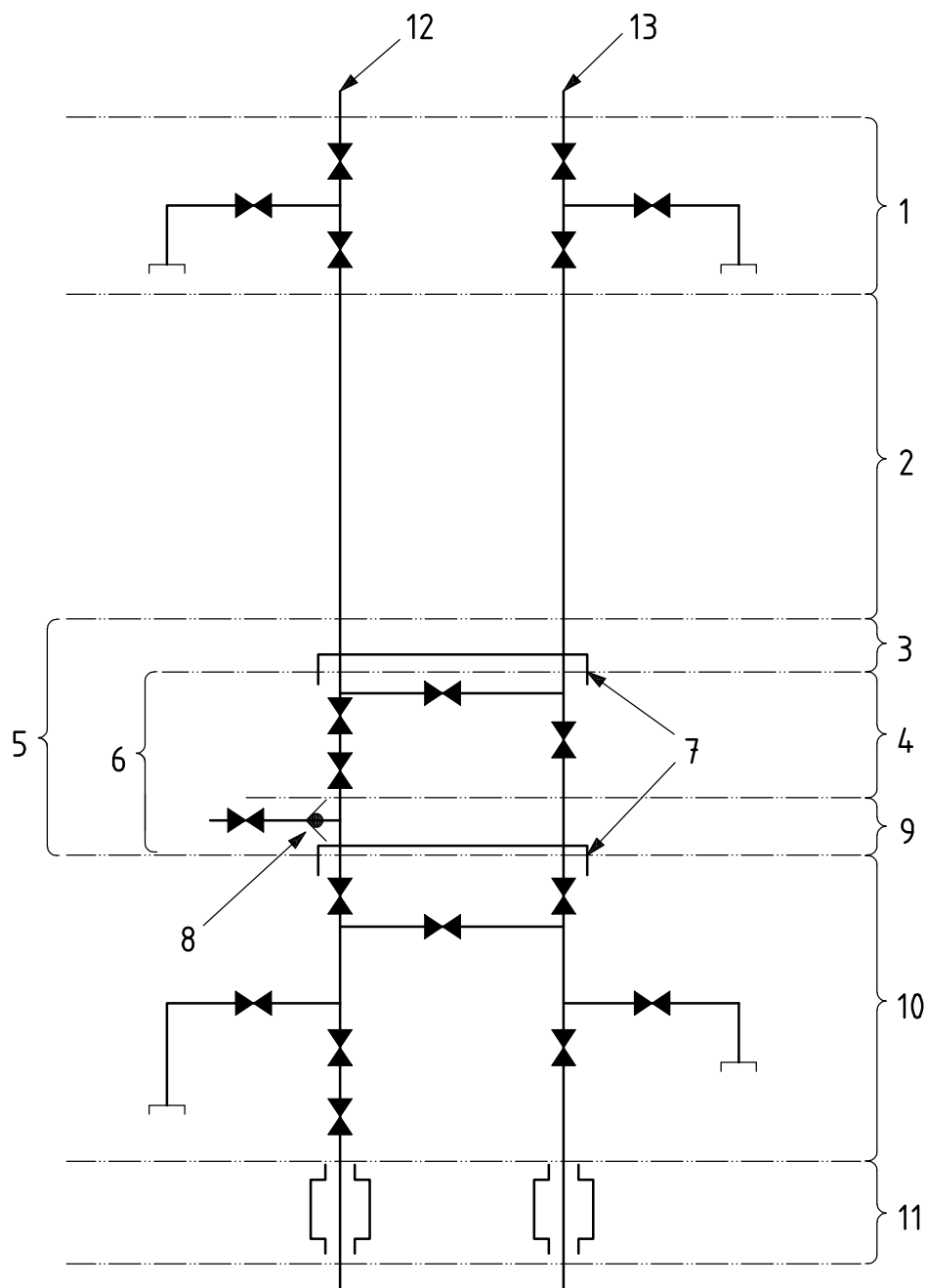
Figure 3 — Typical C/WO riser general arrangement — Tubing hanger mode



Key

- | | | |
|------------------------------|----------------------|--------------------|
| 1 surface tree | 6 tubing hanger | 11 BOP Stack |
| 2 lubricator valve | 7 chemical injection | 12 C/WO riser |
| 3 retainer valve | 8 landing string | 13 production bore |
| 4 subsea test tree | 9 disconnect point | 14 annulus bore |
| 5 tubing hanger running tool | 10 marine riser | |

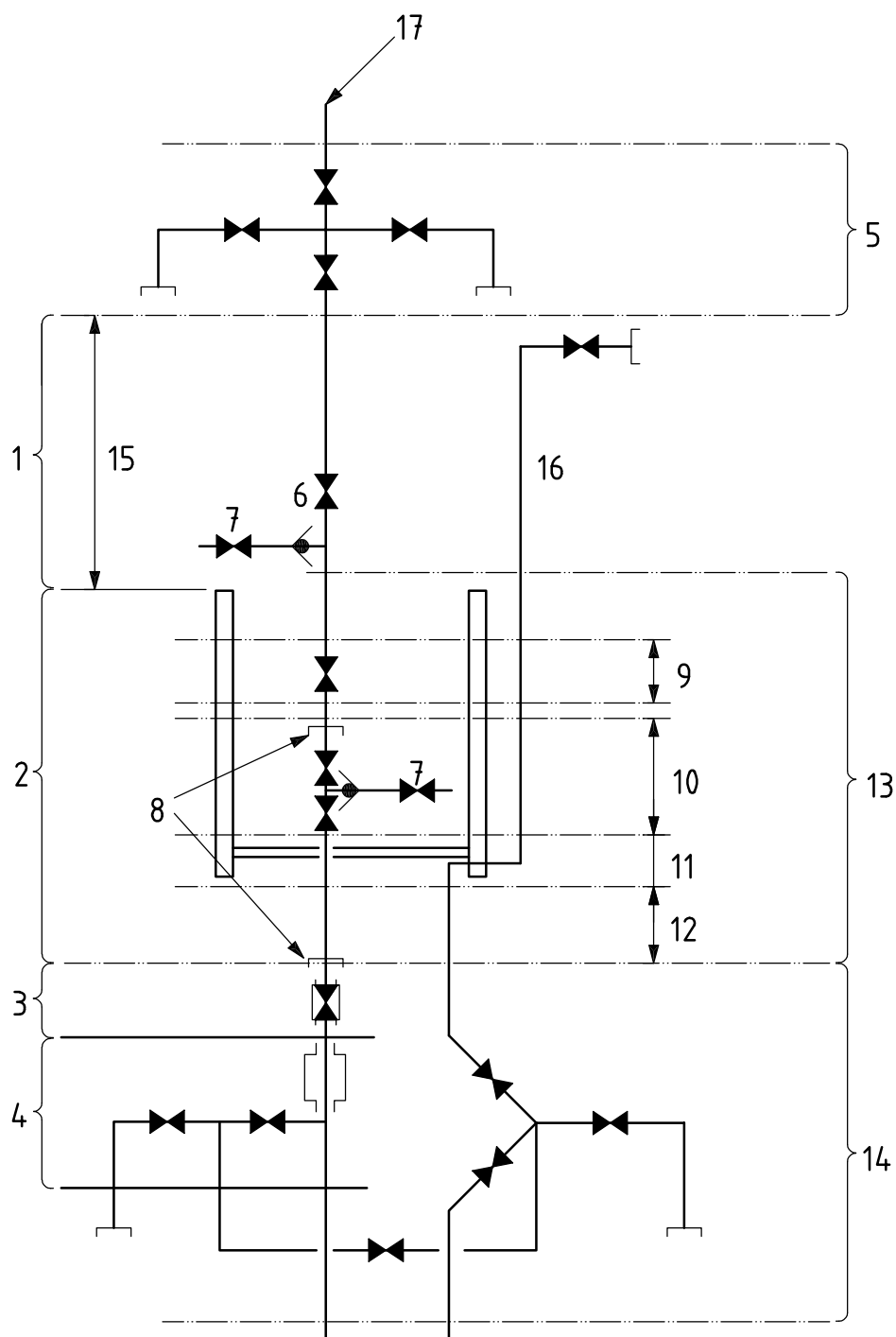
Figure 4 — Typical C/WO riser system schematic — Vertical tree — Tubing hanger mode



Key

- | | | |
|--------------------------------|-----------------------|--------------------|
| 1 surface tree | 6 lower riser package | 11 tubing hanger |
| 2 C/WO riser | 7 disconnect point | 12 production bore |
| 3 emergency disconnect package | 8 chemical injection | 13 annulus bore |
| 4 WCT-BOP | 9 tree running tool | |
| 5 lower workover riser package | 10 vertical tree | |

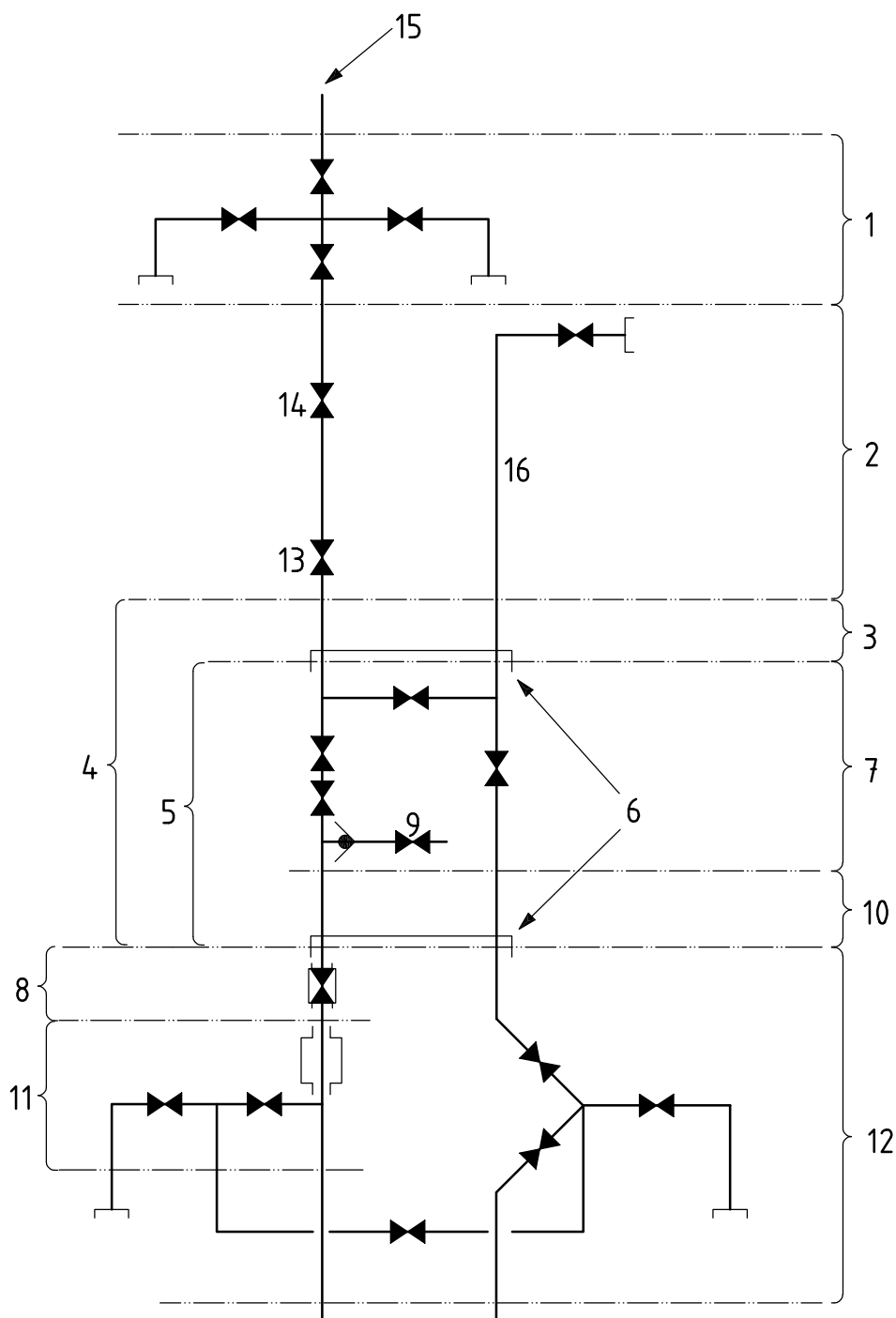
Figure 5 — Typical C/WO riser system schematic — Vertical tree — Tree mode



Key

- | | | |
|---------------------|---|--------------------|
| 1 marine riser | 7 chemical injection | 13 landing string |
| 2 BOP stack | 8 disconnect point | 14 horizontal tree |
| 3 internal tree cap | 9 retainer valve | 15 C/WO riser |
| 4 tubing hanger | 10 subsea test tree | 16 choke/kill line |
| 5 surface tree | 11 slick joint | 17 production bore |
| 6 lubricator valve | 12 tubing hanger or tree cap running tool | |

Figure 6 — Typical C/WO riser system schematic — Horizontal tree — Tubing hanger mode



Key

1	surface tree	7	WCT-BOP	13	retainer valve
2	C/WO riser	8	internal tree cap	14	lubricator valve
3	emergency disconnect package	9	chemical injection	15	production bore
4	lower workover riser package	10	tree running tool	16	annulus circulation hose
5	lower riser package	11	tubing hanger		
6	disconnect point	12	horizontal tree		

Figure 7 — Typical C/WO riser system schematic — Horizontal tree — Tree mode

4.8 Design principles

All equipment in the C/WO riser system included in the scope of this part of ISO 13628 shall be designed in accordance with the requirements specified in this part of ISO 13628.

The overall system design shall be fail-safe.

The system shall be designed to ensure that no single failure will cause an unacceptable risk to personnel safety, the environment and to loss of financial assets.

The possibility of common cause failures shall be identified and measures shall be implemented to minimize their probability of occurrence.

4.9 Operational principles

The C/WO riser system shall be operated in accordance with the requirements specified in 4.13 and the guidance given in Annex B.

As far as practical, all activities associated with the C/WO riser system shall be conducted in such a manner that single failures shall not lead to an unacceptable risk to personnel safety, the environment and to loss of financial assets. This applies both to operational errors and to failure of equipment used directly in operations, as well as equipment used for auxiliary functions.

For all operations, the system design shall account for the most unfavourable combination of functional, environmental and accidental loads, which can be predicted to occur simultaneously, see 6.3. Furthermore, it shall be possible to document that during the development of an unforeseen situation (i.e. loss of vessel station-keeping, heave compensator lock-up, etc.), the C/WO riser system is unable to transmit forces of such magnitude as to threaten the barriers. This requirement applies, both locally (i.e. C/WO system and its barrier elements) and globally (i.e. drilling riser, BOP, horizontal tree, wellhead, conductor, etc.).

The operation of the C/WO riser system shall be limited by the weakest component in the system.

NOTE This requirement is applicable to component design pressure, design temperature and allowable external loads.

4.10 Safety principles

The safety within this part of ISO 13628 requires that gross errors (human errors) shall be controlled by requirements to organization of the work, competence of persons performing the work, verification, and quality assurance during all relevant phases.

To ensure total system safety, the manufacturer shall apply the following principles, in the order presented, when selecting appropriate solutions:

- a) eliminate or reduce hazards as far as is reasonably practicable;
- b) apply appropriate protection measures against hazards which cannot be eliminated;
- c) if appropriate, inform users of residual hazards and indicate whether it is necessary to take appropriate special measures to reduce the risks at the time of installation, use and/or retrieval.

If a potential for misuse is known or can be clearly foreseen, the C/WO riser system shall be designed to prevent danger from such misuse or, if that is not possible, adequate warning shall be given so that the C/WO riser system is not subject to misuse.