Recommended Practice for Flowline Connectors and Jumpers

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1 Scope

This recommended practice (RP) addresses specific requirements and recommendations for subsea flowline connectors and jumpers within the frameworks set forth by recognized and accepted industry specifications and standards. As such, it does not supersede or eliminate any requirement imposed by any other industry specification.

This RP covers subsea flowline connectors and jumpers used for pressure containment in both subsea production of oil and gas, and subsea injection services. Equipment within the scope of this document is listed below.

- Equipment used to make the following subsea connections are included:
  - pipeline end terminations to manifolds,
  - pipeline end terminations to trees,
  - pipeline end terminations to riser bases,
  - manifolds to trees,
  - pipeline inline sleds to other subsea structures.
- The following connection components and systems are included:
  - jumper assemblies,
  - monobore connectors systems,
  - multibore connectors systems,
  - pressure and flooding caps,
  - connector actuation tools.

The following components and their applications are outside the scope of this RP:

- subsea structures,
- hydraulic, electrical, and fiber optic flying leads,
- umbilicals,
- pig launcher/receiver equipment,
- specialized ROV and other tooling.

Equipment for use in high-pressure high-temperature (HPHT) environments is beyond the scope of this document (see API 17TR8 for guidance on subsea HPHT applications).

2 Normative References

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

API Recommended Practice 2A-WSD, *Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*

API Recommended Practice 2X, *Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Technicians*

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment 20th Edition, 2010*

API Standard 6X, *Design Calculations for Pressure-containing Equipment 1st Edition*, 2014

API Specification 17A, *Design and Operation of Subsea Production Systems-General Requirements and Recommendations, 4th Edition, 2006*

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

API Specification 17D, *Design and Operation of Subsea Production Systems-Subsea Wellhead and Tree Equipment, 2nd Edition*, 2012

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

API Specification 17J, *Specification for Unbonded Flexible Pipe*

API Specification 17K, *Specification for Bonded Flexible Pipe*

ASME *Boiler and Pressure Vessel Code* [1], *Section VIII Division 2: Alternative Rules for Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code, Section VIII Division 3: *Alternative Rules for Construction of High Pressure Vessels*

ASME B31.3, *Process Piping*

ASME B31.4, *Pipeline Transportation Systems for Liquids and Slurries*

ASME B31.8, *Gas Transmission and Distribution Piping Systems*

AWS D1.1/D1.1M [2], *Structural Welding Code—Steel*

DNV [3], *Rules for the Classification of Mobile Units*, Part 3, Chapter 1, Section 10

ISO 15590-1 [4], *Induction bends, fittings and flanges for pipeline transportation systems—Part 1: Induction bends*

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1 ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.
2 American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.
3 Det Norske Veritas, Veritasveien 1, 1322, Hovik, Oslo, Norway, www.dnv.com.
4 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1
accessory hardware
The tools, equipment, or materials required for the mounting, operation, and testing of the installed connector system.

NOTE This includes inboard hub end closures, outboard hub end closures, seal removal and replacement tools, ROV interface panel [including hydraulic manifold(s) and tubing] for connector actuation, soft landing system, jumper fabrication jigs, measurement interface caps, debris caps, hub cleaning tools, any tools used to run or make up the connection and seal test equipment.

3.1.2
bending capacity during installation
The maximum bending load which may be applied to the flowline jumper during installation and connector make-up, necessary to overcome fabrication and metrology tolerances and/or elastic deflections from self-weight.

NOTE Vertical flowline jumpers require self-weight or pull-down force and horizontal flowline jumpers require pull-in force to deflect the jumper sufficiently to position the connector for connection onto the inboard hub.

3.1.3
boundary condition
The flowline geometry, external loads, contained fluid and contained fluid flow conditions, metocean conditions, and other parameters required to define the flowline jumper at any point along its length.

3.1.4
connector system
The actuated mechanical connector and related accessories required for its function.

NOTE 1 This includes components such as the inboard hub with structure, outboard hub with connector, alignment guides, soft landing hydraulic cylinders, flowline connection structures at the flowline sleds, and/or tie-in manifolds, line pipe, metal-to-metal seal ring, secondary seal, and fluid coupling for actuation and connector function and seal pressure test.

NOTE 2 The hydraulic actuators for connector make-up and/or soft landing may remain with the system, or may be recovered with a separate connector actuation tool.

3.1.5
contingency seal
An alternate seal used in place of the connector primary metal seal.

NOTE A contingency seal may be used in the event the primary seal or the primary sealing surfaces in the inboard hub and/or outboard hub are unusable due to physical damage, corrosion, or other reasons.

3.1.6
cool down
Time period during which the pipeline operating temperature decreases due to a pipeline flow decrease or stoppage.

3.1.7
flowline jumper
A length of pipe terminated by connector systems between two subsea structures.

3.1.8
hub face separation
Separation of the inboard and outboard hub faces at any point around the circumference caused by internal pressure, external loading, or a combination thereof.

3.1.9
inboard hub
The hub attached to the subsea structure pipe.

3.1.10
integral connector
A connector that contains a non-removable actuation mechanism utilized to lock and unlock the connector from the inboard hub.

3.1.11
lock
The act or state of the connector being fully engaged on the inboard hub and having the full preload applied.

3.1.12
multibore connector
Any connector that has more than a single bore for the transfer of fluids.

NOTE Bores may be concentric, symmetric, or non-symmetric; contained fluids may include produced and/or injected liquids or gases, hydraulic control fluids, corrosion inhibitors, and others.

3.1.13
non-integral connector
A connector that utilizes an external actuation mechanism to lock and unlock the connector from the mating hub.

3.1.14
outboard hub
The hub attached to the flowline jumper pipe.

3.1.15
park
The act of landing the flowline jumper on the subsea structures in the disconnected position.

NOTE 1 For a vertical flowline jumper, the connector is generally in the raised position directly above or adjacent to the vertical inboard hub. For a horizontal flowline jumper, the connector is generally in line with and retained in the retracted or pushed back position from the horizontal inboard hub.

NOTE 2 Other than having connector actuation tools installed in the case of non-integral connectors, the flowline jumper is usually stable in the parked condition which can be achieved by means of the jumper being self-supported or utilizing seabed support as applicable.

3.1.16
preload
The clamping force generated at the connection that is necessary to resist or counteract the separating forces caused by the internal pressure and/or externally applied forces and moments.

3.1.17
primary seal
A gasket forming a metal seal in machined surfaces of the inboard and outboard hubs to retain internal flowline pressure.

3.1.18
rigid jumper
A flowline jumper fabricated using steel pipe, as opposed to flexible pipe.

3.1.19
secondary seal
A metal or elastomeric seal between the inboard and outboard hubs, external to the primary seal, which may act as a test seal, primary barrier to external ambient pressure, and/or secondary barrier to internal flowline pressure.

3.1.20
structural capacity
The external loading with or without RWP which the connector system is able to sustain within the accepted stress limits of the weakest component.

3.1.21
thermal stress
Stresses occurring in the subsea jumper and/or connected piping at start-up and/or shutdown due to the differential between ambient temperature and pipeline operating temperature.

3.1.22
well jumper
A flowline jumper located between a subsea tree and another subsea structure (typically a manifold or PLET).

3.2 Acronyms and Abbreviations

BOP	blowout preventer
CP	cathodic protection
CRA	corrosion resistant alloy
EFAT	extended factory acceptance testing
FAT	factory acceptance testing
FEA	finite element analysis
FIV	flow induced vibration
IOM	installation, operation, and maintenance
JSA	job safety analysis
LBL	long baseline
LP	liquid penetrant testing
MT	magnetic particle testing
MPFM	multiphase flow meter
NCR	nonconformance report
NDE	nondestructive examination
NORM	naturally occurring radioactive material
PDD	product design document
PLEM	pipeline end manifold
PLET	pipeline or flowline end termination
PQR	Procedure Qualification Record

ROT	remotely operated tooling
ROV	remotely operated vehicle
RT	radiographic testing
RWP	rated working pressure
SIMOPS	simultaneous operations
SIT	system integration test
SPFM	single phase flow meter
UT	ultrasonic testing
UV	ultraviolet (light eye)
VIV	vortex induced vibration
VSD	vibration suppression device

4 System Selection

4.1 General

A subsea jumper system consists of a rigid pipe spool or flexible pipe length between two vertically or horizontally oriented hydraulic or mechanical type connectors for the purpose to complete the piping conduit between subsea facilities. Figure 1 displays a few examples of possible connector types, including clamp, integral collet, and non-integral collet connectors. These particular examples are shown oriented vertically, but these types of connectors could also be oriented horizontally. Jumpers can be installed and removed independent of the subsea facilities.

This section provides the framework for making design selections between various subsea jumper systems (e.g. flexible vs. rigid jumper pipe; vertical vs. horizontal jumper and connection systems; and integral vs. non-integral connections). This section will outline the variables that can drive and influence subsea jumper system choice and cover some of the advantages and disadvantages of each system. The information provided in this section is intended to provide the end user with a means of supporting their decision making process, and should be amended as necessary to ensure project specific requirements are appropriately addressed and incorporated during the evaluation process.

4.2 Subsea Jumper System Selection Considerations and Comparisons

4.2.1 Flexible vs. Rigid

4.2.1.1 General

The technical evaluation of the jumper types should be performed in parallel with a project based evaluation, which would consider through life cost of the selected option, suppliers, lead times and procurement costs.

4.2.1.2 Flexible

The following are some advantages of flexible pipe jumpers:

— precise metrology not required for fabrication or installation provided that the subsea equipment is installed in the specified locations so that measurements can be determined during detail design;

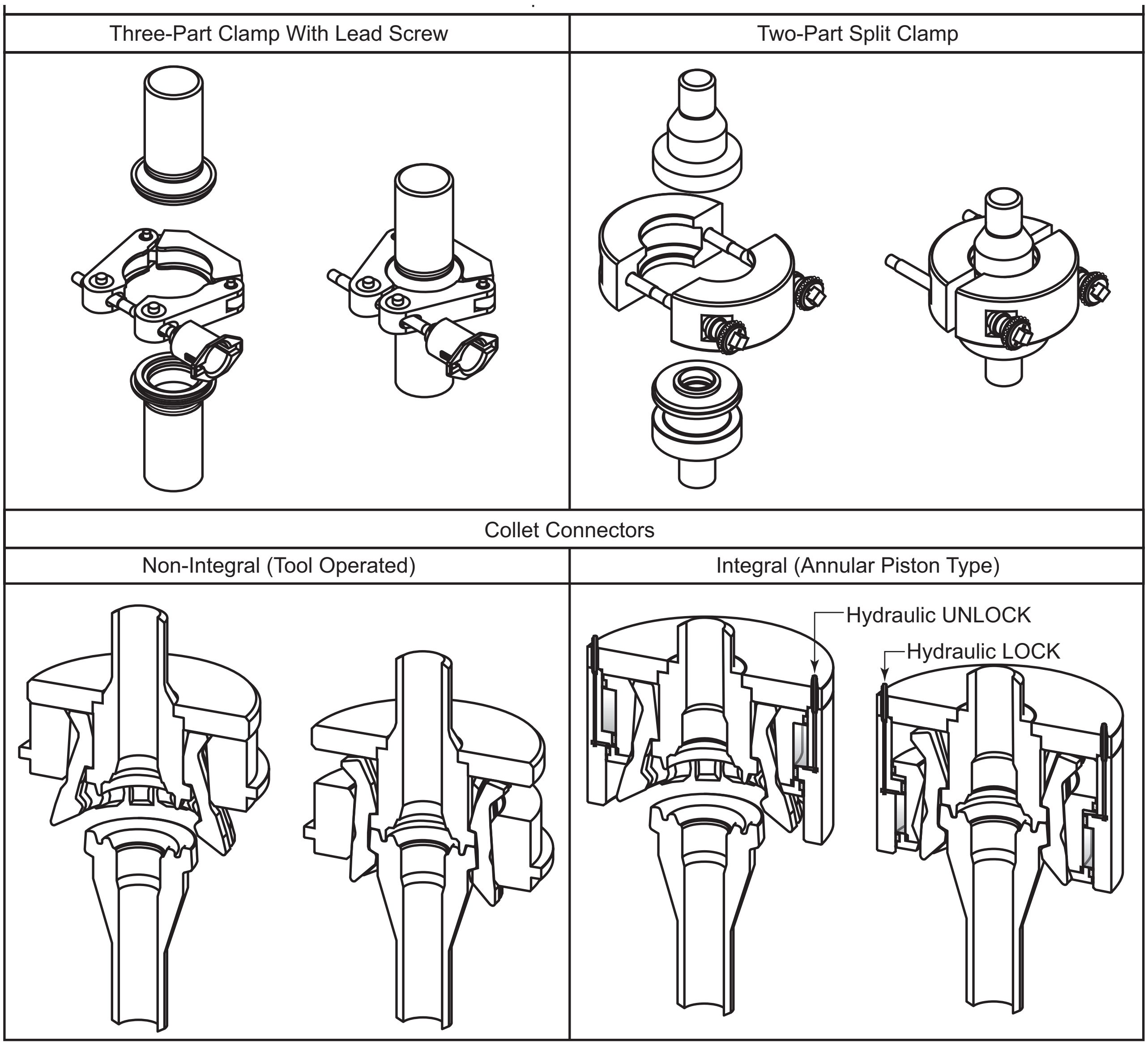

Figure 1—Examples of Connector Types

— less sensitive to loading conditions (thermal growth, well workovers, etc.) that may cause jumper movement during operations;

— less of a concern with VIV since pipe design/configuration is self-dampening;

— corrosion resistant terminations and carcass are available for flexible pipe for sour and chemical resistant service;

— reuse of a flexible jumper may be feasible within same subsea development/range limit;

— flexible jumper can be used for very short length connections where rigid pipe may be too stiff;

— may be used for very long step outs (e.g. satellite wells) where rigid pipe jumpers would not be feasible.

The following are some disadvantages of flexible pipe jumpers:

— fabrication and termination of flexible pipe are complex and require special tooling;

— limited qualified size, internal and external pressure ratings, and temperature ratings;

— more stringent sparing requirements due to an inability to quickly obtain new pipe;

— special considerations required for pigging;

— flexible pipe can be designed with the necessary insulating properties, but difficult to add thermal insulation after manufacture;

— special installation vessels may be needed for flexible pipe installation;

— torsional build up can occur during flexible pipe installation;

— special installation aids such as dead weights are sometimes required at first end installation of flexible pipe;

— flexible pipe with flanged or clamped end connections results in additional leak paths.

4.2.1.3 Rigid

The following are some advantages of rigid pipe jumpers:

— fabrication is possible in a wide variety of working locations allowing incorporation of local content;

— pigging (wax, intelligent, and others) through steel lines is a known and fairly well understood activity (applicable to flowline jumpers only);

— HH trim CRA clad pipe is available;

— large size and thick wall is possible, and therefore wide range of pressure ratings available (internal and external pressure);

— less sensitive to sandy service;

— thermal insulation can be easily added to retain or preserve flowline content heat and extend cool down times for hydrate mitigation;

— can be welded directly to the connector thus eliminating a leak path;

— allows for the welded or flanged insertion of components into the piping such as, but not limited to, flow meters, valves, pig detectors, and sand detectors.

The following are some disadvantages of rigid pipe jumpers:

— precise metrology is required before final jumper assembly/welding and installation;

— sensitive to the deflection of wellheads and pipelines under loading (thermal, workover conditions, and others) which may cause jumper movement;

— FIV can be a concern, but may be mitigated by alternate designs/configurations, flow rates, or use of vibration suppression devices (VSDs);

— VIV can be a concern, but may be mitigated by alternate designs/configurations or by use of strakes;

— limitation on the jumper span length which may congest subsea drill centers;

— reuse of a rigid jumper is most likely not an option without modifications to the piping weldment since it is fabricated to a specific subsea metrology.

4.2.2 Horizontal vs. Vertical

4.2.2.1 Horizontal

The following are some advantages of horizontal jumpers.

— Horizontal jumpers are useful where the project requires self-draining jumpers and/or low profile jumpers for protection in shallow water depths from fishing activities, trawling boards, and/or icebergs.

— Lifting height at quayside and on installation vessel may be shorter.

— Tie-in porches may support horizontal jumpers in a disconnected state while retrieving the host structure (such as a manifold or tree), depending on subsea foundation.

— Metrology may be taken from the tie-in porch structure prior to the installation of the host structure in some cases.

— Horizontal connections may also be installed on subsea support structures prior to the installation of the host structure (manifold, trees).

— Lower jumper height minimizes interference with intervention and production equipment.

— Horizontal jumpers are less susceptible to VIV due to lower profile and seabed support.

— Horizontal jumpers are typically designed to lie on the seabed, which reduces loads applied to the inboard hubs.

The following are some disadvantages of horizontal jumpers.

— Stroking tools and tie-in porch are required to apply and react forces necessary for connector pull-in and push-back from inboard hub.

— A vertical run must be incorporated into the horizontal jumper configuration in order to incorporate a multiphase flowmeter in the preferred vertical orientation.

— Horizontal jumpers are typically designed in multiple planes and therefore stress (tension) may be left in a rigid horizontal jumper after making up the connections, depending on the design of the jumper.

— A rigid horizontal jumper requires more deck space than a rigid vertical jumper during load out and transportation.

— Metrology for horizontal jumpers should include heading, and the survey points on the subsea structure varies depending on the connection system.

— Retrieval of a horizontal jumper may be difficult due to the multi-planar design of most horizontal jumpers.

— Jumper insulation may require installation of doghouses over connectors.

— More space is required to fabricate horizontal jumpers due to large footprint required for out of plane designs.

— Installation rigging for horizontal jumpers is more complicated in most cases and may be very large.

4.2.2.2 Vertical

The following are some advantages of vertical jumpers:

— do not require complex landing porches;

— minimal pipe deflection/pull-in required when making up the connection;

— allow integration of a multiphase flowmeter in the preferred vertical orientation on the jumper;

— typically fabricated in a single plane which aid in installation and retrieval;

— installation of post-installed insulation doghouses is simplified;

— metrology is simplified and can be taken directly from the structure hub.

The following are some disadvantages of vertical jumpers:

— undesirable in shallower water depths where fishing nets/trawling boards are employed and/or icebergs may be encountered;

— typically cannot be parked in order to retrieve the host structure;

— are more susceptible to VIV and fatigue due to exposed profile.

4.2.3 Integral vs. Non-integral Connectors

4.2.3.1 Integral

The following are some advantages of integral connectors for jumpers:

— decreased installation time since no separate trips are required to retrieve connector actuation tools because all actuation and soft landing mechanisms are integral to the connector;

— advantageous for developments which require smaller number of connections;

— not subject to obsolescence of changes in design;

— not dependent on availability of connector actuation tools, especially when compared to non-integral connector designs that have been modified or replaced by newer models;

— wet insulation can be pre-installed versus post-installation dog house.

The following are some disadvantages of integral connectors for jumpers:

— higher hardware cost per connection, but lower tooling rental cost;

— all hydraulic components remain subsea, which introduces additional potential failure modes.

4.2.3.2 Non-integral

The following are some advantages of non-integral connectors for jumpers:

— connector actuating hydraulics can be integrated into the stroking tool, which reduces hardware cost per connector by removing the hydraulics from each connector;

— advantageous for fields which require larger number of connections (also depends on the number of tools required during the installation campaign);

— increased reliability of the actuation system, because all hydraulic components are recovered with the connector actuation tools and can be maintained/repaired prior to use;

— cost increases can be minimized by utilizing connector designs with nonproprietary or simplified ROV tools (e.g. clamp connectors) or by renting the tools.

The following are some disadvantages of non-integral connectors for jumpers:

— longer installation time, because additional trips may be required for recovery of connector actuation tools;

— require upkeep, maintenance, and storage of the proprietary connector actuations tools over the course of the field life.

4.3 Jumper Configurations

Jumper configurations include, but are not limited to, those shown in Figure 2.

The jumper configuration should be optimized for transportation to the field and to minimize ROV obstacles.

A self-sustaining jumper configuration avoids support from the soil; accommodates buoyancy modules or bend restrictors; and positions supplemental hardware in an orientation/location to minimize the effect of bending loads. When seabed support is required, soil data should be obtained and used to analyze the jumper for support as well as the induction of loading.

The project requirement of supplemental hardware, such as, but not limited to MPFM, SPFM, and valve modules frequently requires an interface with hydraulic or electrical flying leads, which apply additional loads to the jumper connection.

Field commissioning plans should specify whether the jumper configuration needs to facilitate pigging.

4.4 Drill Center Layout Guidance

The arrangement of the vertical jumpers plays an important role in determining the location of the trees with respect to the manifold. Most 6 in. and 8 in. nominal pipe diameter rigid vertical jumpers have a typical range of 50 ft to 90 ft (15 m to 27 m). A shorter jumper may be too rigid, and would need to be made taller to allow the deflections necessary for installation. A longer jumper may require a larger installation vessel. Both scenarios may result in increased jumper stresses and a jumper geometry which is more difficult to handle and install. A rigid subsea jumper with a nominal pipe diameter smaller than 4 in. is not normally considered due to excessive flexibility and short span length.

Larger diameter rigid jumpers, such as those used in flowline/pipeline jumpers, have a slightly different length. Most 10 in. and 12 in. nominal pipe diameter rigid vertical jumpers have a typical range of 80 ft. to 130 ft. (24 m. to 40 m).

When considering the drill center layout, the jumper configuration and routings should be evaluated in conjunction with all the other subsea system structures and components to minimize crossing of flowlines, umbilicals, flying leads, and other jumpers. Jumper selection should consider drilling sequence and impact of external accumulation of drill cuttings (particularly true if jumpers and flying leads are to be pre-installed/parked and shifted to final positions at a later date).

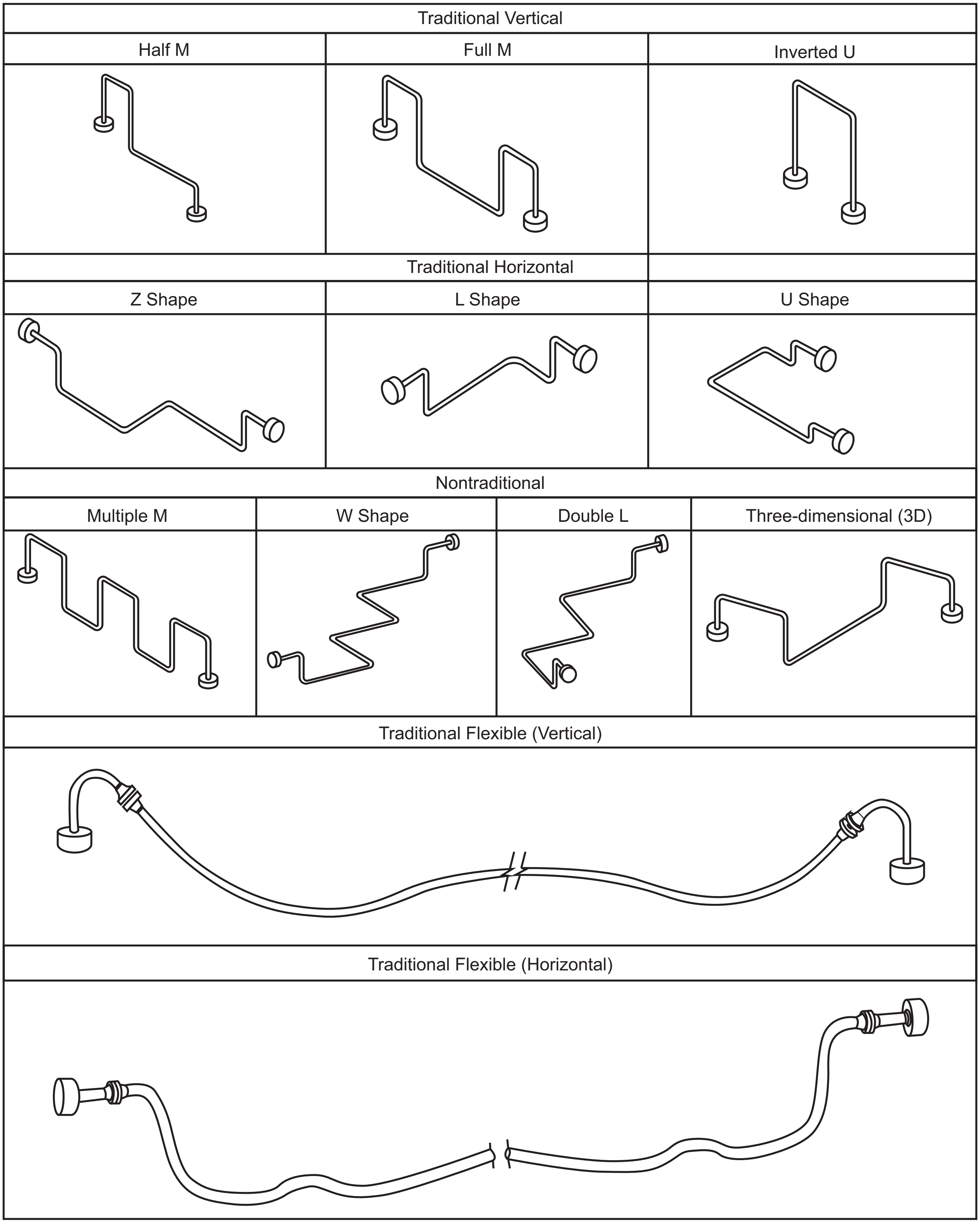

Figure 2—Typical Jumper Configurations

In the event that jumpers are crossed, jumper analysis, ROV accessibility analysis, metrology feasibility analysis, and any other analysis necessary should be performed to prove that the crossed jumper is the most feasible approach.

4.5 Requirements During Installation (that Influence Jumper Selection)

Certain installation requirements may impact selection of a jumper configuration. The inherent installation advantages/disadvantages associated with horizontal and vertical jumpers or integral and non-integral connectors are given in 4.2. Regardless of material or orientation, jumper configurations should be designed for the installed sea state, as installation loads can result in immediate failure. The jumper configuration should descend under its own self weight without causing significant slack in the supporting rigging equipment. Additionally, each jumper connector should be supplemented with the necessary hardware to facilitate alignment and prevent damage upon landing.

For rigid jumpers, unbalanced loads from differing connector sizes may increase the complexity of the spreader bar and/or lift line configuration. The installation vessel capabilities, including adequate deck space and sufficient crane hook height and lift capacity, should be evaluated during the installation vessel assessment.

For flexible jumpers, the minimum bend radius identifies the smallest degree of the curvature the flexible can experience at any one time. Fitting bend restrictors on the flexible jumper outer coating can increase the installation time, specifically important for end connections where production shut-in may be required. In the event the minimum bend radius is exceeded, the flexible pipe manufacturer should evaluate the long-term performance effects.

4.6 ROV/ROT Aspects

The connector manufacturer should reference API 17H when designing the connectors in order to use standard ROV tooling, to ensure all interfaces are ROV friendly and accessible, and to ensure all interfaces are able to withstand incidental ROV loadings. Any additional components to the pipe spool and connectors, such as isolation valves or subsea flow meters, warrants an ROV accessibility study to confirm clash checks with the surrounding subsea hardware.

4.7 Multibore Connection Systems

Multibore jumpers may incorporate production, chemical, and hydraulic lines in the same bundle. This may result in decreased installation time, as a multibore connector allows these lines to be installed and connected simultaneously, and allow for enhanced protection of the individual lines.

Multiple bores in a single outboard hub add complexity to the connection system. The following are advantages and disadvantages of multibore connection systems.

— Multibore connection systems may be concentric or nonconcentric. Concentric multibore connection systems do not require rotational alignment of the outboard and inboard hubs; nonconcentric multibore connection systems do require rotational alignment of the outboard and inboard hubs.

— Multibore connection systems may include integral bores with metal seals for production, water injection, chemical injection, and hydraulic fluid, as well as accommodate hydraulic, electrical, and fiber optic connectors.

— Multibore connection systems may require specialized manufacturing, assembly, and welding techniques.

— The individual metal seals used in a multibore application should be qualified to accommodate the axial and radial tolerances required for machining the outboard and inboard hub sealing surfaces.

— Subsea seal replacement in multibore connection systems may require complex seal replacement tools.

— Intervention requires disconnection of all bores.

Any internal components that are not integral to the multibore connection system outboard hub, inboard hub, and primary and secondary seals are outside the scope of this RP.

5 Connection Equipment

5.1 General

The requirements identified within this section apply to devices used to make and maintain a connection between two structures which are pressure containing. This includes, but is not limited, to connectors, caps, and closures.

5.2 Functional Requirements

The connection system should have the following functional requirements.

— The connector should be self-contained, such that its components are never in an unsecured or unstable position when actuated between the fully unlocked and fully locked positions, in particular for those designs that allow for additional locking stroke when not installed on an inboard hub.

— At the conclusion of FAT, the connector should be interchangeable on all hubs designed for the connector without requiring adjustment.

— The connection system should accommodate the capability to allow for connector cleaning tools and gasket replacement tools.

— The connection system should include visual indication to confirm the outboard hub is correctly landed on the inboard hub before locking.

— The connection system should include visual indication of lock and unlock.

— The connector should provide for gasket retention and protection during installation.

— The gasket should not be used to align the connector and hub. The connector should be aligned with the hub before the gasket is engaged. The gasket should be allowed to self-align in the gasket grooves during alignment in order to mate with the hub profile.

— The connector and inboard hub should accommodate and overcome radial, angular, and axial misalignment that occurs from flowline/jumper fabrication inaccuracies and deflections (within the manufacturer's rated specifications) as well as metrology tolerances.

— The connector or connector actuation tool (as applicable) should have sufficient capacity to overcome jumper misalignments and pull-in loads in order to achieve the manufacturer's rated bending moment, torsion capacity, shear force, and axial force during the locking process.

— The connection should allow for a post-installation pressure test to verify the seal has been made without having to pressurize the bore of the connector. Typically this is accomplished by a low volume annular test external to the primary seal.

— When using a wet-mated seal with a primary and secondary seal for bore fluid containing purposes, both elements should be capable of being tested in order to ensure seal integrity. If the test circuit is subject to bore fluid, then the circuit should be closed off with a mechanism that is sustainable for the bore fluid in question.

— If the primary unlocking mechanism is a permanent part of the connector, a secondary method of unlocking the connector should be available, in the event the primary unlocking mechanism is inoperable. The secondary method should be ROV operable, and be able to apply two times the force required to unlock a new connector, if applicable, as determined from connector design verification and validation testing.

— Connectors without integral unlock features should be designed to accommodate a secondary method to unlock the connector, which is actuated by an ROV tool. Contingencies should be considered in the event the connector primary unlock interface becomes unusable.

— The gasket should be replaceable subsea using ROV deployed tooling.

— Where application of preload is displacement controlled, the minimum preload should be calculated based on the worst case machining tolerances affecting the preload. Alternatively, designs that are preloaded by force (e.g. taper lock or threaded designs) may utilize mathematical models to predict preload when coupled with data gathered through validation testing.

— Connections should have the means to protect the gasket during installation through the use of a soft land system, dampening system, or other means. This method should be validated during validation testing or other means of physical testing.

— The horizontal connector and/or connector actuation tool (as applicable) should be designed to withstand the manufacturer's rated shear force in all directions during final alignment imparted during guidance.

5.3 Design Requirements

The connection system should have the following design requirements.

— The connector should be designed to maintain a locked position without external forces or pressures being maintained. This may be accomplished through the application of a secondary lock mechanism, the intention of which would be to prevent premature unlocking of the connector locking component(s) due to external loading.

— The connector primary locking mechanism and secondary locking mechanism (if applicable) should be designed so as not to be affected by vibration.

— The manufacturer should state the design life of the connector considering all applicable limiting factors including, but not limited to, service, temperature, fatigue, cathodic protection, and elastomeric seals.

— The manufacturer should rate the seawater depth capability of the connection based on the external capacity of the primary seal or the weakest mechanical component that would allow for leakage subsea. Whichever is worse would govern the depth capability.

— The manufacturer should rate the number of lock/unlock cycles for the connector before refurbishment is required (including recoating or relubricating). The manufacturer rating should also reflect any load or capacity reduction associated with an increased number of lock/unlock cycles.

— A connector is considered field serviceable or maintainable only if the connector components are removable without cutting the jumper pipe or disconnecting flowline flanges.

— Connector working capacity should be defined as the lesser of the following.

  — The loading at which the preload of the connection system falls to zero with or without RWP applied. Loss of preload of the connection will not necessarily cause leakage to occur. Hub face separation can be used to determine preload limits for connections that are axially symmetrical and produce a uniform preload at the hub faces. For axially non-symmetric connectors where non-uniform contact pressures exist at the hub faces, the locking mechanism pre-tension should be used to determine the preload limit.

- — The structural capacity of the connector components exceed stress allowable limits as defined in 5.4.4 prior to loss of preload occurring.

NOTE Where manufacturers intend to provide connector capacities beyond the working limits stated above, the design verification and validation methods should be agreed with the end user for specific product applications.

— Hub separation at the gasket location is allowed provided the actual hub separation distance is quantified and is equal to or less than that for which the gasket has been qualified. No leakage should be allowed during validation testing.

— Torsion slippage should be defined as permanent rotational movement of the connector in relation to the inboard hub. The connector torsion capacity should be documented by the manufacturer.

- — A torsionally rigid connector capacity is defined as a maximum of 90 % of the load at which slippage occurs between the mating faces of the connector and hub, with RWP applied. Slippage will not necessarily cause leakage of fluid, but once slippage occurs the connection has failed. Torsion capacity will typically increase as the internal pressure is decreased.

- — If slippage is allowed, the sealing capability of the connector and gasket should be verified through validation testing to withstand the rated angular displacement and cycles. The end user should review and agree on validation requirements based on the application of the product.

— The structural capacity of the connector should be higher than the design capacity of the pipe expected to be used with the connector. Otherwise, the jumper system should be rated to the capacity of the connector or other limiting component.

— Considerations should be made for long-term environmental exposure of hydraulic connector sealing and interface surfaces that may impact unlocking and disconnection of the connector from the inboard hub.

— Sealing components used in hydraulic circuits which may be subject to higher than ambient temperatures but lower than the maximum temperature of the bore fluid should be designed for the minimum and maximum temperatures to which they will be exposed. Hydraulic system minimum and maximum temperatures may be affected by insulation of the connector.

— The connector system, including all components in the locking mechanism, should be designed for the maximum locking force in combination with the lowest coefficient of friction.

— The connector design unlocking force should be at least two times the maximum unlocking force for a new connector, as determined from connector design verification and validation testing. All components in the unlocking mechanism should be designed for the design unlocking force in both mechanical and integral hydraulic connectors.

— The manufacturer should state the RWP of the integral hydraulic chambers and ports, and test them to 1.5 times RWP.

— The connector should be designed to accept a primary metal sealing gasket. Considerations should be made for a contingency gasket, which may be metal and/or resilient sealing type.

— The gasket and mating seal pocket should be designed to minimize risk of damaging the seal pocket during normal connector installation or operation (landing, locking, unlocking, hub cleaning, and seal replacement).

— The connector system should be designed for a rated temperature range as specified in API 6A and API 17D or for other specified minimum and maximum operating temperatures. The manufacturer may specify a different temperature range for parts not directly in contact with production fluid, provided that this is verified by thermal analysis or testing as specified in API 17D.

— All lift points should be designed and proof load tested per API 17D Annex K or comparable codes. Compliance with applicable regulatory requirements should also be ensured.

— Connector pull-in capacity to be defined by the manufacturer.

5.4 Design Verification Requirements

5.4.1 General

The connector system design verification should meet the following requirements. This may include classical calculations and/or FEA. For more detailed requirements, refer to the appropriate codes.

5.4.2 Design Verification Requirements

Design verification should be performed using one of the following methodologies:

a) linear elastic,

b) elastic/perfectly-plastic with small deflection theory,

c) elastic/plastic with strain hardening and large deflection theory.

The design verification may be performed using classical calculations for method a) above and/or by using FEA for methods a), b), or c) above.

The design verification methodology may be in accordance with other recognized standards including any of the following:

— API 6A,

— API 6X,

— API 17D,

— ASME Section VIII Division 2,

— ASME Section VIII Division 3.

The following requirements should be included when performing the design verification.

— Design verification should be performed for all load bearing cross sections of the connector system including the outboard hub and inboard hub.

— As applicable, the maximum preload, internal pressure (RWP and hydrostatic test pressure), tension shear and bending moment should be included for design verification.

— Minimum preload should be analyzed to verify bending capacity.

— Temperature derating of material properties should be included where applicable.

— Nominal material dimensions may normally be assumed, but the effect of tolerances and corrosion/erosion should be included when their effect is significant.

— The effect of varying friction coefficients should be analyzed when applicable.

— Buckling should be analyzed if relevant.

— Displacement at threads and collets should be analyzed to ensure loss of engagement does not limit design capacity.

— The impact of thermal and pressure cycling on the connector sealing capability and components should be analyzed.

5.4.3 Finite Element Analysis General Requirements

The following requirements should be included when using FEA to perform the design verification.

a) The analysis should provide separation load(s) and separation load relaxation rates at the connector/hub interface, including the locations closest to the gasket. For connection systems that are non-symmetric then the application of load should be directed in the area of the weakest section to determine separation load(s). This information should be used as acceptance criteria for determining connector bending capacity during verification testing.

b) Connector designs that utilize a lock ring should be modeled in 3D, especially if the lock ring tangential stresses are critical.

c) Connectors subjected to asymmetric loading (i.e. bending moment) should be analyzed using one of the following modeling strategies:

   1) axisymmetric geometry with axisymmetric loads (i.e. equivalent tension);

   2) initially axisymmetric geometry that models asymmetric loads/response;

   3) minimum half 3D geometric symmetry (half collet segment model, half model with symmetric loading);

   4) full 3D model for non-symmetric geometry and subjected to non-symmetric loading.

d) When performing 3D FEA, a minimum of 180 degrees of circumference should be modeled. If a half collet segment is used, the manufacturer should justify the bending moment direction is conservative with respect to both structural and pressure integrity. Equivalent axial tension method will not capture all effects of bending moment loads, e.g. compression effects that may impact the integrity of the connector.

e) The mesh density used should be appropriate for the geometry. A finer mesh should be employed in critical regions when evaluated against the local strain criterion or for fatigue evaluation.

f) For elastic/plastic analysis with strain hardening, materials should be modeled with true stress-strain curves derived from actual test specimens of representative materials, or using the material model in ASME Section VIII, Division 2, Annex 3D, based on specified minimum yield strength, specified minimum tensile strength, and Young's modulus.

5.4.4 Design Verification Acceptance Criteria

5.4.4.1 General

The manufacturer should use one of the following three analysis methods (linear elastic, elastic/plastic, or elastic/perfectly plastic) to determine connector component and system strength acceptability.

5.4.4.2 Linear Elastic Analysis

Elastic analysis is based on assumption that the material has linear stress/strain relationship and does not experience any yielding or plastic behavior. Stress limits should be calculated and evaluated in accordance with API 6X, Section 4.

a) The design stress intensity should be two thirds of minimum specified strength. The maximum allowable general primary membrane stress intensity at hydrostatic test is 90 % of minimum specified yield strength.

b) Local membrane + primary bending stress intensity should not exceed 1.0 times specified minimum yield strength.

c) The von Mises equivalent stress method may be used to combine stress components instead of stress intensity, wherever stress intensity is specified in this standard.

5.4.4.3 Elastic/Plastic and Elastic/Perfectly-Plastic Analysis

The following acceptance criteria should be applied when using the elastic/plastic or elastic/perfectly-plastic analysis method.

a) Normal design loads should be limited by applying the appropriate load or utilization factors to the structural limit load (determined below).

b) Hydrostatic test pressure loads should be limited by applying the appropriate load or utilization factors to the structural limit load (determined below).

c) Structural limit loads should be in accordance with one of the following:

   1) elastic-plastic stress analysis method according to ASME Section VIII, Division 2, Part 5;

   2) elastic-plastic stress analysis method according to ASME Section VIII, Division 3 (this standard is typically used for HPHT applications and when using this standard for structural capacity it should be performed in conjunction with Article KD-4).

5.5 Design Validation

5.5.1 General

Refer to API 17D and API 6A for details on design validation requirements. The following section has been provided as a guideline for the minimum recommended testing for connector system qualification. Within this section, the term connector also includes the mating hub. This section also applies to end closures that are to be utilized as primary containment barriers for production fluid.

5.5.2 General Testing Requirements

Validation testing should include the following actions.

— Validation testing should be performed on a full scale connector. All critical geometries of the test components should be representative of the production connector.

— The test connector and other pressure containing components to be used for design validation should be hydrostatically tested to 1.5 x RWP in accordance with the applicable API 6A requirements before undergoing validation testing.

— Change to critical sealing, load bearing or locking geometries requires requalification.

— The stiffness of the test equipment should simulate the production equipment. Where blinded bodies are used, sufficient bores should be utilized such that load induced stresses in the connector are comparable to that of production bodies.

— The maintenance performed on prototype connectors should not exceed maintenance performed on production connectors. This includes, but is not limited to, the recoating or relubricating schedule for the connector (if applicable).

— Testing should demonstrate that the connector design is capable of generating enough locking force to achieve the required preload in the field. This should be achieved by verifying hub face separation or through comparison of strain gauge data to FEA analysis results.

— Pressure cycling and pressure hold acceptance criteria should conform to API 17D and API 6A Annex F requirements for PR2 other end connectors.

— For connectors containing hydraulic seals, for example integral hydraulic connectors, the hydraulic actuation portion should be subjected to API 6A and API 17D pressure tests for hydraulic actuators (low and high pressure) with no visible leakage and subject to acceptance criteria of API 17D.

— During connector design validation testing, the connector primary lock should not be energized, by means of an externally applied force (from a connector actuation tool) or pressure being maintained in a locking circuit (for an integral connector), to ensure that the connector remains locked.

— If a secondary lock is included in the connector design, it should undergo a separate test from the primary lock without the use of external force or pressure being maintained.

5.5.3 Seal Testing

Connector seals should be tested for the rated internal working pressure and maximum external pressure. In addition, minimum and maximum temperature testing at the rated internal working pressure should be performed in conformance with API 6A Annex F requirements for PR2 other end connectors Acceptance criteria for all seal testing should conform to API 6A Annex F acceptance criteria for external closures. This testing should also apply to connector contingency seals. Seal testing should include the following actions.

— Seal integrity testing may be performed in the connector or in a test fixture representative of the production connector. A representative test fixture should use identical geometries where critical and be constructed of the same material types and yields as the production connector. Test fixtures should also adequately apply the same preload as seen with a production connector.

— The seal should undergo a 1.5 times RWP test prior to performing API 6A, Annex F testing.

— Testing should include provisions to apply pressure to the seal externally to simulate hydrostatic pressure at water depth.

— Testing should include an annulus test such that the primary seal can be tested to the external pressure rating of the gasket.

— If the connector seal contains a secondary seal, both seals should be tested individually for external pressure resistance.

— The connector seal should be rated for pressure differential external to internal, to assess the suitability of the seal for a specific water depth rating at minimum internal pressure.

— Gaskets that have secondary seals or multiple seals used for a common barrier should have each seal tested individually per Annex F thermal cycling in order to be classified as a true secondary seal.

In the case where the connector design includes additional sealing components—for example, integral hydraulics or gallery seals—these seals should be subjected to thermal testing as applicable. The manufacturer should pressure test these seals at the minimum and maximum temperatures to which the seals will be operated. Testing parameters should conform to API 17D requirements. Additionally, these seals should be exposed to the maximum and minimum temperatures seen during production in order to prove that they are fit for purpose.

5.5.4 Load and Cycle Testing

5.5.4.1 General

Load and cycle testing should be performed to prove the design and document the performance characteristics of the connector. This testing should determine the preload limit under various loading conditions based on the connector locking force. The manufacturer should state the rated capacity of combined loading, and test to this rating.

Load and cycle testing can be performed at ambient temperature conditions. If the connector is intended to be used in applications where high temperatures merit that materials be derated for yield strength, then special provisions should be taken to prove out the design. This can be accomplished through Finite Element Analysis or physical testing per the manufacturer's recommendation. Extreme care should be exercised if thermal testing the connection under pressure and load is undertaken due to the high potential energy involved with these tests.

5.5.4.2 Hydrotesting

Unless previously performed on the connector, a hydrotest to 1.5 times the RWP should be performed prior to any load and cycle testing.

5.5.4.3 Bending and Torsion Testing

The connector should be subjected to bending moment loads to verify the connector's capacity. The connector should be tested in a test fixture which simulates actual internal pressure, tension, torsion, shear (if applicable), and bending loads to be applied in the field. The design external load or combination of loads should be applied to the connector a minimum of 3 times during the test program and as required to establish the connector's bending capacity curve. Connector bending and torsion testing should include the following actions.

— Strain gauges should be used on critical connector components in order to verify preload and induced stress in the assembly during testing. Where applicable, this data should be verified against classical or FEA data.

— For locking mechanisms that utilize a lock ring, bending moment tests should be performed with tension applied in the weakest plane, such as the split on the locking ring. For clamp connectors utilizing drive screw mechanisms, bending moment tests should be performed through the weakest section of hub loading. Typically, bending would be applied with the drive screw on the compression side of bending in order to test worst case.

— A minimum of two hub separation measurement devices should be placed 180 degrees apart in the plane of applied bending moment as close to the gasket as possible to allow for monitoring and quantifying separation at the seal. These separation values should be verified with verification details such as FEA analysis.

— If applicable, after rated bending load has been applied, critical threaded interfaces should be inspected for damage.

— Where drive screw mechanisms are used for actuation, such as clamp connectors, strain gauges should be used on the drive screw in order to verify both strain and input torque.

— If the design criterion is no slippage, the connector should be tested for at least 3 cycles to the rated torsion capacity.

— If the manufacturer allows for slippage, the manufacturer should state such, and test the connector and gasket to prove they are able to withstand the stated amount of slippage for a minimum of 200 cycles at RWP without leakage of the primary metal seal. Validation test parameters may vary depending on the application and should be reviewed and agreed with the end user.

— As a minimum the following tests should be conducted and data recorded in order to qualify the connector. Internal pressure tests should conform to API 17D pressure hold periods. The following load cases are considered to be worst case but this does not exclude other load combinations if deemed critical:

  — rated bending loads at zero pressure and RWP;

  — rated torsion at zero pressure and RWP with no bending loads;

  — rated torsion at zero pressure and RWP with rated bending loads.

5.5.4.4 Pressure Cycle Testing

If the connector and seals are tested together, 200 pressure cycles are required to qualify the seal per API 17D, Table 3. If the connector and seal have been tested separately, then the only additional pressure tests of the connector are those required to establish the connector's combined loading capacity (see 5.5.4.3).

5.5.4.5 Make and Break Testing

A series of lock and unlock cycles should be performed at various preloads as necessary to determine the variations in pressure, torque, or force. This data is to be used to determine the expected unlocking to locking force relationship of a new connector. Connector make and break testing should include the following actions.

— Make and break cycles should be performed on the connector per manufacturer recommendation based on connector life cycle prior to refurbishment (including recoating and/or relubricating). Locking and unlocking of a connector is considered to be one cycle.

— Pressure tests of the seal during cycling are not required.

— Strain gauges should be used on critical connector components in order to verify preload during testing.

— Sufficient testing should be performed to establish the relationship and demonstrate repeatability between make-up force and preload. Further cycles at the expected preload(s) should be performed to simulate the lifecycle of the connector (FAT, SIT, offshore, subsea).

— The amount of pressure, torque, or force used to lock and unlock the connector should be measured and documented in the test report.

— The connector should be locked at the maximum expected lock force to demonstrate the connector can be safely locked and unlocked without damaging the hub.

5.5.4.6 Connection System Validation

Testing should be conducted to verify the connection system can accommodate installation loads and misalignments associated with jumper loading and subsea piping structure orientation. System validation should include the following actions.

— The tool/connector interface should be tested to maximum design loads per the manufacturer's rating.

— Test should include simulation of the landing sequence onto the structure at various angles and/or offsets to prove out landing capability of the connector and guidance system.

— The connection system should be used in conjunction with a test fixture in order to demonstrate the connection system pull-in capacity at rated jumper/flowline loading with maximum pitch and yaw loads. If applicable, a connector actuation tool should be used to verify it is suitable with the connector to overcome maximum loading during the testing.

— The test fixture should be designed such that maximum angular misalignment and lateral displacement between the hub and connector due to fabrication and metrology tolerances are replicated.

— Stroking and locking of the connector system should be performed with the maximum combination of loads (bending, shear, axial) to demonstrate that the connector can overcome the loading and achieve the rated preload. Verification can be done through strain gauging, hub face-to-face measurement, or physical measurement as recommended by the manufacturer.

— A connector seal test should be performed after each stroking test to confirm the sealing mechanism has not been damaged.

— Drop tests should be conducted on the connector/tooling as applicable to verify the maximum rated landing speed of the system and ensure that no damage occurs.

5.6 Factory Acceptance Testing of Connectors

Factory acceptance testing includes the lock force or pressure setting, function test, and hydrostatic pressure test procedures following or concurrent with connector assembly. Factory acceptance testing should include the following actions.

— Individual connector kits/assemblies may be closed upon and pressure tested on a test hub which has the same interfacing geometry as a production hub.

— Where applicable, actuation of a connector should be performed by the connector actuation tool or general equivalent, so that interfaces between the connector and the connector actuation tool are verified.

— All factory acceptance testing should be completed using a production seal or a metal to metal seal which is representative of a production seal.

— Connector lock, unlock, secondary unlock, and other connector specific functions should be tested per API 17D.

— For integral hydraulic connectors, each hydraulic chamber and its associated hydraulic circuit should be hydrostatically shell tested to at least its maximum hydraulic test pressure (minimum 1.5 times its rated working pressure for at least 3 minutes) with no visible leakage and subject to acceptance criteria of API 17D.

— The connector preload setting should account for hub manufacturing tolerances. The connector locking pressure setting should be adjusted (using the manufacturer's hub divergence factors) such that the connector will produce the stated rated preload if locked onto a hub machined to nominal manufacturing tolerances.

— During manufacturing, FAT, EFAT, and SIT, each connector should follow its established refurbishment guideline (as required by number of lock cycles).

— Operating times for connector functions should be specified in the FAT procedure, as required to emulate field operations, and operate within any critical parameters established during design validation.

— The minimum and maximum locking force, pressure, or torque should be specified in the FAT procedure.

— The connector and hub should be hydrostatically tested to 1.5 times RWP unless limited by attached components that are governed by a different code, e.g. a pipeline code allowing for a hydrotest of 1.25 x RWP.

— For multibore connectors, pressure caps, and hubs, each bore should be individually pressure tested to 1.5 times RWP unless limited by attached components. All bores should also be pressure tested simultaneously to RWP.

— An annulus test should be performed on the metal seal to verify the seal integrity prior to performing any bore tests. In a multibore application, the annulus test can be performed on individual seals or on all the seals simultaneously.

— Following FAT, a visual inspection should be performed on all accessible connector surfaces for damage. Burnishing and minor rubbing/scuffing marks on connector and hub contact surfaces (non-sealing surfaces) are normal and not a basis for rejection.

— Insulated connectors may be factory acceptance tested either before or after application of insulation. The factory acceptance testing program for insulated connectors should confirm the following requirements:

  — Insulation does not mask defects or leaks.

  — Application of insulation does not damage hydraulic lines or other external features.

  — Insulation does not prevent normal operational sequences for locking/unlocking in order to achieve full preload.

  — Insulation does not interfere with connector actuation tool or other interfacing equipment (e.g. hub cleaning or gasket change-out tooling).

5.7 Connector Documentation

5.7.1 General

The following section provides a list of connector documentation, which should be generated and included in the equipment design file. This documentation should be available for review by the customer.

5.7.2 Assembly Procedure

This document should represent the assembly procedure for production connectors and should contain all standard bulletins required for the given facility such as, but not limited to safety guidelines and part checklists.

5.7.3 Product Data Information

Product data sheets are documents containing technical information comprised of the following:

— connector system cross section with labeled components;

— connector system technical specifications;

— connector system bending capacity chart(s);

— connector system torsion capacity chart(s);

— connector (or connector actuation tool) pull-in capacity;

— maximum misalignment angle for outboard hub landing (or pull-in, if applicable) onto inboard hub; and

— maximum misalignment angle for outboard hub locking onto inboard hub, if different from maximum misalignment angle for outboard hub landing.

5.7.4 Technical Specifications

The following information, as a minimum, should be listed on the technical specification sheet, in both imperial and metric units (for non-integral hydraulic connectors, some of the following information should correlate to the external connector actuation tool system used and should be labeled as such):

— nominal connector size;

— connector RWP;

— API temperature classification;

— API material class rating;

— maximum water depth rating;

— mass;

— outside diameter;

— height;

— primary piston lock area;

— primary piston unlock area;

— secondary piston unlock area (if applicable);

— piston/stroke lengths for actuation and softland (or pull-in, if applicable);

— fluid volume (lock chamber);

— fluid volume (unlock chamber);

— fluid volume (secondary unlock chamber, if applicable);

— fluid volume for softland (or pull-in, if applicable);

— minimum required locking pressure (minimum required torque, if applicable);

— maximum allowable locking pressure (maximum allowable torque, if applicable);

— maximum allowable softland pressure (or pull-in pressure, if applicable);

— maximum bending and torsion capacities at working pressure; and

— maximum bending and torsion capacities at zero internal pressure.

5.7.5 Bending Capacity Charts

Bending capacity charts show how the bending capacity varies with internal pressure. These charts should be generated with internal pressure on the x-axis (independent variable) and bending moment on the y-axis (dependent variable). There may be multiple capacity lines on the chart, each representing separate gasket/bore sizes and/or separate tensions. If there is only one gasket size for the connector, then a note identifying the gasket size and type should be included on the chart. See Figure 3 for an example of a bending capacity chart of a single connector size showing bending capacities for four hypothetical tension loads. Axis ranges, units, and connector gasket size have been omitted for simplicity.

5.7.6 Torsion Capacity Chart

Torsion capacity charts show how the torsion capacity varies with internal pressure. These charts should be generated with internal pressure on the x-axis (independent variable) and torsion on the y-axis (dependent variable). There may be multiple capacity lines on the chart, each representing separate gasket/bore sizes and/or separate tensions. If there is only one gasket size for the connector, then a note identifying the gasket size and type should be included on the chart. See Figure 4 for an example of a torsion capacity chart of a single connector size showing the maximum torsion before rotational slippage for three hypothetical load cases. Axis ranges, units, and connector gasket size have been omitted for simplicity.

5.7.7 Design Validation Test Report

The design validation test report should include all relevant test results from design validation testing and present key information about the connector design. Key information about the connector derived from testing includes, but is not limited to, the following:

— connector locking pressure sensitivity to hub profile tolerances (if applicable);

— lock-to-unlock pressure ratio and lock pressure to mechanical unlock force (if applicable);

— connector mechanical advantage (design validation testing);

— hub separation load relaxation rates before and after hub separation (if applicable) at various locking pressure (preload) settings and external load conditions;

— torsion capacity of the connector (if applicable) or torsional value at which hub slippage occurred (if applicable).

5.7.8 FEA Report

The FEA report should present all relevant finite element analyses performed on the connector design. The FEA report should include the following key sections.

— Introduction—provides general information about the connector and the analyses, background, and scope.

— Conclusions—presents a summary of the main conclusions derived from the analyses, and provides data that should be used for comparisons between FEA predictions and test results.

— Model description—provides details about the models used in the FE analyses, such as, but not limited to, model dimension (2D vs. 3D), degrees of freedom, contact elements, and material properties.

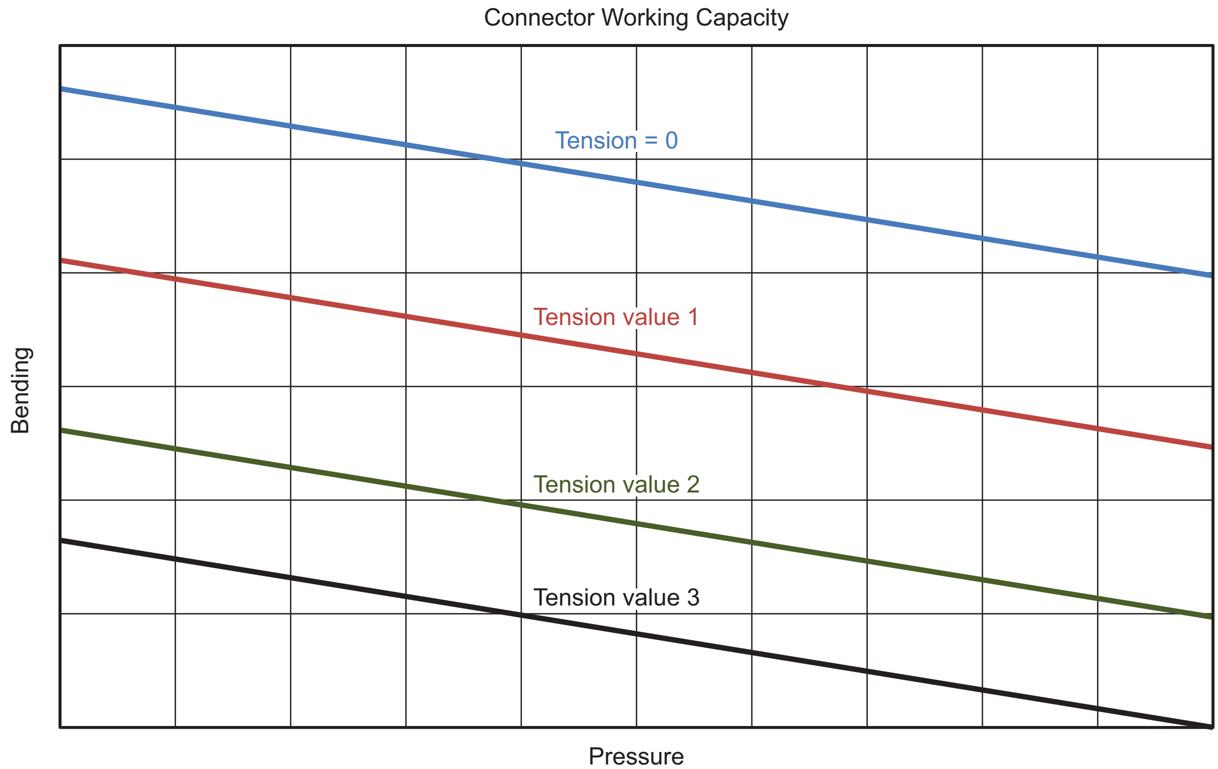

Figure 3—Bending Capacity Chart Example

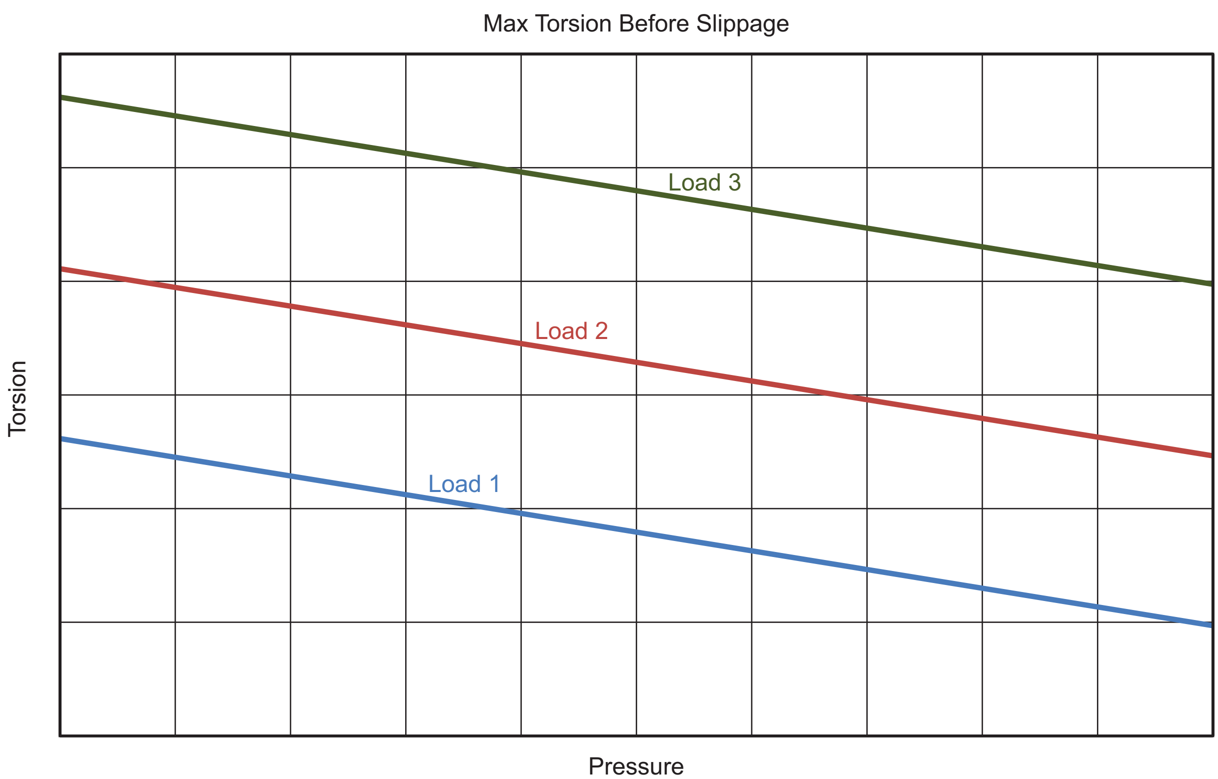

Figure 4—Torsion Capacity Chart Example

— Applied loads and boundary conditions—presents the load cases performed in the analyses, along with the boundary conditions established for the model, such as, but not limited to, fixity, and locations of applied load.

— Discussion of results—covers key details of the analyses and may include, but is not limited, to the following:

  — plots of preload actuation force/pressure during preloading;

  — plots of hub face preload vs. actuation;

  — plots of loads between different components vs. preload and vs. applied load;

  — plots of seal contact pressure or line load vs. preload and vs. applied load;

  — plots of deflection vs. applied load (i.e. deflection due to bending);

  — plots of plastic strain vs. applied load;

  — comparisons with acceptance criteria;

  — identification of limiting component(s) and failure mode(s).

— References—codes, drawings, material specifications.

— Appendix—provides material information and all FEA tables and plots gathered through the analyses.

The following comparisons should be made between FEA predictions and actual test results:

— structural capacity (if applicable);

— characteristics of the lock stroke and the mechanical advantage;

— temperature under external load and/or internal pressure;

— radial thread deflection (if applicable);

— radial actuator ring deflection (if applicable); and

— critical component stress or strain comparison.

5.7.9 Product Design Document (Calculations)

The product design document (PDD) presents all design calculations performed for a given connector. The PDD should cover the connector assembly, outboard hub, and inboard hub. The gasket design analysis is not covered by this document. The PDD should have the following key sections.

— Scope—briefly defines the scope of the analyses.

— Assumptions—states all assumptions made in the design calculations.

— Function—briefly describes how the connector operates.

— Parameters—defines bore size and external load limitations.

— Reference documents—list of all industry codes and standards used to define stress limitations.

— Reference drawings—list of drawings, layouts, and sketches pertaining to the connector and identification of critical geometry.

— Material properties—list of material properties.

— Design analyses—list of all calculations performed on the connector design.

5.8 Pressure Caps

5.8.1 General

This section includes information on pressure caps/end closures for both the inboard hub and connector.

5.8.2 Inboard Hub Pressure Caps

Inboard hub pressure caps/end closures are typically supplied for all inboard hubs. They facilitate pressure testing of the subsea structure piping during fabrication, and pressure testing/flooding/dewatering after subsea installation. They allow the subsea structures to be installed before the jumper connectors are manufactured and/or the jumper is fabricated by serving as a secondary pressure barrier. They also serve to protect the inboard hub sealing surfaces.

Inboard hub pressure caps/end closures may be categorized as follows.

— Surface use only. These pressure caps typically consist of a blind hub and a split clamp or other means of retaining the blind hub to the inboard hub and sustaining the pressure end load. They may be metal or elastomeric sealing.

— Surface installed, ROV removable. These pressure caps are typically disengaged from the inboard hub by a simple ROV operable mechanism.

— ROV installable and removable. These pressure caps are fully operable by ROV.

Inboard hub pressure caps/end closures may be designed for temporary or permanent use. The expected subsea life and subsea facilities design will typically determine material selection, (elastomeric versus metal) sealing selection, and cathodic protection requirements. Other design features for pressure caps/end closures may include but are not limited to:

— allow flooding of a flowline after installation (flooding cap);

— have an annulus test port to allow confirmation of sealing integrity;

— have supply and bleed ports to allow venting of trapped pressure before removal and injection of chemicals (very important if hydrate formation below cap may occur);

— have a contingency release;

— contain a metrology interface.

5.8.3 Connector Body/Outboard Hub Pressure Caps/End Closures

Connector body/outboard hub high pressure caps may be provided to facilitate hydrostatic testing of the jumper after fabrication. These caps may either have the same interfacing geometry as the inboard hub and be retained by the actuation of the connector, or have an alternate locking and sealing system. They have porting to allow for flooding and pressure testing of the jumper.

Connector body/outboard hub low pressure end closures may also be supplied, which allow a jumper to be filled at the surface and lowered to the seabed, at which point they may be disengaged and removed and the jumper connected to the inboard hubs on the subsea structures. They should be ROV operable and have a means of pressure equalization to prevent hydraulic lock.

5.9 Debris Caps

Debris caps are generally used for short term protection of inboard hubs when pressure caps/end closures are not installed. They are designed to prevent inadvertent damage to sealing surfaces. They are typically non-pressure containing and non-fluid retaining, and should be designed to prevent hydraulic lock. They may also be installed into connectors to protect seals, sealing surfaces, and mating faces during storage and transportation. Debris caps should be designed for ease of installation and removal by an ROV. Debris caps which are installed at the surface should be secured in position to prevent inadvertent release during offshore operations and subsea installation.

5.10 Tooling

5.10.1 General

This section includes information on tooling, including connector actuation tools, measurement tool interfaces, seal replacement tools, hub cleaning tools, and connector override tools. All tooling utilized subsea should be designed with ROV interfaces conforming to API 17H. Additionally, these tools should undergo qualification to ensure that they function within applicable loading and misalignments associated with the connection system.

5.10.2 Connector Actuation Tools

Connector actuation tools are required for installation and operation of non-integral connectors. They are typically operated by an ROV. They perform operations such as landing and alignment of the connector with the inboard hub, contain soft landing cylinders (vertical connectors) or stroking cylinders (horizontal connectors) to bring the connector and inboard hub together in a controlled manner, contain actuation cylinders to provide the locking and unlocking force required to set and unset the connector on the inboard hub, and may interface with or facilitate connector metal seal annulus testing. They should have a locking feature to positively secure them to the connector during installation.

ROV operated torque tools are typically used to actuate clamp style connectors.

5.10.3 Measurement Tools

Measurement tool interfaces provide an attachment point on an inboard hub or its structure or on an inboard hub pressure cap/end closure for installation of a measurement tool or measurement tool receptacle. The measurement tool interface location is known relative to the inboard hub pipe axis and mating face, such that metrology taken may be utilized to locate fabrication hubs in relation to one another for jumper fabrication.

5.10.4 Seal Replacement Tools

Seal replacement tools are used to remove an existing metal seal from an outboard hub and replace it with a new metal seal. Such tools may be for surface use only or for subsea operation utilizing an ROV. Seal replacement tools used subsea should be designed to be easily handled and operated by an ROV.

5.10.5 Hub Cleaning Tools

Hub cleaning tools are used to remove debris and calcium carbonate from sealing and mating surfaces. Hub cleaning tools may be manually or hydraulically operated by ROV. Hub cleaning tools should be tested to determine the operational parameters necessary to prevent excessive removal of hub material.

5.10.6 Connector Override Tools

Connector override tools are used to unlock a connector from an inboard hub when the standard means of unlocking the connector has failed or is otherwise unusable. Such tools may be lowered from the surface, and installed and hydraulically operated by an ROV. They should have sufficient capacity to unlock a connector assuming highest required unsetting force.

An ROV operated grinding or cutting tool may be used to sever a clamp style connector actuating screw in order to separate the clamp segments and free the connector from the inboard hub.

6 Jumper Components

6.1 General

In addition to the Connector System, the jumper may include pipe, forgings, and specialized instrumentation. The jumper may also serve as a support structure for other components such as but not limited to anodes, VIV suppression, VSDs, buoyancy, and attachment/parking appurtenances for electric or hydraulic lines.

6.2 Pipe

Jumper pipe may be rigid pipe or flexible pipe.

Design of rigid pipe needs to meet pressure pipe design codes specified by the principal/owner and regulator. Examples of such codes are ASME B31.8, API 1111, and DNV-OS-F101. Design of flexible pipe should be in conformance with standards and recommended practices such as API 17B, API 17J, and API 17K. Where there is a mixture of jumpers on a specific subsea project, e.g. flowline to manifold and manifold to tree jumpers, the pressure design code specified may be different for two types of applications. These codes will typically also have listings of acceptable materials for pipe and other fittings. It is not the purpose of this RP to list all acceptable materials.

6.3 Forgings and Elbows

Components manufactured from forgings and welded directly to jumper pipe should comply with the purchaser or user's material specification(s) and regional regulatory requirements.

Elbows in a jumper may be made from pipe (induction bends) or forgings. If induction bends are used, the induction bends should meet the minimum requirements of ISO 15590-1 or equivalent principal/owner approved standard. If pigging is not required, then target elbows (a specific design that reduces effects of erosion at high flow velocities) can be utilized.

An erosional analysis should be performed to confirm forging and bend geometries can sustain flow rates over the field life.

6.4 VIV Suppression

If analysis confirms that VIV suppression is needed on the jumper, care should be taken that installation of the VIV suppression does not prohibit CP access to the anti-corrosion coating underneath the VIV suppression. The jumper VIV suppression may consist of triple-start helical strakes or other suitable devices.

6.5 Cathodic Protection

Cathodic protection may be provided with anodes located on the flowline jumper or through continuity with the attached equipment.

Anodes should be sized in accordance with DNV-RP-B401 or equivalent codes, and should have a suitable metallurgy for the application.

Where required, the electrical continuity of the system components should be verified prior to installation.

6.6 Instrumentation

The jumper may include intrusive and nonintrusive instrumentation such as but not limited to flow meters, sand detectors, erosion monitors, valves, injection manifolds and pig monitors. Flanged or threaded outlets for the connection of instrumentation which is exposed to produced or injected fluids should conform to the requirements of API 6A and API 17D.

6.7 Thermal Insulation

Thermal insulation may be utilized to retain or preserve flowline content heat and extend cool down times. Thermal insulation of pipe, connectors, field joints, and other components may need to be considered, but is beyond the scope of this document.

7 Jumper Design

7.1 General

A subsea well, flowline, or pipeline jumper provides a flowpath between the subsea equipment. The flowline jumper design should:

— have structural capacity and flexibility to accommodate operational and external loading conditions such as thermal growth, pressure effects, VIV and FIV;

— accommodate the variations of the actual installation metrology and fabrication error of both the jumper and the host structures as applicable;

— accommodate all loads for the chosen deployment method to ensure safe installation;

— accommodate all loads, including flooded volumes, for contingency recovery to the surface, if required;

— provide all ROV interfaces as required;

— provide location and mounting for instrumentation such as but not limited to sand detectors, pressure and temperature transducers, and pig detectors; and

— not interfere with any other permanent or temporary subsea structures (e.g. BOPs).

The flowline jumper is usually designed prior to any equipment being installed, since the jumper is a critical component to start up production in a field development. The uncertainty in equipment location and orientation requires assumptions to be made on tie-in hub locations and angularity, seabed profiles, and hub displacements (this would include installation tolerances, uncertainties, and contingencies). Rigid jumpers have limited installation tolerances; therefore it is normal to design a jumper that has the possibility to be adjusted to the necessary geometry by making just a few field welds to accommodate final metrology of the installed equipment. Lengths and laypaths for flexible jumpers should accommodate the full range of possible connection point positions, and account for the rigidity of and the residual torsion/bending moment within the flexible pipe.

7.2 Primary Design Requirements for Rigid Jumpers and Spools

7.2.1 General

Primary inputs are those parameters which most often control the analysis and the flowline jumper configuration. A complete system change is often required to accommodate an alteration to any one of the primary parameters during the design cycle, and it may be required to limit design parameters in order to produce a practical jumper design. The design deliverables should include a complete statement of design parameters for the flowline jumper.

7.2.2 Connection Systems Orientation

It is of vital importance to the jumper configuration whether the jumper should have horizontal or vertical connection systems. A vertical jumper will most likely be in two dimensions (length and height) where possible, while a horizontal jumper will be in three dimensions (length, height, and width) and generally resting on the seabed.

7.2.3 Systems and Installation Tolerances

Usually when a jumper design is started, none of the equipment on the seabed is installed. All of the equipment for the subsea development needs to be designed in parallel with the jumper design. Hence, the proposed jumper design will have to accommodate for installation tolerances (target box or circle) on the seabed, and for the structures (manifold, PLET, PLEM, or subsea tree) at each end of the jumper. The final jumper design should consider the range of jumper geometries required to satisfy these installation tolerances and other uncertainties.

7.2.4 Installation Loads

A jumper will be welded out at a fabrication yard, transported out to location, and lowered through the splash zone down to the seabed. The jumper will then be landed onto vertical hubs, or in the case of a horizontal jumper onto porches or other structures, in order to be connected. Installation loads should include weight of preinstalled tools, dynamic loads during lifting and transportation (including vessel acceleration loads), impact loads while transiting through the splash zone or landing out subsea, stroking during connection, and stroking during replacement of seals.

7.2.5 Fabrication and Metrology Tolerances

The design of a rigid jumper will be based on accurate measurement of the hubs on the equipment installed subsea. However, these measurements will have certain tolerances which need to be used in combination with the tolerances for jumper fabrication. Jumper metrology is addressed in Section 8 and jumper fabrication is addressed in Section 9.

7.2.6 Thermal and Pressure Loading Expansion

The rigid jumper should be designed for the following thermal and pressure loads:

— motion of the pipeline or end structure due to thermal and pressure growth in the flowline/manifold piping, which is modeled as a boundary displacement to the jumper model;

— direct thermal and pressure expansion in the jumper itself;

— thermal growth of subsea wellheads.

7.2.7 Jumper Operational Loads

Design codes for jumper components should be checked, and then where other codes allow for external pressure, the following guidelines should be used. Temperature and pressure effects, such as pressure containment, jumper expansion, and pressure collapse, should be included in design calculations. The pressure which is valid for the pressure containment analysis is the internal pressure minus the external pressure; hence it is of vital importance to understand how the design pressure is defined. It is necessary to consider both the minimum and maximum hydrostatic pressures in the design at all potential jumper locations. When considering jumper kits that will be used in various locations, the maximum water depth should be used for external pressure collapse calculations while minimum water depth should be used for pressure containment calculations.

7.2.8 Misalignment Effects

Misalignment effects such as but not limited to manifold/PLET settlement, well growth, BOP movements, and pipeline expansion should be used to determine the boundary conditions for jumper design. If a well is worked over, the BOP movement will correspond to the workover rig's ability to hold position over the well. Workover well displacements should be checked against the design assumptions for the jumper or the well jumper may be disconnected if the design assumptions cannot be met based on rig selection.

7.2.9 Jumper Body Loads

The weight of the jumper including internal fluid and any attached equipment, such as ROV control panels and flow meters, should be included in the analysis considerations.

7.2.10 Buoyancy

Buoyancy elements may be used in a jumper design and if so, design parameters should be validated for the entire required lifetime of the jumper. Buoyant force should be calculated based on the end of life values where water absorption is taken into account. The weight in air of the buoyancy should be used for transportation and pre-installation lifts. As well, the end of life value with full water absorption should be used for jumper retrieval in water and in air, if required.

7.2.11 Insulation

Insulation may be used in a jumper design and if so, design parameters should be validated for the entire required lifetime of the jumper. In particular, the end of life weight of wet insulation should be used, if the jumper is recovered to surface. The weight of the insulation in air should also be used during transportation and pre-installation lifts. When analyzing the jumper stresses, the insulation should be evaluated for both positive and negative buoyancy as applicable. As with some insulation, the additional stiffness that it adds to the jumper should also be taken into account, as this may result in higher reaction loads at the outboard hubs.

The insulating materials should be suitable for the environments to which they are exposed, and the level of insulation required. Additionally, the system should be designed to meet the appropriate thermal targets and requirements regarding cold spots. Thermal insulation systems used should accommodate gross deflections and temperature variations of the compliant jumper system during assembly, handling, installation, and operation without cracking, disbonding, or failure.

7.2.12 Seabed Soil Condition

The seabed soil condition needs to be included for friction and stiffness of horizontal spools resting on the seabed. This information is important in order to establish boundary conditions for the jumper.

7.2.13 Accidental Loads

Accidental loads can vary depending on the circumstance, such as area of the field, the field location, and water depth. Examples of accidental loads include but are not limited to the following:

— dropped objects loads;

— seismic loads;

— ROV impact and snag loads in accordance with API 17H;

— icebergs;

— mudslides; and

— snag loads (commercial fishing or other).

7.2.14 Environmental Loading

The rigid jumper should be designed for the following wave and current loads:

— drag and inertia loading due to wave and current;

— onset of vortex induced vibration (VIV) due to wave and current, and eventually fatigue. VIV suppression may be required.

7.2.15 Flow Induced Vibration (Singing)

The rigid jumper should be analyzed for flow induced vibration (FIV), if subjected to gas or multiphase flow conditions, high flow rates, or non-continuous internal geometries.

7.2.16 Fatigue Analysis

Depending on flow conditions (pressure and temperature fluctuations) and likelihood of internal (FIV) and/or external (VIV) vibrations from ocean currents or adjacent equipment such as subsea pumps, fatigue analysis may be required. Typically, fatigue life of weldments will govern, and suitable S_N curves should be selected for the ID and OD of the weldments.

7.3 Design Analysis Deliverables

The jumper design should be performed in accordance with a pipe design code such as ASME B31.3, ASME B31.4, ASME B31.8, API 1111, or DNV-OS-F101. DNV-RP-F112 should be used for jumpers containing duplex or super-duplex materials. The selected code should include both design and fabrication of the jumper pipe. If torsional loads are significant, DNV-OS-F101 may be non-conservative.

The output variables listed below should be provided as required by code or agreed with purchaser for the jumper design evaluation:

— pipe integrity results consisting of stress/strain output/load capacity relative to design code considering relevant load cases (see Section 7.4);

— connector reactions (all moments and forces) considering both installation and operation load cases;

— jumper displacement configuration (to determine clearance required around jumper);

— VIV analysis; and

— FIV analysis.

7.4 Load Cases

A jumper should be checked and analyzed for all the relevant loads that it will be exposed to during its lifetime. Typical load cases are given in Table 1.

Table 1—Example Jumper Load Cases

Jumper Activity	Jumper Load Case
Fabrication, onshore lifting, and testing	— Self-weight of jumper + jumper contents — Effect of pressure testing onshore — Relevant boundary conditions — Lifting in air
Offshore installation	— Self-weight of jumper + connector actuation tools + dynamic load factor — Overboarding and lowering/transiting through splash zone — (proper sea state for installation to be considered, slamming loads are to be in accordance with DNV-RP-C205 and DNV Marine Operations or other similar offshore codes that address dynamic loading in an offshore construction environment) — Lowering towards seabed — Landing out onto seabed equipment — Transportation loads
As-laid	— Simulate relevant seabed support, if applicable — Jumper end vertical support — Jumper self-weight including buoyancy — In-place sag analysis
Tie-in	— Tie-in and make-up/connection loads applied at first end — Tie-in and make-up/connection loads applied at second end
BOP movement	— BOP movement to be included as horizontal displacement for well jumpers. This will depend on the characteristics of the rig selected and the metocean data considered for rig operation.
System installed pressure test	— Displacement of jumper contents with test medium — Internal pressure equal to system test pressure
Operational phase 1 (without feed-in load)	— Displacement of jumper contents with design medium — Pipe Internal pressure equal to design pressure — Content temperature equal to design temperature — Short term and long term settlement — Environmental loading on jumper (drag, inertia, and VIV) — Buckling and collapse evaluations
Operational phase 2 (with feed-in load)	— Maximum deflection (feed-in) from the pipeline is to be applied to Operational phase 1 load case above for flowline jumpers — Maximum well thermal growth is to be applied to Operational phase 1 load case above for well jumpers — Flow induced vibration (FIV) — Short term and long term settlement
Operational phase 3 (shutdown with settlement)	— Internal pressure equal to well shut-in or design pressure — Short term and long term settlement — Environmental loading on jumper (drag, inertia, and VIV) — Displacement of jumper contents with shutdown medium — Temperature is changed in jumper due to well cooling under shutdown conditions

7.5 Analysis Methodology

A finite element based program should be used to model and analyze the structural response of the jumper during the different load cases as relevant. Normally, three dimensional beam element models are used for jumper design. The selected beam elements should allow for a "pipe" cross section, and should account for hoop strain caused by both internal and external pressure. The analyst should be aware of element limitations and verify results as required.

Due to complexity of the geometry, a nonlinear, iterative solver allowing finite (large) displacement theory should be used for final jumper design calculations. Infinitesimal displacement theory may be used during preliminary screening studies to expedite simulations. The analysis should validate unique features, such as elbows, forgings, and flow measurement devices. Detailed FEA of the elbow and associated fracture mechanics analysis may be required to validate stress and fatigue acceptability.

In addition to the analysis of the structural response of the jumper, other issues like buckling, FIV and VIV should be evaluated by use of other dedicated programs, spreadsheets, and hand calculations. The VIV analysis should be performed according to the principles in codes such as DNV-RP-F105 or DNV-RP-C203. Buckling should be evaluated according to the rules in codes such as DNV-OS-F101 or API 1111.

An analysis should be performed to determine if VIV suppression is required based on the environmental conditions and proposed jumper configuration. Critical VIV flowing velocities should be determined and compared to estimated or measured seabed flowing conditions and metocean design criteria. Fatigue analysis should be performed if critical VIV velocities are exceeded. VIV suppression devices may be utilized; however these may significantly increase the nominal drag forces acting upon the jumper segment.

All components in the jumper, such as those designed to API 17D, should take into account the jumper design code being used with regards to hydrostatic testing and external pressure. This may require these components to be rated to a higher working pressure.

7.6 Design Considerations for Flexible Pipe Jumpers

7.6.1 General

The design considerations listed in API 17B and API 17J or API 17K for flexible pipe and system configurations should be applied during the design of a flexible pipe jumper. The following items should also be included for flexible pipe jumper design.

7.6.2 System Tolerances

Flexible jumper design should include fabrication, misalignment, survey, and installation tolerances for the jumper and associated structures.

7.6.3 Jumper Lengths

Flexible jumpers should be designed to accommodate excess length to eliminate subsea metrology measurements and exact length field fabrication yet still capable of being installed as per planned layout.

7.6.4 Connection System

The connection system to be used between the jumper and the structure should be suitable for the planned installation method, and should withstand all system design loads, temperature loads, and fatigue loads. Additionally, these parameters should also be applied to the intermediate flanged or clamped connection components used to join the flexible pipe to the hard pipe section attached to the flowline connector.

7.6.5 Thermal Insulation

If the fluid temperature of the system is to be maintained at a particular level, thermal insulation may be added to the flexible pipe, at the interface between the flexible pipe and connector, and at the connector. The insulating materials should be appropriate for the environments to which they are exposed and the level of insulation required. Additionally, the system should be designed to meet the appropriate thermal targets and requirements regarding cold spots. Thermal insulation systems used should accommodate gross deflections and temperature variations of the flexible jumper system during assembly, handling, installation, and operation without cracking, disbonding, or failure.

7.7 Piggability

The following geometry issues should be investigated if it is necessary to pig flexible or rigid pipe jumpers:

— bore diameter changes between end fittings and auxiliary equipment (erosion monitors, valves, flowmeters);

— pipe cross-sectional ovality;

— jumper pipe bend radius (a large bend radius may be required if using intelligent pigs);

— compatibility of pig components in contact with flexible pipe inner surface;

— interference from intrusive pipe instruments such as erosion monitors and pressure and temperature monitors.

8 Jumper Metrology

8.1 General

The following section concerns measurement methods and requirements for rigid pipe jumpers. Specifically, this section outlines recommendations for acoustic metrology measurements. Other metrology measurements have been and may be used, for example, mechanical and digital taut wire devices as well as laser measurement. For flexible pipe jumpers, this section may be disregarded.

8.2 Offshore Survey

All survey equipment should be calibrated by the manufacturer within 12 months of offshore activities and maintained within the manufacturer’s specifications. An operational integrity check of all survey equipment should be made prior to the survey vessel leaving port or soon after arriving at the work location. Once integration of all survey equipment onto the ROV is completed, all offset dimensions from the equipment to the ROV should be checked and recorded.

8.3 Offshore Deployment

8.3.1 Sound Velocity Profile

To determine the correct sound velocity profile for calibration of the acoustic system, a velocity profile should be performed at the project site. The sound velocity cast, utilizing a temperature, depth, and salinity probe, should be performed prior to and after taking the metrology measurements. Alternatively, the ROV may be equipped with a velocimeter to produce real time velocity measurements while carrying out the work.

8.3.2 Gyrocompass

A survey grade Under Water Gyrocompass should be used to determine orientation of all subsea hardware. The Gyro should be properly aligned, calibrated, and operated as per the manufacturer's recommendation, and steps should be taken to ensure nearby large ferromagnetic objects (such as wellheads, subsea trees, manifolds, pipelines, etc.) do not effect measurements. After orientation readings are complete, a post-dive gyro check should be performed, once the ROV arrives back on deck.

8.3.3 Measurement

Measurements obtained during metrology include, but are not limited to, the inclination of each hub, the horizontal distance between hub centers, the relative depths of each hub, and a seafloor profile between hub sites. The following actions should be included when planning for jumper metrology.

— Hub positions and jumper azimuths are typically obtained using a long baseline (LBL) acoustic positioning method relative to a seafloor array.

— Long baseline transponders with inclinometers are typically used to acquire straight-line distances between hub centers.

— Transponder buckets should have markings to visually assist the ROV with alignment of the transponder at 90 degree intervals. Transponders may be placed directly into a hub or into a receptacle with the offset from the hub documented.

— A sufficient number of baseline measurements and inclination readings should be made between hub centers to ensure accurate results. The transponders should be rotated within the buckets 90 degrees, and the measurements repeated until measurements are completed within all four quadrants. Transponders should be switched between hubs and all measurements repeated.

— Elevation measurements should be made at each hub to determine relative depth offsets.

— A bathymetry system should be used to derive the relative sea floor profile between hubs to check for seafloor anomalies that may dictate jumper routing or clearance with the seabed.

— Typical linear measurement tolerances are ±2 in. (50 mm) hub-to-hub and angular measurement tolerances are ± 0.5 degree at each. However this is dependent on several factors including but not limited to distance, metrology method, and accuracy of metrology equipment utilized.

Final metrology drawings should be prepared by the survey contractor showing the results of the offshore metrology. The drawings should show the pitch and roll of each hub, horizontal distance between hub centers, relative depth between hubs, and a seafloor profile between hub centers.

A summary report should be prepared containing metrology drawings, calculations, measured hub inclinations (pitch, roll, and orientation), measured structure and hub positions from the LBL array, tool offsets, hub heights, measured slant range distance between hubs, measured relative depths between hubs, and horizontal and vertical distances between hubs.

8.4 Onshore Survey

Although other methods may be utilized, fabrication stands that duplicate the subsea hub positions are typically used during onshore fabrication of jumpers. Conventional survey techniques may be used to determine the horizontal position, elevation, and hub inclination of each jumper connection point after the fabrication stands are set up. Typical linear measurement tolerances are ± 1/8” (3 mm.) hub-to-hub and angular measurement tolerances are ± 0.1 degree at each connection point.

The following actions should be taken as a minimum to ensure the test hubs on the fabrication stands maintain the surveyed position during jumper fabrication:

— design fabrication stands with sufficient rigidity;

— locate and anchor fabrication stands on a solid foundation to ensure that the jumper loading will not cause the stands to tip over or prematurely displace;

— immobilize hub position and angular adjustment mechanisms.

The jumper manufacturer should be prepared to demonstrate through calculations and/or analysis that the methods used will maintain the test hub positions throughout the fabrication process.

8.5 Post-fabrication Survey

After jumper fabrication is complete, a post-fabrication survey may be required to verify the horizontal position, elevation offsets, and hub inclinations of each jumper connection point, relative to the approved final metrology drawing. Acceptance tolerances should be consistent with the tolerances assumed during the design.

9 Fabrication and Testing Considerations for Rigid Jumpers

9.1 Applicable Welding Codes

Pressure retaining welding should be performed in accordance with a recognized standard, such as ASME B31.3, ASME B31.4, ASME B31.8, API 1104, ASME Section VIII, or comparable codes.

Structural welds should be performed in accordance with AWS D1.1 or comparable codes.

All weld procedures should be qualified prior to use. A PQR should be qualified in accordance with the requirements of the applicable welding code such as ASME Section IX, API 1104, or AWS D1.1. Welders and welding operators should be qualified in accordance with the applicable welding codes.

Consideration should be given to development of weld repair procedures for pressure retaining welds.

9.2 Welding and Pipe Fit-up Consideration

Pressure containing forgings, pipe elements, and pressure containing welds should be designed to allow for adequate access for welding and NDE.

Consideration should be given to fatigue critical welds. For welds designated as fatigue critical, consideration should be given for O.D. and I.D. grinding of such welds to improve fatigue resistance. The grinding procedure should be qualified with analytical and empirical data prior to use.

To enhance the quality of the welds especially for fatigue service, consideration should be given to minimizing misalignment. Most design standards provide guidance on recommended maximum misalignment during pipe fit-ups.

Welding equipment should be calibrated and maintained in good order to ensure that the quality of welded joints meet the standards in the applicable specifications. Certificates showing that equipment is valid for the period of use should be made available to end user upon request.

9.3 Jumper Assembly

Jumper kits are typically prefabricated, and the final field joints for the jumper are made post-metrology to account for actual pitch, roll, and elevation of and distance between the mating hubs on the subsea structures.

It may be necessary for adjacent straight pipe sections to be angularly offset in order to obtain the necessary jumper configuration. In such cases, the applicable piping code should be referenced for acceptable geometry and stress limitations. Angular deviations between pipe sections of 3 degrees or less do not normally require design consideration as a miter bend.

Proper orientation of jumper connectors, valves, and penetrations should be confirmed before welding. Equipment to be attached to the jumper, such as control tubing and instrumentation, should be located as necessary to prevent interference with or impact from ROVs, installation rigging, and dropped objects. ROV panels for connector and valve operation should be located to allow for ROV access.

Prior to start of the fabrication work, a preproduction meeting between the fabricator and end user should be held to address the following items:

— approved inspection and test plans;

— approved fabrication drawings;

— approved and qualified welding specifications;

— weld repair procedures;

— qualified welder certifications;

— qualified NDE procedures and personnel;

— pipe fit-up procedures;

— OD and ID grinding procedure for fatigue sensitive welds; and

— nonconformance reporting procedures.

9.4 Onshore Fabrication Site Tooling and Requirements

The following equipment and services should be available at the onshore fabrication site.

— Fabrication stands replicate orientation of flowline hubs on subsea structures. The fabrication stand pitch angle, yaw angle, and height should be capable of being oriented to match offshore metrology data.

— Connector actuation tools are required for operation of non-integral connectors, and should be available at the fabrication site to facilitate the fabrication and testing activities.

— The fabrication stands should be fitted with test plates/hubs that are adjusted to simulate the actual pitch, roll, and elevation taken from the metrology data of the production hubs. Test plates/hubs also facilitate pressure testing of the jumper after fabrication is completed.

— Transportation stands may be required for onshore storage and offshore transportation of the jumper if the fabrication stands are not used for these purposes. These stands should be able to support jumpers of different heights and lengths.

— Spreader beams may be required for handling large jumper kits or a fully assembled jumper during lift testing, movement at the fabrication site, and subsea installation. Cranes with suitable capacity and hook height for lift testing and loadout of the jumper should be available on-site. Lift clamps and associated lifting devices (chain, wire rope, shackles) should be designed and load tested per API 17D or comparable codes.

— The fabrication site should be able to accommodate the weight, height, and length of the jumper when setting up the fabrication stands.

— The fabrication site should be located quayside to facilitate loadout of the jumper, and the vessel used to transport the jumper offshore should be able to access the quayside fabrication site.

9.5 Insulation Considerations

Insulation may be required on flowline jumpers to meet specific thermal performance requirements. The insulation material should be qualified for the required application. The selection and application of insulation on flowline jumpers should include the following requirements.

— The insulation material should withstand the required temperature and hydrostatic depth pressure.

— The insulation material should withstand dynamic loads applied during transportation and installation.

— The insulation material stiffness should be evaluated and included in jumper stress analyses if it results in significant additional stiffness in the jumper.

— The insulation material weight in air should be included in jumper lifting and support calculations.

— The insulation material submerged weight or buoyancy force should be included in jumper stress analyses.

— The jumper insulation effects on current drag and VIV should be included in jumper stress analyses.

— The insulation material manufacturer's application and repair instructions should be followed.

— The insulation material manufacturer's pipe surface preparation requirements should be met prior to application of insulation material.

— The insulation material manufacturer's minimum cure time requirements should be met to prevent insulation cracks and disbondment subsea.

— The insulation material bond strength to the pipe coating should be less than the coating bond strength to the pipe (this would ensure that in the event of damage to the insulation, the jumper pipe is not exposed to seawater).

— Routing of control tubing and instrumentation along the jumper should be confirmed prior to application of insulation.

— Confirm insulation does not interfere with the connector actuation tool operations during FAT.

— Fastener and tubing material used under or embedded in insulation should be suitable for the service temperature.

— Sections of the jumper that require intervention, such as locking/unlocking the connector, should use prefabricated doghouses of clam shell or box design to provide the necessary system thermal performance.

— The insulation material manufacturer's recommended field joint insulation requirements should be met.

9.6 Factory Acceptance Testing

The following actions should be performed as a minimum during jumper factory acceptance testing.

— The jumper connectors should have undergone a factory acceptance test by the manufacturer prior to fabrication of the jumper.

— Hydrotesting of the jumper should not commence until all NDE results of the welds have been reviewed and found to comply with the specified codes by a qualified NDE inspector.

— Verify correct installation of ROV mounted controls instrumentation.

— The bore of the jumper should be cleaned to remove all welding slag, scale, sand, and other loose material after fabrication and before locking the connectors onto the inboard hubs or test hubs, so that such material does not become lodged in the sealing or mating faces during the connection process.

— If the jumper needs to be piggable, a drift testing should be performed prior to hydrotesting. If the jumper configuration does not allow for ease of drifting after fabrication, then the jumper kits should be drifted prior to final assembly, and NDE should confirm there is no excessive root penetration of the final field metrology welds.

— During fabrication and testing, the jumper should be supported along the span as necessary to ensure that the jumper weight due to insulation, jumper mounted components, and internal fluids will not overstress the jumper.

— A gasket seal test should be performed prior to hydrotesting the jumper.

— Control tubing which may be subjected to contained fluid, including post-installation (backseat) testing of the connector gasket, should be rated for the applicable design pressure, and should be tested in accordance with the applicable design code for the jumper.

— Considerations should be given to the need for addition of a corrosion inhibitor to the test medium used for jumper hydrotest, especially when the jumper bore is not a CRA material.

— The test set up should incorporate pressure relief devices to ensure the jumper is not over-pressurized during filling operations or during hydrotesting.

— Trapped air should be bled from the jumper prior to commencement of hydrotesting. This may require locating jumper end at high point, use of internal vent tubing through end cap, pigging, or vacuum filling. This is of particular importance for jumpers with an irregular shape or uneven internal surfaces, which may result in greater tendency for trapped air. Vertical jumpers of a coplanar design may benefit from hydrotesting in a horizontal or other non-vertical orientation to simplify filling with test fluid.

— The jumper should be hydrotested in accordance with the requirements and acceptance criteria of a recognized standard, such as ASME B31.3, ASME B31.4, or ASME B31.8. Minimum hold times should be in accordance with the recognized standard, and should only start after pressure stabilization has occurred.

— The jumper should be lift tested in its installation configuration (either empty or flooded) to confirm the handling characteristic of the spreader bar and rigging arrangement. This lifting test should be analyzed during the jumper design to ensure the jumper is not lifted outside the boundaries of the allowable stresses that may cause it to fail. This task should be performed prior to jumper loadout to allow time for remediation of any encountered issues.

— Final jumper weight should be recorded during lift testing, and clearly stenciled on the jumper.

— Interface between the fabricated jumper and connector actuator tools should be checked. The capacity of the connector actuation tool should be clearly understood, so it is not handled outside the supplier recommended capacity. Also, consideration should be made on checking the interface between the fabricated jumper and other connector tooling where appropriate.

— Electrical continuity should be checked between jumper piping and all components not welded directly to the piping. Remediation should be performed on those components which are determined to be electrically isolated or have an unacceptably high resistance value by installing cables, adding anodes, removing coating between components, or other means necessary to achieve the required electrical continuity.

— Interfaces with any jumper mounted equipment, such as ROV panels, valve actuators, sand detectors, and flow meters, should be checked.

— Markings or stenciling for jumper lifting points, ROV interfaces, required owner identification information, and subsea connection points (e.g. Tree end, Manifold end) should be verified.

— Insulation dog house interface testing should be performed to ensure proper fit and function. Corrosion protection of exposed surfaces area inside the dog house should be provided if necessary.

9.7 Fabrication Data Books

A jumper fabrication data book should be assembled for archival and regulatory purposes, and should include the following documentation:

— inspection reports for RT, UT, LP, MT, and hardness testing;

— all applicable NCRs;

— welding procedure specifications;

— welder qualification records;

— metrology reports;

— as-built fabrication drawings and weld maps;

— bill of material/equipment list with part numbers, serial numbers, and other identification permitting traceability for all jumper components;

— survey reports of fabrication stands;

— completed FAT procedures;

— calibration certificates for all gauges and chart recorders;

— lift test certificates;

— rigging arrangement drawings.

9.8 Transportation and Storage

Most flowline jumpers are fabricated and ready for offshore deployment within several days of completing the FAT and SIT activities. If the flowline jumper is pre-rigged to a spreader bar prior to loadout, the jumper and spreader bar should be supported using transportation stands suitable for offshore transportation that have been designed in accordance with API 2A-WSD or comparable industry standards.

In the event that there is a significant delay from the time SIT activities are completed to offshore installation, suitable storage and preservation procedures should be followed to maintain the integrity of the jumper. The jumper should be drained and dried after testing in preparation for storage. If applicable, a corrosion inhibitor should be applied to uncoated steel surfaces, and protective covers should be installed at ends of jumper.

For prefabricated end kits that go into storage, sealing surfaces and hydraulic ports should be protected to maintain their integrity. Jumper kits and their components should be covered using UV protection tarps if they are stored outside for extended periods.

10 Jumper Installation and Recovery

10.1 General Installation and Recovery System Requirements

Design of jumper assemblies should include safe access for personnel to ease preparation, handling, installation, testing, and recovery. System design should incorporate standard interfaces where practical.

Installation method and equipment selected for jumper installation/recovery should ensure safe and reliable operation in accordance with the selected intervention strategy taking into consideration preparation requirements, installation vessel specifications, available resource limitations/restrictions, and environmental conditions.

Installation systems (temporary and permanent) should not cause obstructions or restrict intervention access and should not present any hazard to the permanent equipment during installation, release, reconnection and removal. During installation and recovery operations, installation systems should be designed to allow cessation of activities without compromising safety or integrity of equipment.

Lifting/installation arrangements should be designed to minimize lifting height, giving consideration to the types of vessels needed to perform survey and installation activities. The use of one multipurpose vessel for performing several tasks versus the use of several specialized vessels should be considered. Where possible, system design should not be dependent on unique vessels and should be capable of being installed and recovered in a practical weather window.

Environmental conditions should be considered during design, and limits defined for installation and recovery of equipment. These environmental conditions should include:

— wind speed,

— current velocity,

— current and wave heading, and

— significant wave height.

Installation/recovery analysis should be performed after vessels have been identified for all equipment handling, testing and running/recovery procedures. Installation/recovery tools and procedures should be design based on failure mode philosophy that prioritizes human and environmental safety, well-control, and system operability, reliability and integrity.

10.2 Installation and Recovery Equipment

10.2.1 Spreader Beam Assembly

Spreader beams are used to facilitate lifting of the jumper assembly for onshore and offshore/subsea handling. The typical spreader beam consists of a single span of pipe or other beam element with associated rigging. For a horizontal jumper, a more elaborate frame system may be required. The basic spreader beam assembly should:

— adequately support all planned jumper lengths, weights and configuration types including any attached rigging, connector actuation tools and/or transportation stands;

— prevent gross deflection of the jumper pipe when lifted;

— be stable in the submerged condition, including buoyancy and weight removed after installation;

— accommodate dynamic loading due to vessel heave;

- provide adjustable lift points along its entire length to accommodate different jumper lengths and configurations;
- utilize ROV releasable shackles or hooks for disconnecting from the jumper after land out;
- accommodate parking alongside the jumper during transportation, load out and recovery;
- allow access for connecting and disconnecting from the jumper on deck;
- include tugger line attachment points for deck positioning.

10.2.2 Lifting Clamps

Typically, lifting clamps are permanently mounted to the jumper and provide safe lifting points for attachment to the spreader beam assembly. Lifting clamps remain subsea after jumper installation, and should include cathodic protection. The clamps may be attached directly to the jumper pipe or in some instances be installed over insulation. The effects of clamping over softer material such as insulation should be included during clamp design, and possible damage to the insulation should be prevented during lifting/loading through the clamp. All lifting clamps should be designed and proof load tested per API 17D, Annex K or comparable codes. Compliance with applicable regulatory requirements should also be ensured.

10.2.3 Transportation Stands

Transportations stands provide support for the jumper and connector actuation tools as applicable during transportation, loadout and recovery operations. These stands should provide interfaces for the jumper to be locked in place and seafastened as needed. Transportations stands are usually prefabricated for particular jumper geometries. If required, transportation stands can have temporary access ladders and inspection platforms for tool installation, inspection and/or operation.

10.2.4 Padeye Design

All pad eyes used for offshore lifting should be designed and proof load tested per API 17D, Annex K or comparable codes. Compliance with applicable regulatory requirements should also be ensured.

10.2.5 Equipment Certification and Inspection

All rigging, lifting equipment, and associated lifting gear intended for mobilization, temporary use or otherwise stored in readiness for offshore installation, should be thoroughly inspected to API 17D requirements on a regular basis to ensure such equipment is fit for purpose.

No rigging or lifting equipment (including pad eyes and other lifting points) should be used without accompanying appropriate, valid and in-date certification.

No rigging or lifting equipment (including pad eyes and other lifting points) should be used if showing signs of damage, significant wear or alteration. Reasonable wear and tear may be accepted providing it is approved by a competent, qualified and responsible person.

10.3 Operations Manuals

An operations manual should be developed for the jumper installation/recovery, and should include the following documents:

- project quality plan;
- project health, safety, and environment plan;

— project emergency response plan and flowchart;

— communications plan;

— equipment lists;

— jumper mobilization procedure;

— seafastening layouts;

— seafastening procedures;

— subsea survey procedures;

— installation procedures;

— testing procedures;

— recovery procedures;

— as-built drawings;

— installation sequence drawings;

— rigging procedures and drawings;

— safe lift areas definition and drawings;

— HAZOP report; and

— rigging lists and certificates.

10.4 Jumper Loadout

10.4.1 Preloadout Activities

Prior to beginning any operations, a mobilization briefing should be performed and include the following:

— establish a chain of command;

— scope of work;

— mobilization schedule;

— responsibilities during mobilization;

— results from any job safety analyses (JSAs);

— results from risk assessment;

— description of vessel alarms;

— location of emergency stop buttons;

— muster points and evacuation routes;

— vessel familiarizations; and

— vessel permit system.

A method of communication by which all parties can be contacted should be defined. For loadout, communications should be defined and available for the following parties:

— onshore crew;

— supply vessel bridge;

— operations control;

— deck crane; and

— deck crew including any winch operators.

10.4.2 On-deck Safety Considerations

A job safety analysis (JSA) should be performed for each defined scope of work. As a minimum, the following items should be subject to an on-site job safety analysis:

— SIMOPS of loadout activities on deck;

— lifting of equipment onboard;

— working at heights; and

— on-site seafastening activities including cutting, grinding, and welding operations.

A JSA should be performed at the beginning of each shift/activity, at which all personnel involved with the activity should be briefed on the hazards associated with the activity(s) and the procedures and precautions to be followed.

Access around the deck during mobilization and loadout should be restricted due to the concentrated layout and density of installation equipment required to perform the work. Care should be taken by all personnel during mobilization to ensure personal safety while negotiating the deck walkway corridors between preinstalled equipment and during loading operations by quayside cranes. Care should also be given to any other work taking place at the same time and within close proximity of any cutting, grinding or welding operations.

Any high level access of a fixed or temporary nature should be first checked for use by the on-board safety representative prior to use. Any personnel using such access should observe all necessary safety precautions and mobilization of safety equipment as instructed or advised by the safety representative in accordance with the contractor's safety and construction procedures.

Fire watch personnel should be informed of all deck cutting, grinding and welding operations, and should be positioned in areas on the vessel where there is a potential fire risk.

10.4.3 Deck Preparations for Loadout

All seafastening activities should be performed under the vessel permit-to-work system (when applicable).

Equipment should be positioned in accordance with the deck plan. Any modifications to this should be agreed between the offshore superintendent, installation engineer, project engineer, the vessel master, and the deck foreman.

Deck layout and seafastening should be inspected and approved by the vessel master prior to sail away.

Cutting and grinding equipment, whether mechanical, electrical, or oxyacetylene, should only be used by suitably qualified and experienced personnel and should be performed with relevant and approved hot work permits as necessary and as issued in accordance with vessel procedures.

Welding should be performed only by qualified and experience welders using approved welding procedures. All welding, particularly that required for operational purposes (lifting, handling, seafastening) should be monitored, inspected, and approved using qualified methods of NDE. The vessel must be certified gas free prior to any welding activities.

Seafastening weld NDT inspection should be according to DNV Rules for the Classification of Mobile Units Part 3 Chapter 1 Section 10, AWS D1.1, API 2X or comparable codes.

10.5 Preinstallation and Recovery Activities

The method of communication by which all parties can be contacted should be defined. For installation and recovery activities, communications should be defined and available for the following parties:

— vessel bridge,

— operations control,

— surveyors,

— ROV control,

— deck crane,

— deck crew including any winch operators, and

— company representative/installation supervisor.

Prior to any supply vessel operations, communications should be established between all work stations. Inter-vessel communication tests should be carried out.

All deck crane operations should be through the deck supervisor, or his nominated personnel. Once a load has passed through the water column, all communications should be through the installation supervisor or his nominated personnel.

Basic system checks should be performed on the ROV as well as any transponders, ensuring that all battery supplied units are fully charged, tested and switched on.

An ROV site survey should be performed to check for debris around the jumper and mating hubs. The survey should also include a visual inspection of the jumper path between the two structures it is connecting.

10.6 Jumper Installation

10.6.1 General

Safe lift zones should be set up for deployment and recovery activities. Equipment should be transitioned to and from the worksite once a predetermined distance above the sea floor has been reached.

In preparation for jumper installation, pressure caps (if installed on subsea structures) should be removed and hubs cleaned. If required, protective covers should be placed over the hubs.

The deck crew should check all lift rigging, ensure loose objects are either removed from the jumper or are properly secured for transit through the splash zone, and attach taglines as needed. Confirm all seafastening on the jumper has been removed, and the jumper is unlocked from the transportation stands.

Once the jumper has been lifted clear of the deck, the supply vessel or cargo barge should be repositioned away from the installation vessel prior to lowering the jumper through the splash zone. Maximum jumper lowering speed through the water column should be defined by the installation contractor. Installation speed can be controlled via buoyancy modules as necessary.

The ROV should monitor the jumper's descent through the water column and confirm visually that the jumper has reached a predetermined distance above the sea bed; if necessary heave compensation should be engaged prior to land out.

The jumper should be landed out one end at a time with the ROV aiding in positioning. Land out speed should not exceed the value specified by the jumper/connection system designer.

After the jumper has been landed out subsea onto the host structures, the rigging should be slacked off and disconnected from the jumper. The installation rigging package should be positioned a safe distance away from the subsea equipment before recovery to the surface.

After each end of the jumper has been locked to its mating hub, a seal test should be conducted at each connector to verify a positive seal has been achieved. This seal test is typically performed via an ROV hot stab interface located on the jumper.

After seal tests, the tooling packages should be disconnected from the jumper connectors, rigging attached, and the tooling packages positioned a safe distance away from the subsea equipment before recovery to the surface.

10.6.2 External Seal Test Requirements

The seal test hydraulic line should be purged of air, such as by pumping hydraulic fluid through the line before locking the jumper connector onto the inboard hub if practical.

The jumper connector manufacturer should provide a suggested seal test procedure in the IOM manual.

Seal test pressure should be allowed to stabilize before performing a minimum 15 minute hold. Jumper connector seal test hydraulic lines are usually small diameter and short in length; consequently they hold only a minimal volume of hydraulic fluid. Therefore, it may take a period of time for test pressure stabilization to occur.

10.6.3 Seal Test Failures

The jumper connector manufacturer should provide a seal test flow chart. This flow chart should provide suggested courses of action for all conceivable seal test anomalies which may be encountered, and may consider an internal pressure test.

In the event of a seal test failure which requires subsea seal replacement, the jumper connector manufacturer should provide seal removal and replacement tools, and should include procedures for their use in the IOM manual.

10.6.4 Jumper Wet Parking

In some cases a jumper may be landed out and left subsea for a period of time before connecting to inboard hubs. This is referred to as "wet parking". Once the jumper is landed out onto the host structures, the installation rigging is removed and recovered to the surfaces. The jumper end connections can be made up at a later time. This allows the operator flexibility with vessel utilization.

10.7 Jumper Recovery

The recovery of an installed jumper requires the same level of planning as the installation of a new jumper. A jumper recovery should be performed in such a manner as to minimize damage to the jumper or subsea hubs and support structures, minimize release of pipeline contents to the environment, and to safely recover the jumper onto a surface vessel. A contingency plan should be made for a jumper recovery, and should include flushing of the pipeline before jumper removal, a method to capture residual hydrocarbons in the pipeline, capping of exposed hubs, and surface handling and transfer of the flooded jumper.

10.8 Hazards

10.8.1 Dropped Objects

If there is the potential for an unsecured object to fall into the water and damage wellsite(s) and/or existing infrastructure, a dropped object analysis should be performed to define an exclusion zone for material handling.

10.8.2 Naturally Occurring Radioactive Material

Naturally Occurring Radioactive Material (NORM) management is beyond the scope of this document; however contingency plans should be made when retrieving a jumper to surface that has been in service, if production history indicates scale and sedimentation in the pipe may contain radioactive material.

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