Remotely Operated Tools and Interfaces on Subsea Production Systems

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Introduction

This recommended practice has been prepared to provide general recommendations and overall guidance for the design and operation of remotely operated tools comprising ROT and ROV tooling used on subsea production systems for the petroleum and natural gas industries worldwide.

Specific recommendations are used where a standard design or operating principle has been adopted in the industry for a period of time. Requirements valid for certain geographic areas or environmental conditions are included where applicable.

The functional recommendations for the tooling systems and interfaces on the subsea production system allow alternative solutions to suit the field specific requirements. The intention is to facilitate and complement the decision process rather than replace individual engineering judgment and to provide positive guidance for the selection of an optimum solution.

Remotely Operated Tools and Interfaces on Subsea Production Systems

1 Scope

This document provides recommendations for development and design of remotely operated subsea tools and interfaces on subsea production systems in order to maximize the potential of standardizing equipment and design principles.

This document does not cover manned intervention, internal wellbore intervention, internal flowline inspection, tree running, and tree running equipment. However, all the related subsea remotely operated vehicle/remotely operated tool (ROV/ROT) interfaces are covered by this standard. It is applicable to the selection, design, and operation of ROTs and ROVs including ROV tooling, hereafter defined in a common term as subsea intervention systems.

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 17A/ISO 13628-1, *Design and operation of subsea production systems—General requirements and recommendations*, including Addendum 1 (2006)

API Specification 17D, *Specification for Subsea Wellhead and Tree Equipment*

API Specification Q1/ISO 29001, *Specification for Quality Programs for the Petroleum, Petrochemical and Natural Gas Industry*

ISO 9001:2008 [1], *Quality Management Systems—Requirements*

ASNT SNT-TC-1A [2], *Recommended Practice and ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel*

BS 7172-2 [3], *Code of practice for safe use of cranes—Part 2: Inspection, testing and examination*

DNV 2.7 [4], *Series*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

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

3.1.1
deployment system
All equipment involved in the launch and recovery of the ROV and ROT system.

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1 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

2 American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

3 British Standards Institution, Chiswick High Road, London W4 4AL, United Kingdom, www.bsi-global.com.

4 Det Norske Veritas, Veritasveien 1, 1322, Hovik, Oslo, Norway, www.dnv.com.

3.1.2
heave-compensated system
System that limits the effect of vertical intervention vessel motion on the deployed ROV and ROT system.

3.1.3
guideline
Recommendation of recognized practice to be considered in conjunction with applicable statutory requirements, industry standards, standard practices, and philosophies.

3.1.4
manufacturer
Company responsible for the manufacture of the equipment.

3.1.5
operator
Company that physically operates the ROV (delivery system).

3.1.6
payload
The amount of additional tooling weight carried on the vehicle when it is trimmed neutrally buoyant in seawater.

3.1.7
pull-in head
End of pipeline acting as attachment point for the pull-in wire.

3.1.8
remotely operated tool system
ROT system
Dedicated, unmanned, subsea tools used for installation and inspection, maintenance, and repair (IMR) tasks that require lift and/or handling capacity beyond that of free-swimming ROV systems.

NOTE The ROT system comprises wire-suspended tools with control system and support-handling system for performing dedicated subsea intervention tasks. They are usually deployed on lift wires or a combined lift wire/umbilical. Lateral guidance may be via guidelines, dedicated thrusters, or ROV assistance.

3.1.9
remotely operated vehicle
ROV
Free-swimming or tethered submersible craft used to perform tasks such as inspection, valve operations, hydraulic functions, and other general tasks.

NOTE ROVs can also carry tooling packages for undertaking specific tasks such as pull-in and connection of rigid spools, flexible flowlines, umbilicals, and component replacement. Alternatively modules or tools may be deployed by crane and mated with the ROV subsea.

ROVs are grouped within the following main categories:

— *OBSROV (observation class ROV; MCA Class I and Class II)*—These vehicles are small vehicles fitted with cameras/lights and may carry sensors or inspection equipment. They may also have a basic manipulative capability. They are mainly used for inspection and monitoring.

— *WROV (work class ROV; IMCA Class III)*—These vehicles are large ROVs normally equipped with a five-function grabber and a seven-function manipulators. These commonly have multiplexing controls capability that allows additional sensors and tools to be operated without the need for a dedicated umbilical system. WROV are split into two classes: medium WROV and large WROV depending on their defined work scope. WROVs can carry tooling packages to undertake specific tasks such as tie-in and connection function for flowlines, umbilicals, and rigid pipeline spools, and component replacement.

3.1.10
ROV toolskids
Equipment skids or packages that can be attached onto the external surface of the ROV and are used to perform dedicated tasks.

3.1.11
skid system
Storage, transportation, lifting, and testing frames to facilitate movement of the ROT systems and the modules and components to be replaced or installed.

NOTE Skids are used in combination with a skidding system.

3.1.12
termination head
Part of the tie-in system interfacing with the end of the pipeline or flowline.

3.1.13
through frame lift
Maximum in air load capacity of ROV frame for underslung packages and tooling.

3.1.14
tie-in system
Integrated or separate pull-in and connection related equipment.

3.1.15
validation
Confirmation that the operational requirements for a specific use or application have been fulfilled through the provision of objective evidence.

NOTE Typically validation is achieved by qualification testing and/or system integration testing.

3.1.16
verification
Confirmation that specified design requirements have been fulfilled, through the provision of objective evidence.

NOTE Typically verification is achieved by calculations, design reviews, hydrostatic testing, and factory acceptance testing (FAT).

3.2 Abbreviations

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

CCO	component change-out
CL	center line
DWT	deep water test
FAT	factory acceptance testing
HPU	hydraulic power unit
ICS	intervention control system
IMR	inspection, maintenance, and repair

MQC	multiquick connector
OBSROV	observation class ROV
ROV	remotely operated vehicle
ROT	remotely operated tool
TDU	tool deployment unit
WROV	work class ROV

4 Subsea Intervention Concepts

4.1 General

4.1.1 Components

It is the intent of this standard to take a systemwide approach to the design and implementation of subsea intervention.

A subsea intervention system typically includes the following components:

a) tooling for dedicated intervention tasks;

b) complimentary equipment (tool basket, guideposts, etc.);

c) deck handling equipment;

d) control system;

e) deployment/landing equipment;

f) guidance and entry equipment;

g) ROV spread interface with equipment and tools.

4.1.2 Intervention Methods

There are several methods to ensure safe and efficient guidance of the subsea intervention system to the subsea work site. Typical methods include:

a) surface guideline systems,

b) guidelineless systems,

c) subsea deployed guideline systems,

d) thruster assisted systems,

e) ROV assisted guidance.

4.1.3 Selection

The selection of equipment and intervention methods should be decided when establishing the intervention strategy (see 4.6).

Common recommendation for the subsea intervention systems should be used as far as practical. However specific recommendations for ROV and ROT systems and their subsystems are included in separate chapters where design or operational requirements require as such.

4.1.4 Design

Design of subsea systems and associated remotely operated tooling system in an optimum manner is dependent on a system design approach. The main focus areas in this respect are standardization of interfaces, equipment, and intervention methods. Subsea intervention systems should be designed in parallel with subsea production systems to allow for intervention friendly solutions for the life of field. The specification covers tooling design, design of intervention interfaces on the subsea equipment, and guidelines for implementing intervention friendly designs.

The design should focus on the safe and efficient handling including deck handling, operation, and maintainability of the subsea tools and interfaces. System for easy testing after mobilization should be provided.

4.1.5 Other Considerations

The standards for the selection and use of remotely operated tooling interfaces have generally selected one interface for a specific application. The inclusion of a particular approach or recommendation does not imply that it is the only approach or the only interface to be used for that application.

In determining the suitability of standardization of remotely operated tooling system interfaces for installation, maintenance, or inspection tasks on subsea equipment, it is necessary to adopt a general philosophy regarding subsea intervention. Details of the intervention philosophy is described within this recommended practice (RP), as are the associated evaluation criteria used in selecting the interfaces incorporated into these recommendations.

This RP is not intended to obviate the need for sound engineering judgment as to when and where its provisions are to be utilized, and users need to be aware that additional or differing details may be required to meet a particular service or local legislation.

With this document, it is not wished to deter the development of new technology. The intention is to facilitate and complement the decision processes, and the responsible engineer is encouraged to review standard interfaces and reuse intervention tooling in the interests of minimizing life cycle costs and increasing the use of proven interfaces.

The interfaces on the subsea production system can apply equally to ROTs and ROVs.

4.2 Typical ROV Configurations

ROV are essentially configured for carrying out intervention tasks in six ways (see Figure 1):

a) with manipulators for direct operation of the interface (Figure 1a);

b) with tool deployment units (TDUs) (Figure 1b);

c) with toolskids mounted on the external surface of the ROV, either underslung, rear, front, or side mounted (Figure 1c);

d) with single point docking tool (Figure 1d);

e) the operation may be supported by an external underslung basket that is used to store commonly utilized manipulator deployed tooling within easy access (Figure 1e);

f) with a manipulator-held tool, including hydraulic or electric stabs for supply of hydraulic or electric power (Figure 1f).

WROVs have normally a base configuration consisting of a left-hand five-function grabber arm and right-hand seven-function manipulator.

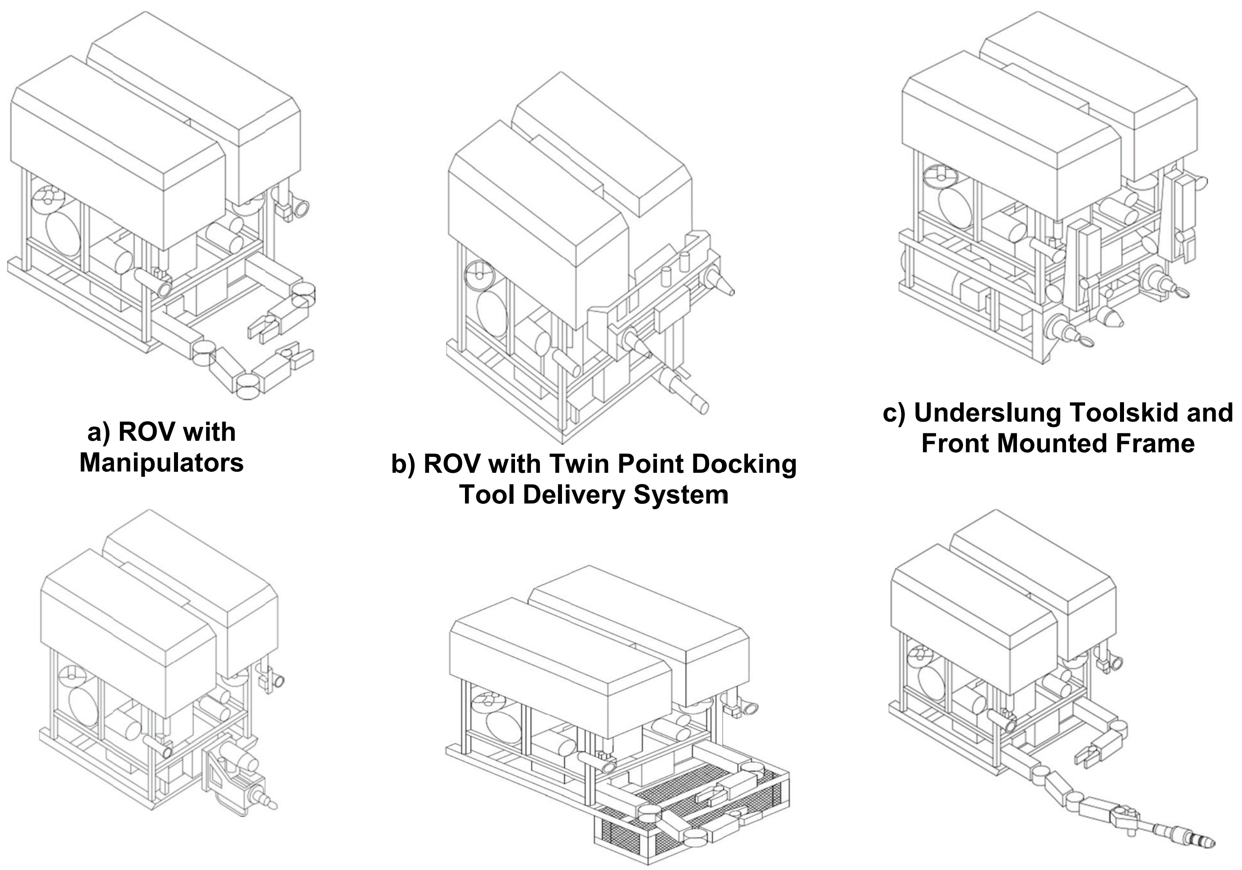
Interface tooling, so far as possible, should be designed to operate with a range of WROVs and not be limited in application to one design only, thus allowing the use of ROVs and intervention vessels of opportunity. For the purpose of securing access for safe and efficient ROV operations, a dimensional envelope, representing the majority of ROVs in the market, is specified, see 6.2.1.

4.3 Intervention Vessels

For various geographic regions and environmental conditions, different intervention vessels are used for the performance of installation and IMR activities.

In harsh environments, IMR vessels equipped with moon pools and dedicated handling systems, have been used extensively in order to allow for all year operations, while other areas less exposed to wind and sea have used standard supply vessels.

These are important aspects when selecting the intervention strategy for individual fields.



a) ROV with Manipulators

b) ROV with Twin Point Docking Tool Delivery System

c) Underslung Toolskid and Front Mounted Frame

d) Single Point Docking Tool Delivery System

e) ROV with External Basket

f) ROV with External Handheld Tooling

Figure 1—Typical WROV Operationally Configured

Figure 2 shows ROV and typical interfaces on a subsea tree.

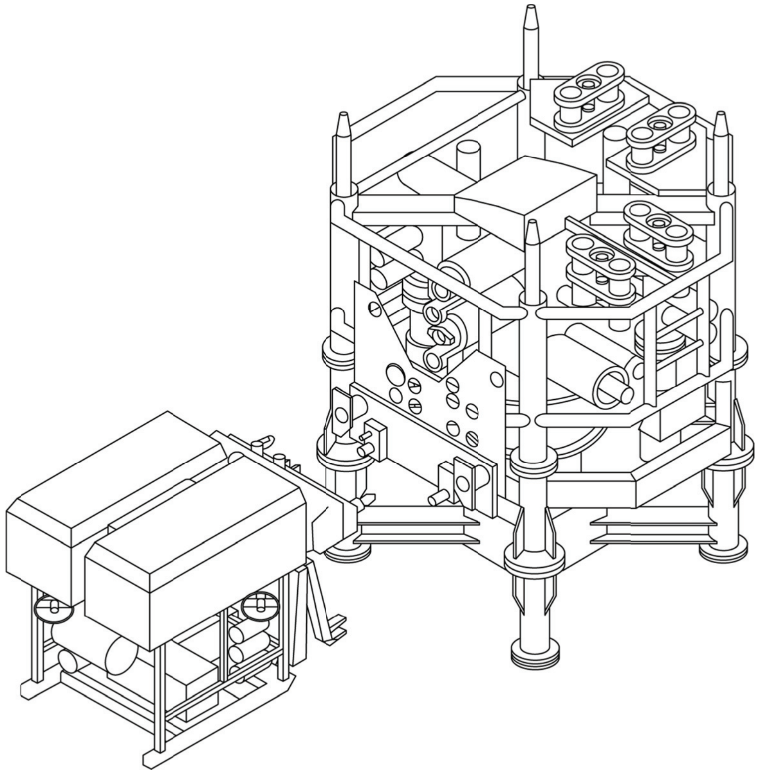


Figure 2—Typical Interfaces on a Subsea Tree

4.4 Component and Module Intervention

Installation and retrieval of subsea components and modules may be performed by use of ROVs or ROTs or a combination of these.

The replacement of subsea components and modules that cannot be carried by a ROV may be handled by a lift line or drill pipe designed to support the weight and dynamic loads of the tool and the component being replaced.

The operation may be supported with a second down line such as a separate control umbilical or via the ROVs umbilical/tether.

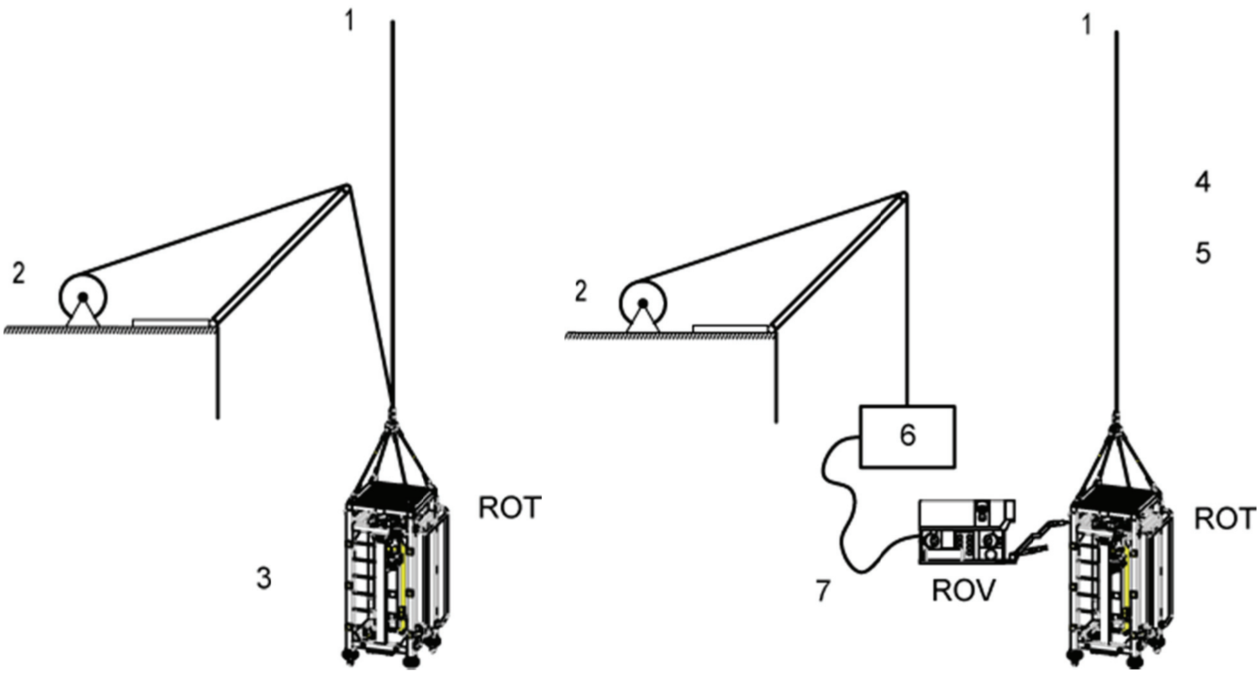
If multiple lines are used, it is recommended to select separate deployment areas of the intervention vessel to avoid entanglement.

NOTE ROTs includes tools that are initially deployed subsea by a crane or winch. The tool could then be utilized and manipulated by ROV and flown to the working location.

The tools can be controlled and operated by dedicated, self-contained control system, through the ROV control system or by mechanical actuation by use of manipulator or ROV tools.

An illustration of alternative subsea intervention systems for component or module intervention is shown in Figure 3a and Figure 3b.

The breakdown of the subsea intervention system into subelements and components as presented in this RP should not pose limitations on the selection of new intervention concepts whose functionality and reliability can be documented.



a) ROT with Self-contained Control System

b) ROT with ROV Manipulation/ROV Supplied Hydraulic and/or Electric Power

Key

1 lift wire (crane or winch)

2 ROT control system

3 option 1: ROT with self-contained control system

4 control option 1: control through electro/hydraulic supply from ROV

5 control option 2: mechanical actuation by ROV

6 tether management system

7 option 2: ROT operated by and through ROV

Figure 3—Typical ROT Configuration

4.5 Tie-in Systems

4.5.1 General

Diverless tie-in systems are used for connection of rigid flowlines, flexible flowlines, and umbilicals to subsea equipment. These connections can be orientated vertically, horizontally, or at the angle that best suits the installation.

A typical connection system would consist of the hub mounted on the subsea tree or manifold (inboard hub), the hub connected to the end of the flowline or umbilical (outboard hub), a seal plate, clamp, cap, and the connection tooling. During the operation, various installation aids will be used, such as pull-in heads, pressure caps, debris caps, etc. On completion of the connection sequence, permanent protection or insulation covers may be required to be installed over the connection.

The inboard hub normally has minimal movement as it is usually attached to the main structure. The outboard hub on the pipeline or spoolpiece is normally stroked in towards the inboard hub. When the hubs are in the fully stroked position, they should be correctly aligned and orientated. Note that if the connection is a multibore then orientation of the outboard hub will be required during the stroking operation.

The connection mechanism can then be actuated. This may be a multipart clamping arrangement, collet clamp, or a bolted flange. The tooling involved may range from a simple hydraulic hot stab or torque tool through to an integrated bolt/nut handling mechanism.

Pull-in of hubs can be in the horizontal plane, with or without buoyancy, or of a hinge and lockdown type assembly.

Hot stabbing for seal tests is normal. Low-pressure back seal tests may be used to verify seal integrity. It is recommended to have this test circuit independent from the main control system, including an isolation valve and gauge for leakage monitoring.

The tie-in connector should:

a) achieve a reliable diverless connection that is capable of being tested for its integrity (sealing will be either metal-to-metal or a combination of metal and elastomeric sealing);

b) achieve a short-stroke connection minimizing hub movement and residual stress;

c) allow for subsea seal surface cleaning and inspection;

d) allow for subsea seal replacement.

4.5.2 Flowline Tie-in Systems

Flowline tie-in systems are used for tie-in of rigid and flexible flowlines and spools.

The tools may be designed as a combined pull-in and connection tool, or as separate tools.

Various connector types, such as clamp, collet, mandrel, or bolted flanges, may be used with the tools.

4.5.3 Umbilical Tie-in Systems

Umbilical tie-in systems are normally combined pull-in and connection tools, which additional to axial alignment provide a means of rotating the connector.

4.5.4 Flying Leads Connections

Flying leads may be connected as individual electric or hydraulic lines or as part of multiple line connection by use of a junction plate.

4.6 Intervention Strategies

4.6.1 General

The development of an intervention strategy is of high importance for the overall field architecture and should be determined on the basis of a multidisciplinary systems approach at an early stage of systems engineering.

The intervention strategy selection may be based on use of a combination of tooling including ROV, autonomous underwater vehicle, and ROT technologies.

The following list states aspects impacting the intervention strategy and should be considered when developing a strategy:

a) field development plan;

b) field architecture and infrastructure;

c) environmental and metocean data;

d) mobilization and demobilization of subsea intervention systems and associated modules;

e) deck handling principles;

f) standardization of tools and interfaces;

g) quantity of tools (including backup tools and tools needed onshore during fabrication and testing);

h) guidance method of modules and tools;

i) replacement in one or two tooling missions;

j) multipurpose tools vs dedicated tools;

k) the selection of mechanically operated tools vs hydraulically or electrically operated tools;

l) reuse of intervention systems;

m) wet storage of tools;

n) categorization of critical and noncritical operations;

o) deck space requirement and deck layout;

p) operational issues with respect to the IMR vessel (e.g. simultaneous operations between subsea intervention and drilling or completion activities);

q) environmental aspects (including e.g. water depths, current conditions, and seabed conditions);

r) access at the subsea location;

s) need for technology qualification;

t) subsea worksite tool function verification equipment (e.g. torque or pressure verification);

u) need to develop testing philosophy.

4.6.2 System Considerations

The design, configuration, and operation of the subsea intervention system impacts directly on the life cycle cost for the entire subsea production system. In order to obtain a subsea production system design providing safe and cost effective intervention operations, it is important to obtain a closed loop between subsea production system design and the subsea intervention system design.

4.6.3 Subsea Intervention System Development

Subsea intervention systems should be designed with consideration for all phases of an intervention operation, which typically are:

a) mobilization (specific issues at the location in question);

b) deck handling and preparation;

c) launch, descent, and landing;

d) planned and unplanned intervention and task;

e) testing;

f) retrieval;

g) demobilization;

h) contingency operations;

i) emergency situations (e.g. IMR vessel drift-off).

During the evaluation, consideration should be given to reasonably foreseeable misuse of the subsea intervention system.

Selection of subsea intervention systems running philosophy is determined by:

a) availability requirements (logistics and mobilization time for equipment);

b) field-specific parameters (water depth, wave, current, and seabed conditions);

c) intervention vessel requirements and interfaces (deck space requirement and deck layout);

d) ROV requirements, including the number and class of ROV required to perform the various intervention tasks;

e) intervention task-specific parameters (planned vs unplanned operation, complexity, frequency, and subsea to interface considerations).

4.7 System Interfaces

4.7.1 General

To ensure safe and efficient operations, the intervention vessel interface information should be communicated between the tool supplier and the tool operator.

4.7.2 Equipment

Intervention vessel interface information from the equipment manufacturer should include equipment datasheets for both ROV tools and ROT and include the following information:

Equipment performance data:

a) specific utility requirements (e.g. air, water, electricity, fluids);

b) specific communications protocols with control system;

c) video and data output capabilities;

d) equipment dimensions; operational footprint (e.g. ROV panel docking);

e) depth rating;

f) center of gravity and center of buoyancy;

g) weight in water/in air.

Interface data:

a) electrical and hydraulic connections (including electrical supply requirements);

b) hydraulic requirements (e.g. fluid, flow, torque, number of turns, pressure, cleanliness);

c) deployment and handling requirements.

Transport data:

a) dimensions, footprint ,inclusive transport container, etc.;

b) sea-fastening and deck load distribution;

c) utility requirements (e.g. air, water, electricity, fluids);

d) ROV topside equipment interface requirements;

e) system layout drawings/equipment drawings/pictures;

f) contact information.

User documentation including necessary details for mobilization, operation, maintenance, preservation, storage, and transportation of the specific equipment:

a) handling and operation instruction including maintenance and preservation;

b) technical description and component identification including pictorial representation (for spare part ordering);

c) interface data;

d) equipment performance data;

e) lifting certificates;

f) outline operation procedure;

g) hydraulic schematics and electrical wiring diagrams;

h) maintenance, preservation, and storage program;

i) drawings.

5 Subsea Intervention Systems Design Recommendations

5.1 General

This section provides functional recommendations for the design of remotely operated subsea intervention systems. Recommendations for respectively ROV and ROT based tooling systems have as far as possible been merged into common sections. Equipment specific recommendations are specified where applicable.

5.2 Surface Equipment

5.2.1 General

Based on the selected intervention strategy, the remotely operated tools may require guidance during launch and recovery and landing and retrieval onto the subsea system. This subsection states recommendations for equipment used for handling of the tools on deck, and deployment/retrieval operations.

The recommendations given apply in general for equipment needing a handling system due to weight, lifting height, or accessibility.

5.2.2 Deck Handling Systems

Deck handling equipment and launching techniques should be selected to ensure that a wide range of intervention vessels can be used. Flexibility should be provided without compromising safety and reliability of the work, both on surface and subsea.

Main issues are:

a) means of moving subsea intervention equipment on deck (skid systems vs use of intervention vessel cranes);

b) means of deploying and landing subsea intervention systems (winches and simple mobile A-frames vs use of complex purpose-made heave-compensated systems);

c) means of installing on and removing from the intervention vessel (mob/demob);

The selection of equipment should be dictated by the nature of the intervention task (e.g. tie-in operation, module replacement), safety for personnel, environmental considerations affecting the operation, and time available to carry out the required operation.

The following recommendations apply:

a) skids and baskets for the various tools and the involved modules should provide safe and efficient transportation and deck operations;

b) lifting points should be designed according to a recognized lifting standard (e.g. API 17D, BS 7121-2);

c) each tool, including the toolskids, should be supplied with handling devices (e.g. lifting slings) certified for the maximum expected dry handling mass. This should, where applicable, include the dry mass of the module to be handled by the ROT;

d) the toolskids and baskets should be balanced for safe lifting and handling with the dedicated tool and, when applicable, with the replaceable module installed;

e) on the surface, replacement of components and modules in the various tools should be performed by skidding when required for safe operation due to intervention vessel movement;

f) when required, toolskids should include all facilities (piping, valves, and gauges, etc.) for function testing of the various tools.

5.2.3 Deployment Equipment

5.2.3.1 General

This subsection contains functional recommendations for the equipment and tools during the deployment and landing phases of the intervention task.

The following recommendations apply.

a) Operations in which sensitive components, as part of the subsea system, are involved should be carried out in a two-step sequence. The ROT should be landed and sufficiently secured prior to manipulation of sensitive components (e.g. hydraulic lines).

b) The guide funnels on the equipment and tools should enable safe, simple, and efficient entering and securing of the guidelines and eliminate trapping of the wires.

c) The design of the deployment system should consider emergency operations (e.g. intervention vessel drift-off).

d) The number of lines from the surface to the subsea work area should be minimized to reduce the possibility of entanglement.

e) When a subsea intervention system is deployed in a guidelineless operation, means of lateral and rotational control is recommended while entering into the subsea area in which sensitive components are exposed at the same level as the ROT.

f) In order to achieve safe operation, the equipment, tools, and the transportation skid should enable entering on tensioned guidelines.

g) Sufficient running clearance between the ROT and the nearest obstructing element should be ensured. Minimum 1.0 m (3.3 ft) clearance while on guidelines and 0.2 m (0.65 ft) while on guideposts should be provided. Cursor systems, guidecones, and guideposts should be secured to avoid movements above the tolerance limits [1.0 m (3.3 ft) topside and 0.2 m (0.65 ft) subsea]. Running clearances for guidelineless systems needs to be defined. Protection of surrounding equipment by use of bumper bars may be considered.

h) For guideline based operations, equipment, and tools should be designed for operation without heave compensation and with a maximum landing speed of 1.8 m/s (6 ft/s). A soft landing system should be considered for sensitive equipment.

i) If a soft landing system is utilized, it should be easy to activate and lock in retracted position for use with an active heave compensated system. The system may also be of a passive design such as a water based soft landing system.

5.2.3.2 Lift Wire and Umbilical Winch Systems

5.2.3.2.1 General

The following recommendations apply.

a) Winch load calculations shall be in accordance with the relevant standards and regulations in which appropriate considerations have been made for the dynamic loads.

b) Constant-tension winches should allow for instant and direct switchover from normal operation to constant tension.

c) As well as local control, the winches should be equipped with a mobile remote operation to ensure a safe and well monitored operation.

d) The lifting winch or deployment system should include a facility for depth display during operations.

e) An overload protection system should be considered when selecting winches.

5.2.3.2.2 Guideline Winch System

The following recommendations apply.

a) Guideline winches should include an adjustable constant-tension mode, with the capacity to operate with the guideline in tension during maximum design operation condition.

b) The guideline winches should have a defined operational tolerance (e.g. +15 % to –30 % of set value).

c) Guidelines should include an ROV operated guideline anchor for easy attachment and release—guideline anchors should include an emergency release system (consider standardization across the project).

d) Guideline anchors used for lifting (e.g. guideposts) should be certified for the applicable load.

5.2.3.2.3 Umbilical Winch System

The following recommendations apply.

a) Umbilical winches used for combined lifting and control functions should have ample lift and brake capacities to handle the complete weight of the ROT system in air and in water. The capacity evaluation weight should include mass of the ROT, the module to be installed if any, and the full length of the umbilical including hydrodynamic effects. Loads to be defined based on field specific environmental data and intervention vessel characteristics.

b) Umbilical winches should include an adjustable constant-tension mode, with the capacity to operate with the umbilical in tension during maximum design operation condition.

c) Umbilicals should have a system for easy attachment to the lift wire, when applicable.

d) Umbilical winches not used for ROT lifting should have sufficient lift and brake capacities to handle the full length of the umbilical, including dynamic amplification.

5.2.3.2.4 Lift Wire Winch System

The following recommendations apply.

a) Lift wires should be of a low-grease and torque-balanced design.

b) A fiber rope or a ball-bearing swivel may be evaluated (alternative).

5.2.4 Tool and Equipment Deployment

A method for handling the tools and equipment on the intervention vessel deck and deployment to the subsea work site should be planned carefully taking into consideration:

a) safe handling considering the environmental condition in the work area;

b) intervention vessel facilities (a vessel typical for the geographic area should be used as a basis, if no specific intervention vessel has been selected);

c) intervention system design (size, weight, and shape);

The following general recommendations apply:

a) manual handling of equipment should be limited to 25 kg (55 lb). Heavier equipment should be prepared for handling by use of forklift and crane;

b) for operations in harsh environments, the need for use of deck handling cranes should be minimized. A skidding system, or restraining system to avoid swinging loads, should be used for transporting the subsea intervention system and/or the components between working deck and launching position to ensure safe handling. Recommendations for toolskid systems are given in 5.3.2;

c) access to the master link for lifting should be from deck level;

d) where personnel are expected to climb onto a tool, module, or module stack-up for handling, inspection, or maintenance, design considerations should be given to the placement of ladders, footrests, handholds, temporary gratings, and attachment points for safety lines and fall-arrest systems;

e) design and operation of all electrical systems on surface should be in accordance with applicable standards and regulations (equipment voltage and frequency should be considered). Special attention should be given to equipment for use in explosion-hazard areas;

f) the lifting equipment shall be designed and documented in accordance with applicable standards and regulations;

g) design loads for lifting equipment should include hydrodynamic loads, where applicable;

h) transport skids should have provisions for fork lift interface;

i) tools, components, modules, skids, and trolleys should have provisions for sea-fastening;

j) dedication sea-fastening attachment points should be clearly marked "For sea-fastening only." Each sea-fastening point should be dimensioned for 1G acceleration in any direction;

k) the deck jumper (umbilical/cable) for use during deck operations should be of sufficient length to enable flexibility with respect to the surface equipment layout;

l) the deck jumper (umbilical/cable) should be adequately protected against damage during use and storage;

m) the deck jumper (umbilical/cable) should be provided with reeling mechanisms.

5.3 ROV Tools

5.3.1 General

Specific design recommendations for ROV interface tooling can be found in Section 6 of this document.

Size, shape, and center of gravity of ROV tools and equipment should allow for safe and efficient operations by use of ROVs.

Maximum submerged weight of ROV manipulator handled tools should not exceed 50 kg (110 lb).

NOTE If the weight limit must be exceeded, considerations to size, shape, and handling should be made.

ROV operated tools should have the facility to visually monitor their actions by use of ROV in case of direct intervention control system (ICS) control system malfunction (e.g. hot stab pressure gauge port, torque tool turns counter).

5.3.2 ROV Mounted Skids

The height, width, and overall length of the toolskid package and its mounting position on the vehicle should take into consideration space restrictions in the launch and recovery system, particularly for moon pool or hanger deployed systems.

Recommended size, for an underslung toolskid, is less than 0.5 m (20 in.) in height and length and width in accordance with the ROV envelope.

Weights of the skids should be checked vs through frame lift capacity of the selected ROV.

Skids should be designed to be capable of being neutrally buoyant in any configuration within its purpose.

The design and layout of the skid should take into account access to skid components for service and maintenance.

The ROV skid should be designed to support the total weight of the ROV if landed on the deck without support

The global weight of the ROV including the skid and the tether management system shall not exceed the SWL of the launch and retrieval system.

5.4 Module/Component Replacement Tools

This subsection contains functional recommendations for the installation or replacement of subsea components and modules.

The following general recommendations apply:

a) the subsea intervention system should provide a safe locking (including double securing function) of the replaceable module during handling, deployment/retrieval and operation;

b) replacement of modules should be based on vertical retrieval and re-entry to the landing receptacle;

c) if power failure occurs or is switched off during running, the replaceable module should remain locked to the tool;

d) the module to be installed should be landed in a two-step sequence—the two steps should not go automatically but allow for a stop in between for inspection:

   1) landing the dedicated subsea intervention system on the subsea landing structure,

   2) final alignment of the module onto the subsea interface;

e) when a module is to be retrieved, the subsea intervention system should be designed with sufficient flexibility to self-align and freely enter the module mating point;

f) modules interfacing pressurized equipment (e.g. valve insert, clamp connection) should have provisions for verifying that internal pressure is bled off. It should also be possible to verify the seal integrity on connection points;

g) all actuated functions that may prevent retrieval of the tool should have a local override or interface for a separate override tool in order to recover the tool.

5.5 Tie-in Systems

5.5.1 General

This subsection describes the functional recommendations of the pull-in and the connection operation.

The following considerations should be taken into account for tie-in operations:

a) parameters related to the dedicated pipeline/flowline;

b) operational issues with respect to the intervention vessel (e.g. simultaneous operations between subsea intervention and drilling or completion activities);

c) environmental aspects (including e.g. wave height, water depths, current conditions, and seabed conditions;

d) limitations subjected to the alternative tie-in methods (e.g. winch capacity or length of pull-in rope);

e) subsea production system field layout.

The tie-in system includes in general the following main equipment:

a) tools for pull-in and connection, either as separate tools or a combined tool;

b) connectors and seal assemblies;

c) hubs, caps, and terminations;

d) pull-in porches/alignment structures;

e) laydown equipment;

f) auxiliary tooling (hub cleaning and inspection, seal replacement, etc.). The subsea electrical connection system should be covered by a recognized industry standard.

5.5.2 Pull-in Tool

The following recommendations apply for a system that uses a pull-in tool to move the outboard connection across the seabed:

a) the pull-in tool should perform the complete pull-in operation in a single run and secure the pipeline/flowline in a safe and defined position;

b) the pull-in tool should be mechanically locked to the subsea structure or the inboard hub during pull-in operations;

c) hydraulic cylinders or a subsea winch may be used for final pull-in sequence. Alternatively, a surface pull-in winch/take-up reel may be used from a fixed structure;

d) winch capacity on a pull-in tool should be designed for the expected max forces during tie-in of pipeline/flowline/risers plus an additional 10 % load;

e) the pull-in tool should be capable of performing pull-in without back-tension in the pipeline/flowline;

f) skew load on the pull-in tool should be included based on the maximum entry angle of the wire;

g) if direct ROV pickup of the pull-in wire is not possible, a wire delivery mechanism should be included;

h) the ROV or the pull-in tool should establish the connection between the pull-in wire and the termination head/pull-in head;

i) the pull-in tool or the ROV should be able to release the pull-in wire;

j) if a pull-in head is mounted on the outboard hub, this should be removed either by the pull-in tool at completion of pull-in, by ROV, or by the connection tool prior to commencement of hub stroke-in.

5.5.3 Connection Function

The following recommendations apply:

a) the connection tool should be able to perform the complete connection or disconnection operation in a single run;

b) safe storage positions for the outboard hub should be available both before a connection and after a disconnection;

c) the connection tool should be designed to meet the maximum connection force required for mating or demating of the fixed and the stroking hub;

d) the connection tool should be mechanically locked to subsea structure or the fixed hub during connection operations;

e) loads from the pipeline/flowline should not cause any leakage in the connection;

f) the stroking force generated by the connection tool should take into account all forces transmitted to the connection system;

g) the connection tool should have the capability to enter, catch, and align the hubs at a defined worst-misalignment condition;

h) it should be possible to replace the seal assembly either by the connection tool or by a ROV. If a spool-piece connector is used, the seals should be a part of the connector assembly (rather than the hubs), in which case it should be possible to retrieve the complete connector in order to replace the seals at the surface;

i) if clamp connectors are used, the connection tool, or where applicable a ROV, should incorporate facilities to ensure that the makeup and break-out torque applied is kept within the specified torque range. In addition, turn-counting of jackscrew revolutions should be considered for enhanced operation feedback and operator information;

j) the connection tool should include means of testing the seal integrity after a connection is made up;

k) the connection tool should be capable of connecting a single subsea pig launcher to the inboard hub of a single-bore pipeline/flowline.

5.5.4 Connector and Seal Assembly

The following recommendations apply for connectors and related seal assemblies:

a) any preload should be maintained mechanically without use of hydraulic pressure;

b) the connection should withstand cyclic loads caused by pressure, temperature, and external loads;

c) for secondary seals and backup seals, elastomer materials with verified service performance may be used;

d) the connectors for the pipelines/flowlines should permit repeatable connections and disconnection, preferably without the need for replacement of the seals;

e) connectors should be of a standard size/rating to facilitate beneficial interfacing with the connection tool design. Emphasis should also be put on standardizing the interface between the connector and the connection tool;

f) the clamp connector should be replaceable remotely without retrieval of either hub to surface;

g) pigging requirements should be taken into consideration when selecting seal internal diameter;

h) the connector should allow for external pressure testing of the connection. If so, the annular area between the primary metal seal and the environmental seal should be vented to avoid pressure buildup in case a leak develops in the metal-to-metal seal;

i) multibore connections should have a system for orienting the seal assembly relative to the hubs;

j) connectors should be designed for uniform force distribution around the hub circumference;

k) connectors should incorporate features that prevent unintentional release due to impact from tools, ROV, falling objects, or tool failures or due to any other operational loads;

l) the load capacity of the connections should ensure seal integrity for all operational loads;

m) both pipeline/flowline and header should have sufficient load capacity to withstand pull-in, stroke-in, and alignment loads. In addition, residual preload for final alignment of the hubs should be taken into consideration. Adequate assisting marine operations to protect pipeline/flowline from overstressing should be considered;

n) the distance between fixed and stroking hubs should enable installation/retrieval of applicable equipment, such as pull-in head, caps, seals, and connectors. Required back-stroke should consider interfacing equipment;

o) it should be possible to perform seal-seat inspection and cleaning of both inboard and outboard hub faces prior to final connection;

p) the resulting face-to-face angular gap after engaging the hubs should allow the clamp to enter the hubs with proper margin and provide final alignment and makeup of the connection.

5.5.5 Hubs, Caps, and Termination Heads

The following recommendations apply to the hub, caps, and termination heads of connection systems:

a) hydraulic lines should include check valves to prevent loss of hydraulic fluid or ingress of water and dirt when disconnected. In case of risk for clogging of check valves, the hydraulic lines should be fitted with protection caps when disconnected;

b) all surplus bores in standard multibore hubs should be permanently plugged;

c) in case of defect lines in the umbilical, it should be possible for multibore seal plates to utilize the spare lines in the umbilical by means of bypass solutions;

d) hubs should not represent a flow restriction;

e) hubs in piggable lines should have inside diameters flush with the line;

f) the hub seal preparations should, in case of damage, accommodate a contingency seal surface by installation of modified seal rings;

g) required pressure caps/blind hubs should be installed/retrieved by use of the ROT. Alternatively, the caps can be installed/retrieved by an ROV tool. The pressure caps should be connected by means of a connector and should have the same rating as the hub/bores it blinds off;

h) the long-term protection cap should include means of protecting the seal area. The long-term protection cap should be installed on surface and retrieved by the ROV or alternatively by the ROT;

i) the long-term protection caps should prevent intrusion of salt water to the hub sealing areas and should not be pressure containing. If required, a pressure-equalization device should be included;

j) the short-term protection cap should protect against dirt and seawater circulation and be installed/retrieved by ROV;

k) the inboard protection and pressure caps should include means of venting the manifold piping;

l) the inboard protection and pressure caps should include means of filling of manifold preservation fluid, to facilitate a complete filling of the manifold piping;

m) there should be provision for installation of dirt protection plugs on any vital part;

n) the termination head should be optimized with regards to mass, dimensions, and interface with the pipeline/flowline;

o) the termination head should withstand all loads from the pipelines and transmit them into the subsea structure;

p) the termination head should have wire-attachment points for laydown purposes or in case a pull-out of the pipeline/flowline is required;

q) the termination head/pull-in head and corresponding clamp should prevent accidental release during all phases of the installation and pull-in operations;

r) the pull-in head should enable connection of an ROV-installed hot stab for flushing and pressure-testing purposes. The possibility of using the hot stab for pigging purposes should be evaluated;

s) the termination head/pull-in head should enable bleed-off of internal pressure;

t) the pull-in head should be retrievable to surface;

u) the umbilical termination head should have a marking system for rotation identification;

v) the umbilical termination head may have provision for installation of electrical coupler receptacles;

w) the umbilical termination head should have provisions for installation of removable plugs and covers, protecting the electrical coupler receptacles.

5.5.6 Pull-in Porches/Alignment Structures

The following recommendations apply:

a) pull-in porches should provide capture and alignment;

b) the porches should withstand installation loads;

c) the pull-in porches should be designed to withstand or to be protected from snag loads (e.g. from lift wires and guidelines);

d) maximum entry angles of the termination head should be defined as it enters the alignment funnel.

5.6 Subsea Intervention Tooling Control and Actuation

5.6.1 General

Through the evolution of remotely operated tools, a variety of control systems and actuation principles for the tools have been established.

This subsection covers recommendations for control and actuation of the subsea intervention tools within the following main categories:

a) self-contained control system;

b) control systems controlled via ROV control system;

c) mechanical actuation;

d) deck pack for testing, cleaning, removal of water, and replacement hydraulic fluid.

5.6.2 Common Recommendations for Control Systems

The main purpose of the control system is to provide a safe and efficient means of operating the various tool functions, and to monitor essential tool parameters such as:

a) pressure;

b) flow;

c) position indicators;

d) self-diagnostics;

e) interlocks;

f) data logging;

g) operating parameters as applicable (e.g. torque, etc.).

5.6.3 Self-contained Control Systems

5.6.3.1 General

Self-contained control system may include:

a) surface control system;

b) surface/subsea communication;

c) subsea control system.

This subsection contains the following general recommendations for the ICS:

a) hydraulic control components should meet standardized pressure classes;

b) the capacities of the electrical and hydraulic systems in the ICS should provide for some increase in the number of functions;

c) the hydraulic system should be designed to maintain specific cleanliness and water content requirements. A typical cleanliness level is SAE AS4059 Class 8B-F or ISO Class 17/14 (see ISO 4406 [2]). Mechanisms for obtaining the required cleanliness level should be maintained throughout the whole process, including fabrication and assembly;

d) when selecting the type of hydraulic fluid, the interfacing equipment (i.e. ROV systems and workover systems) should be taken into consideration. The need for qualification and compatibility verification should be evaluated;

e) separate purifier drain and fill connections should be fitted to all hydraulic reservoirs;

f) all electrical equipment should be water-ingress-protected and have active electrical insulation monitoring (e.g. in accordance with IMCA AODC 035, *Code of practice for the safe use of electricity under water*);

g) the equipment should be supplied complete with all necessary interface piping, instrumentation, cabling, and deck jumpers in order to avoid on-site installation, except for connecting the units;

h) all control cables, piping, umbilical terminations, connectors, hoses, and associated equipment should be supported and protected adequately to prevent damage or contamination during storage, testing, equipment handling, and operation;

i) all lines, cables, fittings, and connectors should be clearly marked to enable easy identification and connection. The marking should include the pressure rating and test date;

j) multiconnectors should be evaluated to reduce hookup time;

k) the same type of fitting should be used for the same pressure classes;

l) the number of different types of fitting should be minimized throughout the system.

5.6.3.2 Surface Control Systems

The following recommendations are relevant for a purpose-built surface control container for the subsea intervention system.

The surface control equipment should:

a) provide for safe, effective, and reliable control and monitoring of all subsea intervention system functions, including testing;

b) include audio/visual contact between the subsea intervention system surface control unit and the ROV surface control unit;

c) provide facilities for monitoring applicable surface activities and for communication to crane/winch;

d) include facilities for computerized storage and printout of relevant feedback data from the various operations;

e) provide facilities for video recording of the subsea intervention system operations, including ROV operations for complementary work;

f) enable deck-positioning flexibility (e.g. location of doors, safety exits, control panels, cable inlets/outlets, etc.);

g) have an operator-friendly design. Control panels should be easily readable with logical and understandable markings. The total number of monitors should reflect the maximum number of functions to be monitored simultaneously;

h) have proper lighting, ventilation, temperature control, and noise protection;

i) allow easy access to all components for maintenance and repair;

5.6.3.3 Surface/Subsea Communication

The following recommendations apply to a subsea intervention system with a dedicated umbilical.

The umbilical can either be clamped to a lift wire or armored to provide lifting capability as an integrated solution.

Recommendations for communication should include:

a) the umbilical should contain necessary power cables, fiber optic lines, twisted pair signal cables, and coaxial cables for power and signal transmission. Minimum one each spare power, fiber, coax, and twisted pair should be included;

b) the umbilical design should be suitable for the application required, particularly in respect to torque balance, tensile strength, elongation, fatigue bending, and rough handling, all in combination with good flexibility and low mass to ensure ease of handling and operation;

c) a combined umbilical/lifting wire should be considered. The combined umbilical/lifting wire shall be certified according to an applicable standard such as DNV Standard for Certification No. 2.22, *Lifting Appliances*;

d) the umbilical should be designed able to operate under full load with all the umbilical on the winch drum, accounting for heat production in the umbilical;

e) in umbilicals containing hydraulic lines, the hydraulic return line should always have a pressure higher than ambient in order to prevent seawater ingress. Alternatively, other suitable seawater ingress-prevention facilities may be considered;

f) the umbilical terminations should be of lightweight design to enable handling and connection/disconnection by a maximum of two operators;

g) the umbilical should be fitted with a ground wire of necessary size to prevent electrical potential differences between the subsea intervention system and the surface equipment. All systems should have active electrical insulation monitoring (e.g. in accordance with IMCA AODC 035, *Code of practice for the safe use of electricity under water*);

h) the umbilical termination should include an umbilical bend restrictor;

i) the umbilical junction plates should be easy to operate. Guidance, alignment, and orientation features should be provided to ensure correct coupler alignment and prevent coupler damage during connection and disconnection;

j) the umbilical and liftwire attachments should include a feature for safe disconnection of the umbilical and the liftwire from the ROT in case of intervention vessel drift-off.

5.6.3.4 Subsea Control System

The following recommendations apply:

a) the subsea intervention system may be operated by use of a subsea hydraulic power unit (HPU), either subsea tool-mounted or via a ROV;

b) the HPU installed should be mounted on a subframe isolated from the lifting frame by shock-absorbing elements (e.g. elastomer mounts);

c) all hydraulic components in the subsea intervention system should be compatible with the hydraulic fluid used in the surface control system;

d) the subsea intervention system should have provision for flushing of the hydraulic system;

e) all hydraulic lines and components should be sufficiently protected from overpressure (e.g. by adequate use of pressure-reducing or pressure-relief valves);

f) subsea electrical and electronic units should be properly protected. Atmospheric containers and/or oil filled pressure-compensated compartments should be used, where applicable;

g) alarm should be provided upon critical low pressure and reservoir levels in the hydraulic system.

When an ROV is used in an override or contingency function transfer (e.g. power and/or control through a hot stab connection), the following recommendations apply. Reference may also be made to recognized industry standards.

a) The transfer of fluid between the two systems should be based on fluid compatibility. Alternatively, a hydraulic motor/pump unit placed in the ROV skid should be considered to avoid interference of hydraulic fluid between the ROV system and the subsea intervention system.

b) When a ROV is docked on the subsea intervention system, the ROV should still be able to perform complementary work and monitoring tasks on ROV friendly accessible and viewable areas.

5.6.4 Control Systems Controlled via ROV Control System

ROV control systems may be used for control and monitoring of remotely operated tools within the following main categories:

a) hydraulic power supply from separate umbilical from surface and control signals from ROV;

b) hydraulic power and control signals supply from ROV.

6 ROV Interfaces

6.1 General

This subsection considers individual interfaces and their respective function, identifies the key required attributes, and provides the detail necessary to allow fabrication. When selecting an interface, reference should be made to the preceding sections of this RP.

Special attention should be given to the location of the interfaces relative to the ROV position during operation, and the need of space around the interface for easy access with the ROV manipulator or grabber (see annex A). Typical manipulator operating envelops can be found in Annex B.

It is recommended to verify all ROV interfaces with the actual equipment or a gauge with verified tolerances to avoid future interface clashes.

6.2 ROV Access Recommendations

6.2.1 ROV Dimensions

The following typical dimensions can be assumed for access validation of the various ROV classes to ensure operational flexibility.

— OBSROV: 2 m (length) × 1.5 m (width) × 1.5 m (height) (6.6 ft × 4.9 ft × 4.9 ft).

— Medium WROV: 3 m (length) × 2.5 m (width) × 2.5 m (height) (9.8 ft × 8.2 ft × 8.2 ft).

— Large WROV: 3.5 m (length) × 3 m (width) × 3 m (height) (11.5 ft × 9.8 ft × 9.8 ft).

If additional skids/tools are mounted to the ROV, the ROV size should be increased accordingly.

6.2.2 Elevation of ROV Interfaces

ROV interfaces should be elevated to a minimum level of 1.5 m (4.9 ft) above seabed to avoid interference due to seabed disturbance. Additional elevation may be required depending on seabed conditions and geographic regions.

6.3 Stabilization

6.3.1 General

A ROV is required to be stable during the carrying out of tasks, whether those tasks are manipulator or dedicated tooling tasks. This stabilization is achieved in a number of ways, including:

a) working platforms,

b) grabbing,

c) docking,

d) suction cups or feet.

6.3.2 Working Platforms

6.3.2.1 Function

If the task to be performed requires vertical or both vertical and horizontal access, the incorporation of a working platform into the subsea structure could be the best solution.

The working platform should be designed to accommodate loads from the ROV during landing and operation (thrustdown loads + ROV mass/weight).

6.3.2.2 Application

Working platforms may be formed by utilizing part of the subsea structure, such as protection covers, or specifically as a purpose-built platform.

6.3.2.3 Design

Platforms can be constructed of grating or may be of bar construction of sufficient area to support the ROV. Platforms for ROV use should be flush and free from obstruction.

6.3.3 Grabbing

6.3.3.1 Function

This provides a standard interface for an intervention system for station keeping during the execution of tasks. Grabbing may be by ROV manipulator arm with parallel or intermeshing jaw or a TDU configured similarly.

6.3.3.2 Application

An interface should be provided on all items of subsea production hardware to allow ROV stabilization during operations based upon grabbing.

6.3.3.3 Design

A grabber bar should be as shown in Figure 4. The grab bar should be designed to allow access to the whole working area at the specific equipment. The vertical part of the grabber bar should include mechanical stops every 0.5 m (20 in.) for avoiding unintentionally sliding of the ROV.

The grab bar should not be located close to sensitive equipment in order to avoid damage.

Grabbing intervention interfaces should be designed to withstand a minimum force of 2.2 kN (500 lbf) applied from any direction and a gripping force of 2.2 kN (500 lbf) applied from any direction.

6.3.3.4 Operation

Grabbing handles may be used as a docking interface or in conjunction with a docking interface. The handles may also be designed as bumper bars to provide protection to the interface panel.

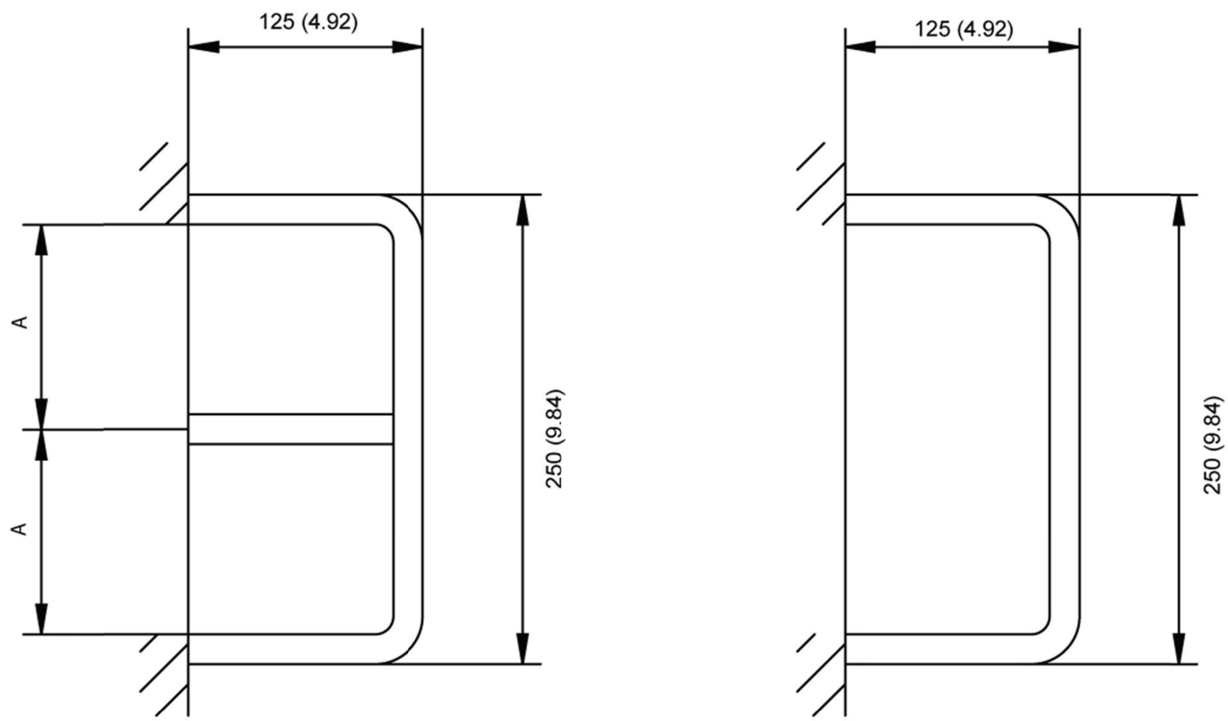
6.3.4 Docking

6.3.4.1 Function

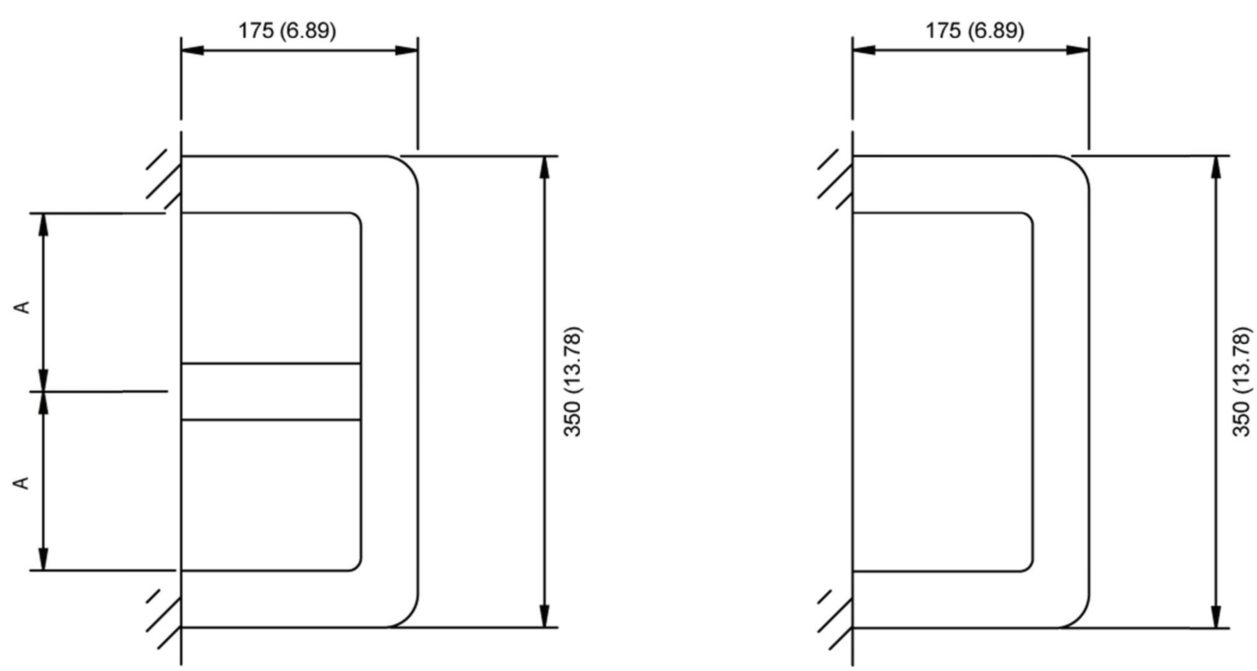
This RP interface provides an intervention system for station keeping and firmly attaches a ROV to an underwater structure in order to prevent ROV movement during the execution of tasks and provide a positive location for repeatability of tasks. The docking receptacle profile is shown in Figure 5.

Fail-safe mode for the docking probes should be defined in accordance with the application.

Dimensions in millimeters (inches)



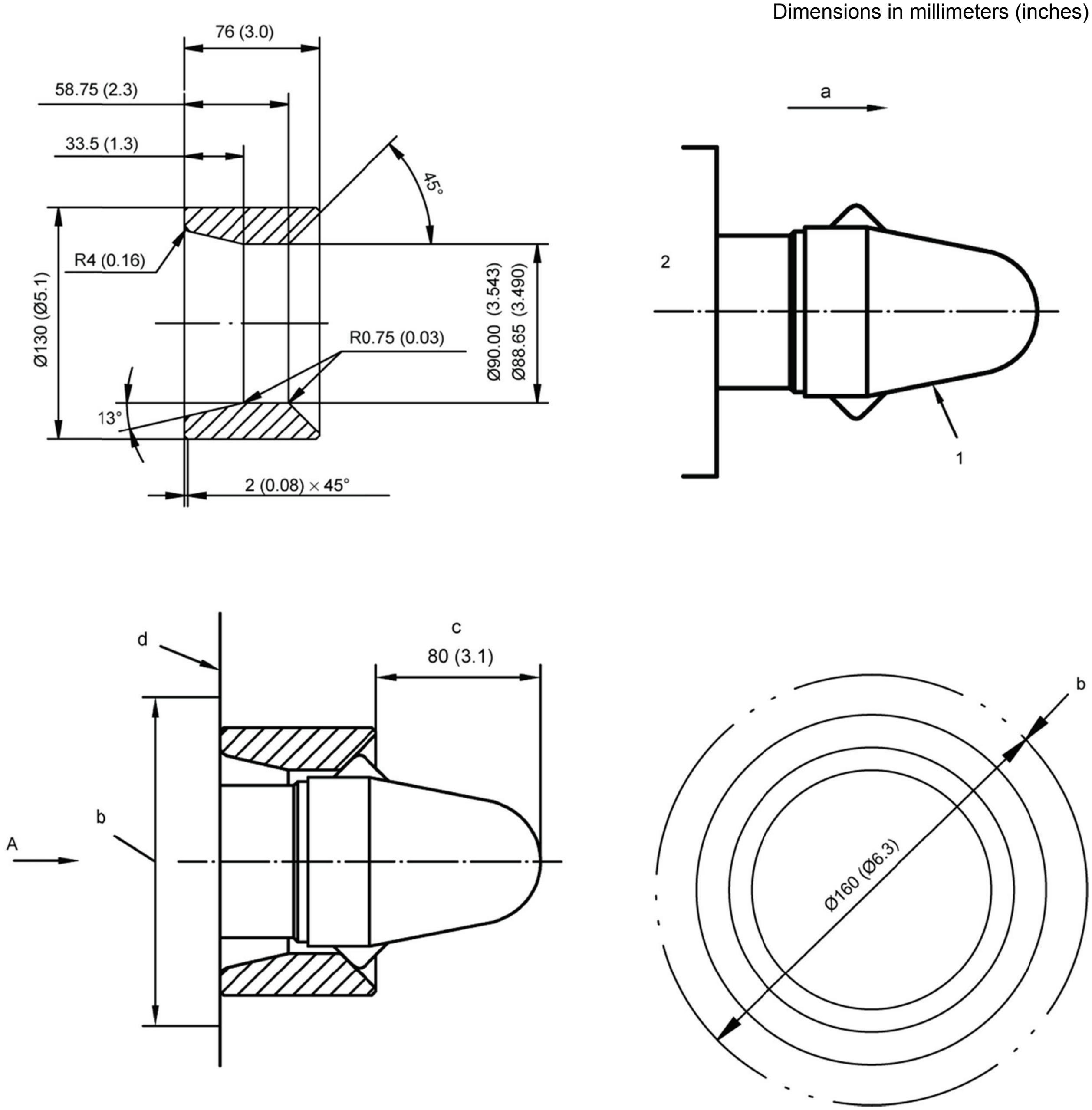
a) Type A: Bar Diameter = 19 mm (0.75 in.)



b) Type B: Bar Diameter = 51 mm (2 in.)

Figure 4—Grabbing Handle (Grabber Bar) for Stabilization

Dimensions in millimeters (inches)



Key

1 docking probe

2 ROV tooling

a direction of docking

b area to be free of obstruction

c clearance for probe

d docking face

Figure 5—Docking Probe and Receptacle

6.3.4.2 Application

Docking is to be used where the loading of the subsea equipment interface is not desirable, as in the case of the operation of needle valves or hot stabs, where heavier loads are being handled, as is the case of a flying lead stab plate connection, or where many interfaces are close together, as in a panel.

Generally, positive docking is used where the tooling configuration is to be operated by a single- or twin-docking TDU, but is also used to provide positive stabilization during manipulator operations. A docking receptacle is used in conjunction with a docking probe mounted on the ROV. The docking probe is typically a hydraulically operated device with fail-safe release and overload limitation features.

The docking receptacles are incorporated into the structure of the subsea equipment and may be positioned with either a horizontal or vertical axis. The receptacle may be a separate bolted or weld-in unit or can be incorporated as part of the subsea equipment.

Docking receptacles may be used singly, in pairs or in other combinations. The docking receptacles allow the ROV to dock and deploy tooling in configurations to suit particular applications. Figure 6 shows a vertical face twin probe docking layout complete with recommended positional tolerances. Figure 7 shows a vertical face single probe docking layout complete with recommended positional tolerances. This layout is representative of those used for valve operation or override on subsea trees. The tooling envelope shown illustrates a standard area into which tooling interfaces may be fitted, in order to be reached by the tooling system or manipulator arm.

6.3.4.3 Design

The docking receptacle shown in Figure 5 can be used this application.

When incorporating a docking receptacle into a subsea structure, it is recommended that as a minimum the support structure be designed to withstand the forces and moments shown in Figure 8. These values are based upon a typical WROV docking and docked to the receptacle, using the parameters given in Table 1.

For any designed system, the engineer should assess the specific requirements and adjust the values if necessary. Figure 6 and Figure 7 show recommended minimum areas around the receptacles that are to be kept clean in order to allow docking probe access. In general, placing receptacles within a flat plate area rather than in an isolated position greatly aids ROV docking.

The docking receptacle should be manufactured from a material with a minimum tensile strength of 450 MPa (65,300 psi), but the engineer is free to specify other materials where different load conditions exist.

Protection from marine growth and corrosion will be necessary in most environments, and consideration should be given to the use of corrosion resistant materials or appropriate coatings.

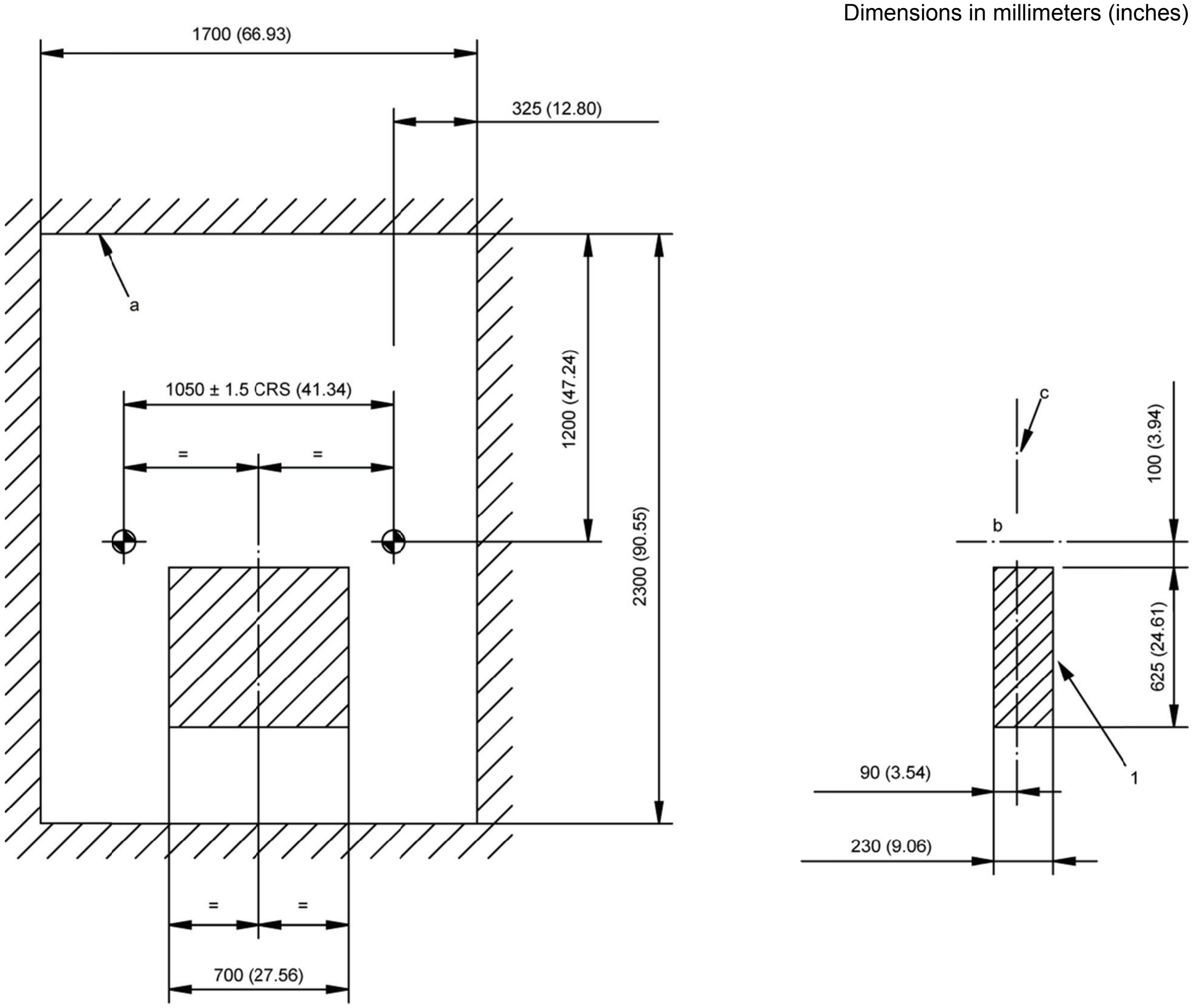
The means of attaching the docking receptacle is optional.

Table 1—Typical Docking Parameters

Docking velocity	0.82 ft/s (0.25 m/s)
Lateral current (whilst docked)	8.2 ft/s (2.5 m/s)
ROV thrust (whilst docked)	100 % full

NOTE The ROV impact load: Based on ROV mass m = 3000 kg, velocity v = 0.25 m/s, the energy from ROV impact is 93.75 J ($E = 1/2\ mv^2$), which can be used for impact analyses.

Dimensions in millimeters (inches)



Key

1 torque tool

a recommended clearance area for access to and allowance for cameras, support brackets, etc.

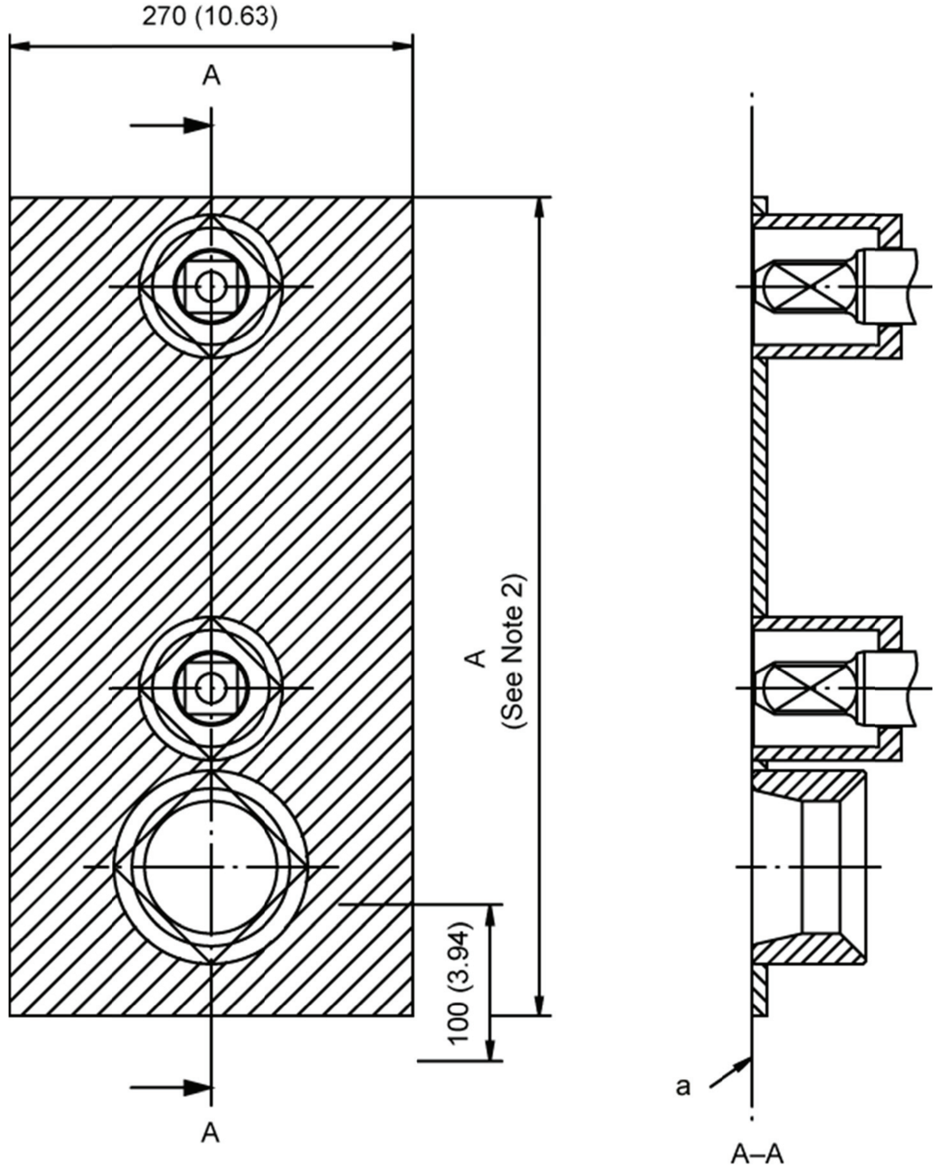
b center line of docking probes

c docking face

NOTE Penetration envelope into a structure is typically in the range of 140 mm (5.5 in.). Specific tooling can be made for greater depths of penetration.

Figure 6—Typical Tooling Envelope for Twin-docking TDU

Dimensions in millimeters (inches)



Key

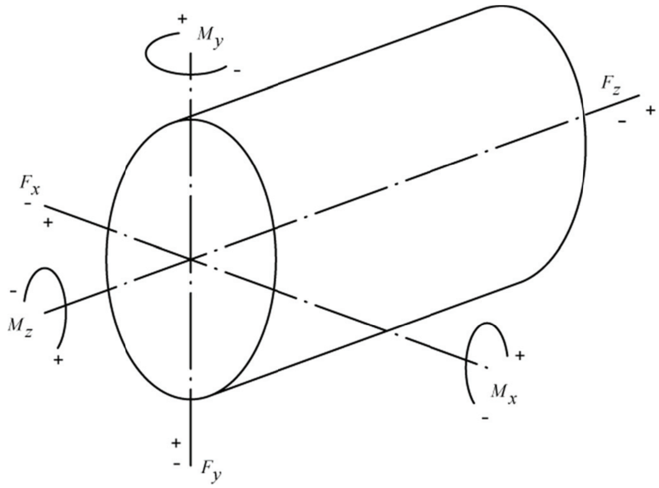
a docking face

NOTE 1 Area shown shaded to be kept flat and free from obstructions.

NOTE 2 Dimension A is normally in the range 350 mm (13.78 in.) to 550 mm (21.65 in.), depending on the tooling requirement.

NOTE 3 Features shown in the figure other than receptacle location and envelope are for reference only.

Figure 7—Typical Tooling Envelope for Single-docking TDU



M_x	±4,425 ft-lb (6,000 Nm)	F_x	±1,124 lbf (5,000 N)
M_y	±4,425 ft-lb (6,000 Nm)	F_y	±1,124 lbf (5,000 N)
M_z	—	F_z	±1,124 lbf (5,000 N)

Figure 8—Docking Receptacle Loading

6.3.4.4 Operation

The ROV approaches the docking location and free flies the docking probe or probes into the docking receptacle or receptacles. The probe is then actuated by the ROV, locking the dogs behind the rear profile pulling the probe flange against the docking face.

6.3.5 Suction Cups or Feet

6.3.5.1 Function

Suction cups or feet consist of an arm attached to the ROV with a suction cup on the end in contact with the structure that is activated by the ROV, in order for the vehicle to maintain its position relative to the interface.

6.3.5.2 Application

Suction cups or feet may be used when carrying out unplanned manipulative operations.

6.3.5.3 Design

The interface requirement of the subsea structure is a flat surface adjacent to the task area for the suction cup and within the grabber arm range.

6.4 Handles for Use with Manipulators

6.4.1 Function

This interface provides means for ROV operations involving subsea equipment requiring linear or rotary action or both.

6.4.2 Application

The handles are used in conjunction with a ROV manipulator, or purpose-built tooling, to allow direct operation of the interface or device.

6.4.3 Design

The interface consists of a T-bar, D-ring, or X-bar (fishtail) arrangement attached to the equipment to be operated. This handle is grasped in the jaws of a manipulator or a purpose-designed tooling receptacle (see Figure 9). The snagging potential of the T-bar should be considered when selecting an interface configuration.

Due consideration should be given to the maximum forces that will be applied during operation. To reduce or avoid load transfer from the ROV to the equipment, it is recommended to have a compliant section mounted between the handle and the tool.

For rotary applications, the stem should be capable of resisting the maximum torque that will be generated during its operation where the risk of damage to equipment may occur when using a manipulator. Wherever possible, end stops should be built into the equipment to prevent overstressing of the handle stem, which should resist the maximum forces that are considered to be generated when operating the equipment in the worst conditions.

The type of handle should be standardized for the entire subsea system and compatible with the same manipulator end effector.

6.4.4 Operation

The handles are operated by locating them directly in the jaws of a manipulator (see Figure 9) or by securing them in a purpose built tooling receptacle such as a TDU fitted with a torque tool (see Figure 10).

Attention should be given to providing markings indicating the direction of travel in which a handle will move in order to reduce the chance of attempted operation against the limit of travel and subsequent travel damage to the handle bar itself.

6.5 Rotary (Low-torque) Interface

6.5.1 Function

This interface provides for the ROV operation of subsea equipment requiring a rotary action.

6.5.2 Application

The interface is used in conjunction with a ROV mounted torque tool for the operation of subsea needle valves and other low-torque function.

6.5.3 Design

The rotary low-torque interface (see Figure 11) consists of a bar or paddle enclosed in a tubular housing. Not all of the designs incorporate physical stops. When designing this interface, physical stops should be considered to prevent damage to equipment.

The interface is generally mounted with the drive stem horizontal but may be mounted vertically, if required.

The interface receptacle may be incorporated into a panel by bolting or welding or may be free-standing or made as part of the subsea equipment. In the case of panel mounting, the panel should be flush with the docking face.

Due consideration should be given to the maximum forces that will be applied during operation. To reduce or avoid load transfer from the ROV to the equipment, it is recommended to have a compliant section mounted between the handle and the tool.

The stem should be capable of resisting the maximum torque that will be generated during its operation where the risk of damage to equipment may occur when using a manipulator. Wherever possible, end stops should be built into the equipment to prevent overstressing of the handle stem, which should resist the maximum forces that are considered to be generated when operating the equipment in the worst conditions.

The interface flange should be designed to withstand 258 ft-lb (350 Nm) torque, bending force of 738 ft-lb (1000 Nm), and an axial force of 450 lbf (2000 N) in order to operate at the specified torques.

Protection from marine growth and corrosion will be necessary in most environments, and consideration should be given to the use of corrosion resistant materials or appropriate coatings.

The interface is approached by the ROV tool along the drive stem axis and therefore access is required in this area.

6.5.4 Operation

The ROV mounted torque tool is presented to the interface along its axis, orientated to engage the tool drive adapter on the T-bar or paddle. Once fully engaged, the tool can provide continuous rotation in either direction with all torque reacted by the ROV deployment system. This interface has no built-in guidance for assisting engagement.

6.6 Rotary Docking

6.6.1 Function

This provides docking, torque reaction, alignment, and socket mating for ROV deployed rotary tools.

6.6.2 Application

The receptacle is commonly fitted to valve panels on subsea equipment (e.g. trees, manifolds, control modules, and templates), and is suitable for any operation requiring a rotary override (see Table 2). Alternative designs for end effectors can be found in Annex C.

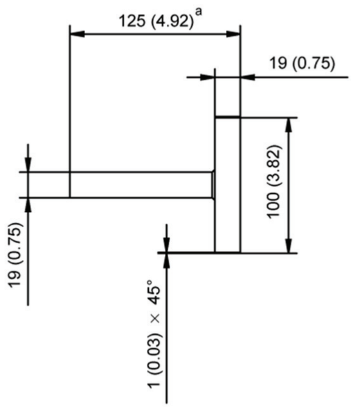
6.6.3 Design

The interface shown in Figure 12 consists of a tubular housing with a top mounting plate. The mounting plate contains two torque reaction slots located 180° apart. The base of the tubular housing is machined to accept a shaft bearing. The size of the machined hole and support bearing will vary according to the receptacle class (see Table 3).

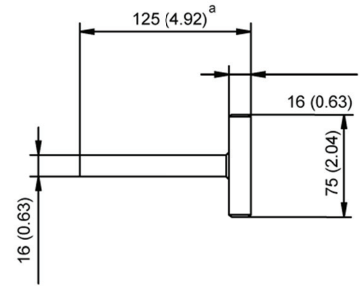
6.6.4 Design Recommendations

The receptacle is generally mounted with the drive stem horizontal, but may be mounted vertically, if required.

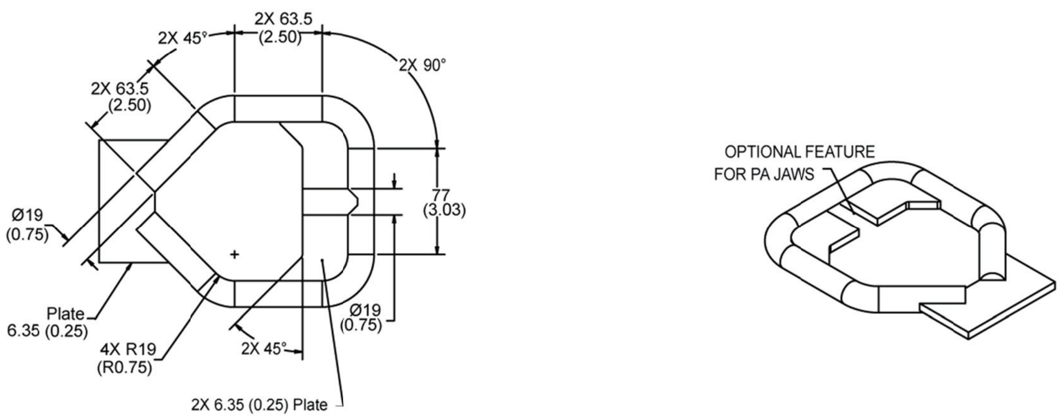
Dimensions in millimeters (inches)



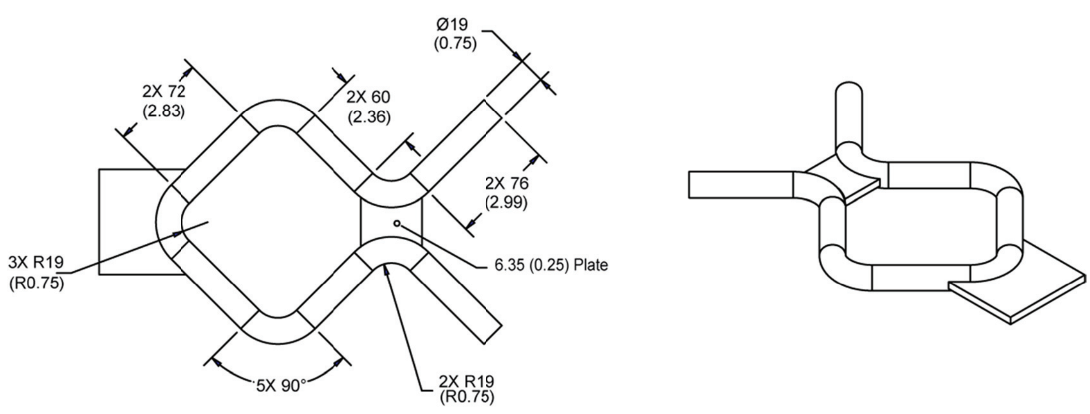
Type 1



Type 2



Type 3



Type 4

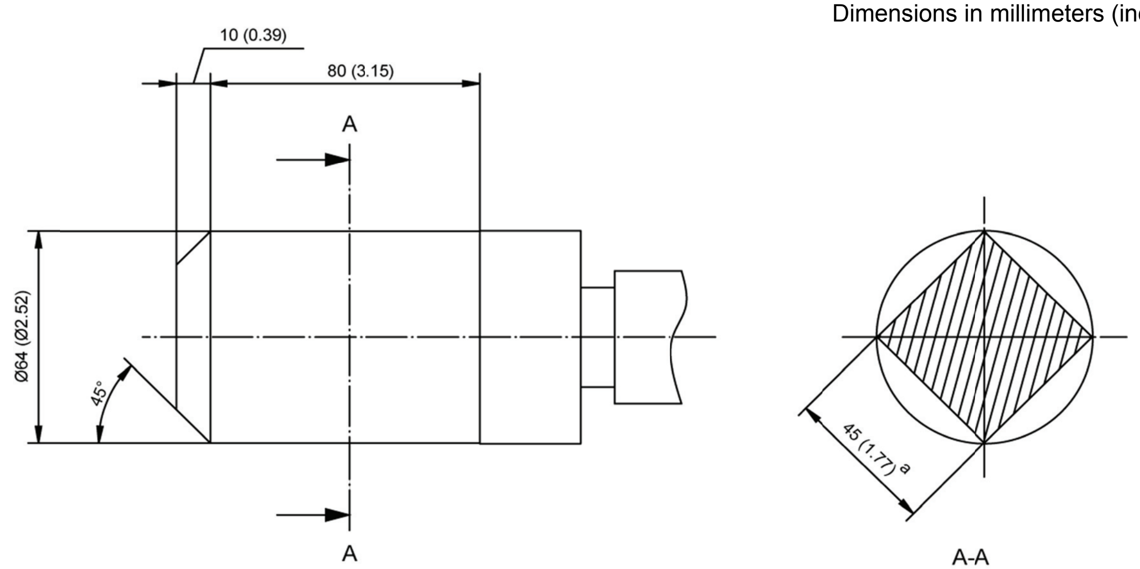
Key

1 large T- handle (NOTE snag potential)
2 small T-handle (NOTE snag potential)
3 D- ring handle [bar diameter = 19 mm (0.75 in.)]
4 X-bar (fishtail) handle [bar diameter = 51 mm (2 in.)]
a clear area for manipulator

Material strength = 450 N/mm^2 (65 kip/in.^{2}).

Figure 9—Handles for Use with Manipulators

Dimensions in millimeters (inches)



Key

a across flats

Figure 10—Handle for Use with TDU

If the tool is being deployed by a manipulator or a TDU, it is possible to position the receptacle in any orientation to suit the range of the manipulator. The receptacles are normally manufactured from a low carbon steel with minimum yield stress of 250 MPa (36,0000 psi) and protected by an epoxy paint system. Where protection from debris and the long-term buildup of hard marine growth is required, this should be by the use of receptacle covers.

6.6.5 Operation

The torque tool will normally be centrally mounted on the lower front frame of the ROV (single point docking).

The ROV will present the tool to the receptacle interface. With the tool fully mated the drive stem can be operated as required by the torque tool. All generated torque is reacted within the tool receptacle.

NOTE The receptacle design is also suitable for the manipulator deployment of tools. The choice of deployment method can be made as needed to suit the specific interface layout.

6.7 Linear (Push) Interfaces, Type A and Type C

6.7.1 Function

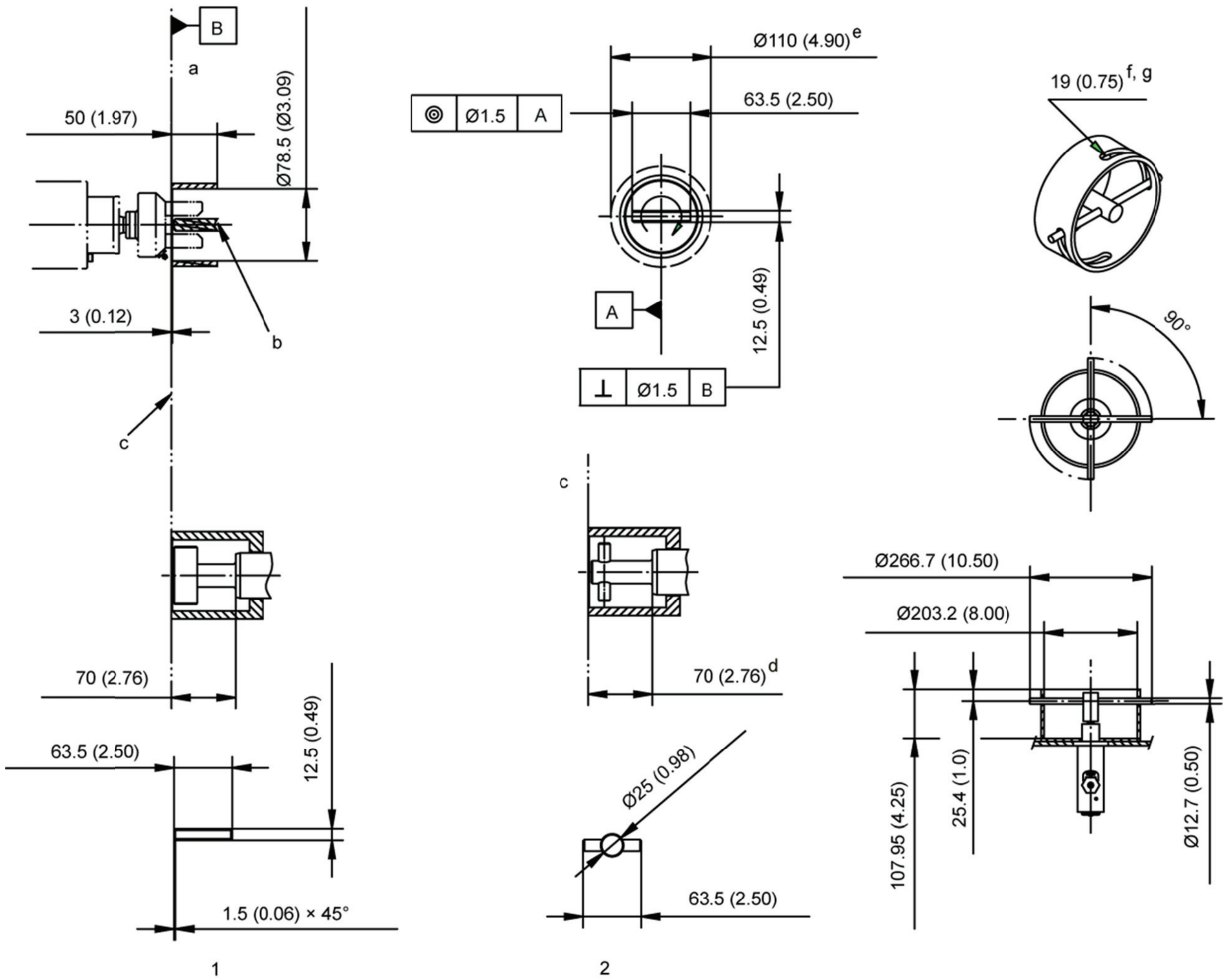
This standard interface provides for the ROV operation of subsea equipment requiring a push action.

6.7.2 Application

It is used in conjunction with a ROV mounted tool, primarily for the override of hydraulic gate valves allowing ROV opening of the valve after fail-safe closure. In this application the interface is usually incorporated as part of the valve actuator and can be operated with the valve under pressure.

The interface may, of course, be incorporated into any piece of underwater hardware requiring a push action of this type and magnitude.

Dimensions in millimeters (inches)



a) Type A   b) Type B   c) Type C

Key

1 flat paddle style (Type A)

2 T-bar handle (Type B)

a depth for tool access

b rotary valve handle can be T-bar or flat paddle style

c docking face

d tooling receptacle with T-bar handle

e tool diameter

f full radial slot

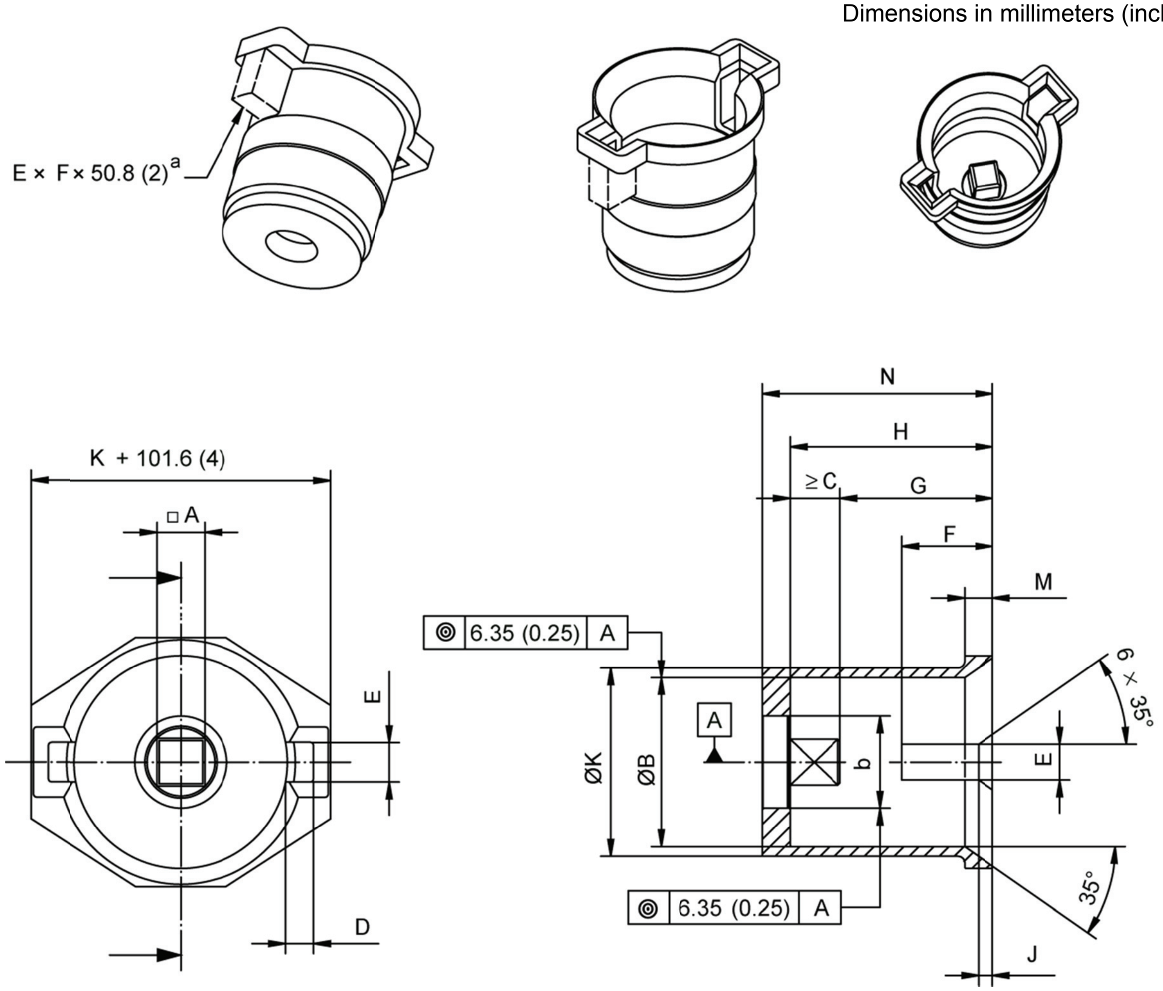
g 2 ×180° apart

To avoid damage to the valve handle, it is important that the top operating end be maintained within the receptacle.

Maximum torque rating = 75 Nm (663.8 lbf-in.).

Figure 11—Low-torque Receptacle

Dimensions in millimeters (inches)



Key

a clearance both ends

b see Note 1 in Table 3

Figure 12—Rotary Torque Receptacle

Table 2—Rotary Actuator Intervention Fixture Classification

Class	Maximum. Design Torque N·m (lbf·ft)
1	67 (50)
2	271 (200)
3	1,355 (1,000)
4	2,711 (2,000)
5	6,779 (5,000)
6	13,558 (10,000)
7	33,895 (25,000)

Table 3—Dimensions for Receptacle Classes 1 to 7 (See Figure 12)

Dimensions in millimeters (inches)

Dimension	Class						
	1	2	3	4	5	6	7
A square	17.50 (0.687)	17.50 (0.687)	28.60 (1.125)	38.10 (1.50)	50.80 (2.00)	66.67 (2.625)	88.90 (3.50)
B	154.0 (6.06)	154.0 (6.06)	154.0 (6.06)	154.0 (6.06)	190.5 (7.50)	243.0 (9.56)	243.0 (9.56)
C min.	41.0 (1.62)	41.0 (1.62)	41.0 (1.62)	41.0 (1.62)	63.5 (2.50)	89.0 (3.50)	89.0 (3.50)
D	38.0 (1.50)	38.0 (1.50)	38.0 (1.50)	38.0 (1.50)	57.0 (2.25)	82.25 (3.25)	82.25 (3.25)
E	32.0 (1.25)	32.0 (1.25)	32.0 (1.25)	32.0 (1.25)	38.0 (1.50)	44.5 (1.75)	44.5 (1.75)
F	82.5 (3.25)	82.5 (3.25)	82.5 (3.25)	82.5 (3.25)	127.0 (5.00)	178.0 (7.00)	178.0 (7.00)
G min. G max.	140.0 (5.51) 146.0 (5.75)	140.0 (5.51) 146.0 (5.75)	140.0 (5.51) 146.0 (5.75)	140.0 (5.51) 146.0 (5.75)	140.0 (5.51) 146.0 (5.75)	222.0 (8.75) 228.0 (9.00)	435.0 (17.13) 441.0 (17.38)
H	181.0 (7.12)	181.0 (7.12)	181.0 (7.12)	181.0 (7.12)	206.0 (8.12)	—	—
J	12.7 (0.50)	12.7 (0.50)	12.7 (0.50)	12.7 (0.50)	—	—	—
K min.	168.5 (6.63)	168.5 (6.63)	168.5 (6.63)	168.5 (6.63)	—	—	—
M	25.4 (1.00)	25.4 (1.00)	25.4 (1.00)	25.4 (1.00)	—	—	—
N	194.0 (7.63)	194.0 (7.63)	194.0 (7.63)	194.0 (7.63)	—	—	—

As an alternative to dimension A, end effector shapes as found in Annex D for the appropriate torque range may be used.

All dimension tolerances are as follows:

0.x ± 0.5 (0.020)

0.xx ± 0.25 (0.010)

C: $^{+127}_{\ \ 0} \left(^{+0.05}_{\ \ 0}\right)$

NOTE 1 Chamfer on the end of the end effector profile is 45° × 1.65 (0.06) maximum.

NOTE 2 Clearance behind antirotation slots [E × F × 50.8 (2)] is to allow for locking feature option provided by some tools.

NOTE 3 All dimensions to be "as-built/Installed" dimensions, including actual coating.

NOTE 4 Dimension M is both flange thickness and chamfer lead-in.

6.7.3 Design

The interface [see Figure 13 (Type A) and Figure 14 (Type C)] consists of an interrupted flange around a central stem. The flange allows a ROV mounted tool to be engaged upon the interface using a "push and turn" action. The central stem can then be driven into the interface while the force produced is reacted at the flange.

The interface can be mounted in either the horizontal or vertical plane.

The maximum push force specified for Type A and Type C is based upon the force required to open gate valves at full differential pressure in most subsea applications.

The interface flange should be manufactured from material with a minimum tensile strength of 450 MPa (65,300 psi) in order to operate at the above loads, but the engineer is free to specify other materials where different load conditions exist.

Protection from marine growth and corrosion will be necessary in most environments, and consideration should be given to the use of corrosion-resistant materials or appropriate coatings.

The interface is approached by the ROV tool along the stem axis; access is therefore required in this area. In addition, a clear space around the interface is required, as shown for the tool diameter.

6.7.4 Operation

The ROV mounted tool is presented to the interface along its axis in an orientation allowing it to engage in the slots of the flange. The tool is then rotated 45° clockwise to lock behind the flange. Once in this position the central stem is acted upon by the tool actuator. The tool may then be released by the ROV, if required, leaving it engaged on the interface, holding the "pushed" position.

Release of the tool requires the release of the force within the tool holding the stem, followed by a 45º rotation anticlockwise allowing it to be withdrawn from the interface. In the case of hydraulic gate valve overrides, the internal fail-safe spring in the valve actuator returns the stem to the original position.

Linear push devices can be operated by manipulator or by TDU. It is important to check the stroke on the TDU to ensure sufficient clearance to fully make up the linear push device, and subsequently remove it. The top of the interface should be located not more than 25 mm (1 in.) below the panel face.

6.8 Linear (Push) Interface, Type B

6.8.1 Function

This standard interface provides for the ROV operation of subsea equipment requiring a push action.

6.8.2 Application

It is used in conjunction with a ROV mounted tool, primarily for the override of hydraulic gate valves allowing ROV opening of the valve after fail-safe closure. In this application the interface is usually incorporated as part of the valve actuator and can be operated with the valve under pressure.

The interface may, of course, be incorporated into any piece of underwater hardware requiring a push action of this type and magnitude.

6.8.3 Design

The interface (see Figure 15) consists of a flange around a central stem. The flange allows a ROV mounted tool to be engaged upon the interface using a "hook-over" action. The central stem can then be driven into the interface whilst the force produced is reacted at the flange.

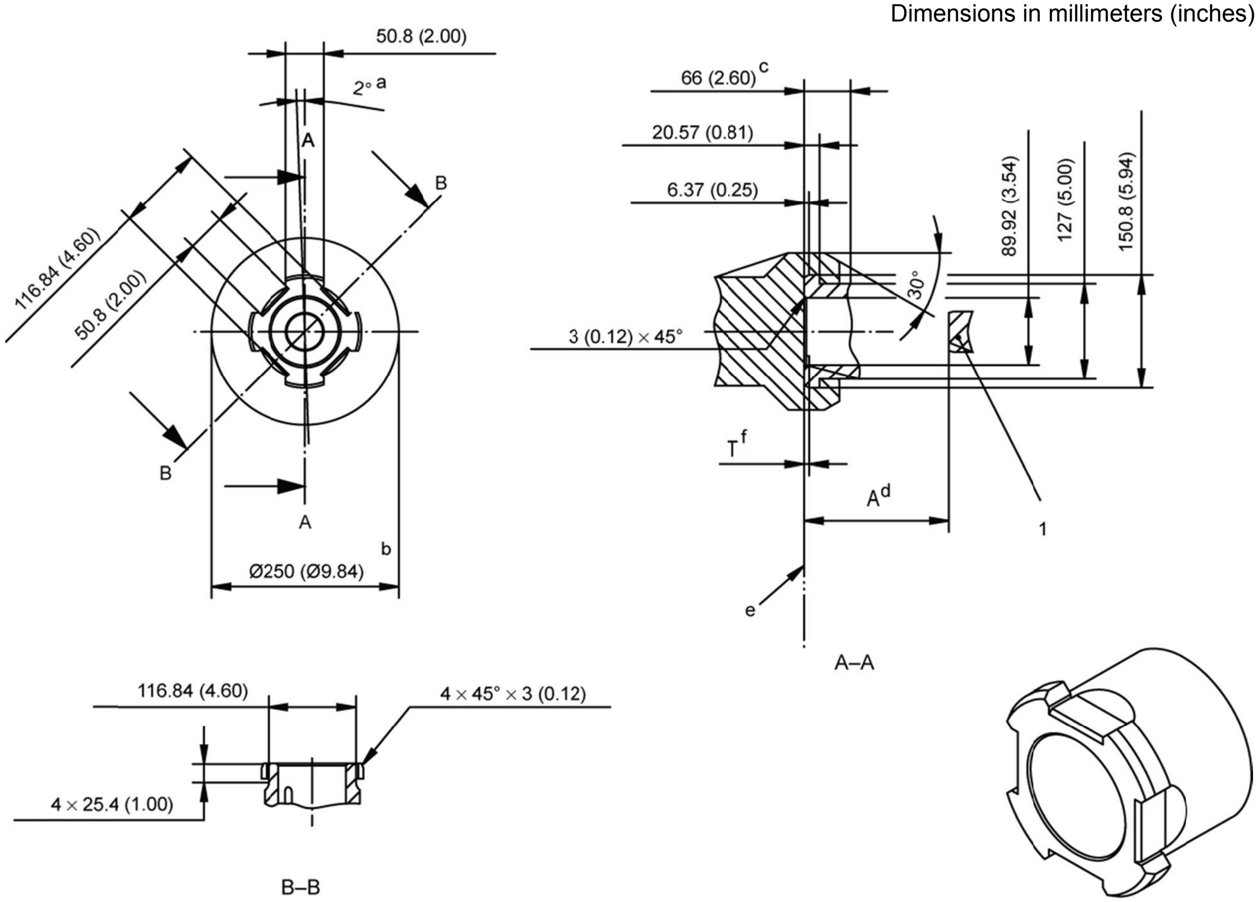
The interface can to be mounted in either the horizontal or vertical plane.

The interface flange should be manufactured from material with a minimum tensile strength of 450 MPa (65,300 psi) so that it can operate at the specified loads, but the engineer is free to specify other materials where different load conditions exist.

Protection from marine growth and corrosion will be necessary in most environments and consideration should be given to the use of corrosion resistant materials or appropriate coatings.

The interface is approached by the ROV tool along the stem axis. ROV tooling access is required in this area. In addition, a clear space around the interface, and adjacent interfaces requiring locking tools in place in both positions, is required, as shown in Figure 15, for the tool diameter and engagement.

Dimensions in millimeters (inches)



Key

1 valve stem

a angular tolerance

b minimum clearance

c minimum clearance allowing tool engagement

d dimension A depends upon tool stroke

e docking face (tool interface)

f dimension T = 5 min

Nominal linear force exerted by tool = 745 kN (167.5 klbf).

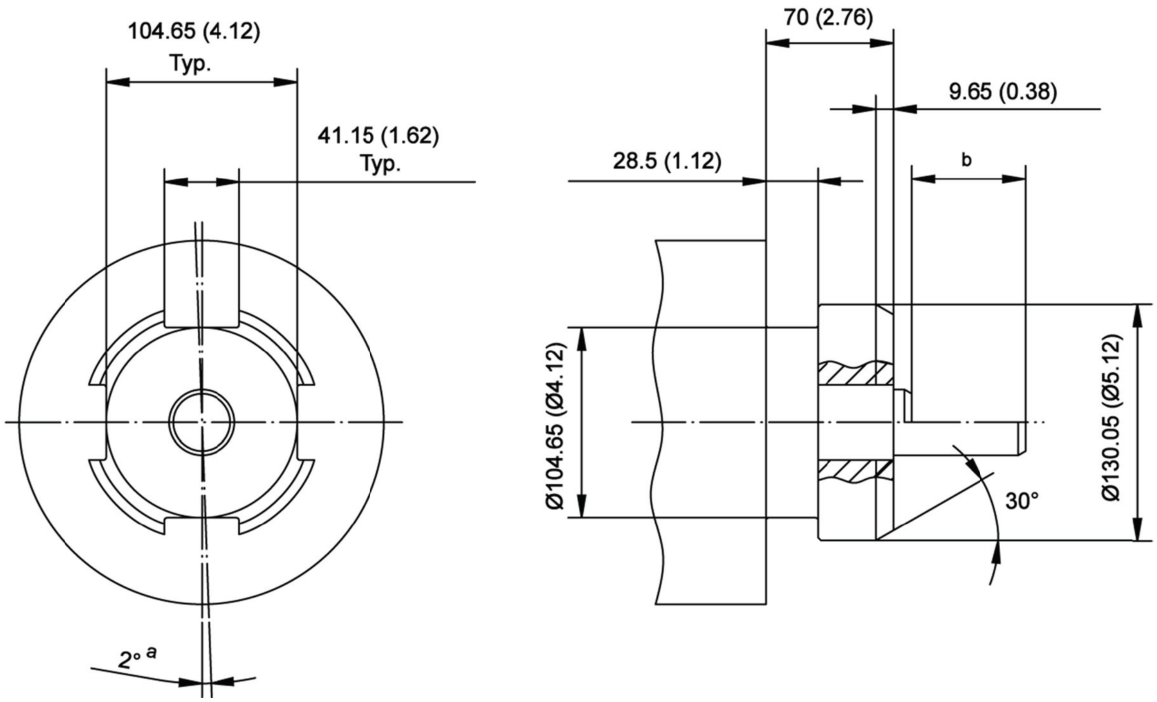
Figure 13—Linear Push Interface Type A

6.8.4 Operation

The ROV mounted tool is presented to the interface by hooking it over the flange. Clearance is therefore required above and in front of the interface as shown in Figure 14. Once in this position, the central stem is acted upon by the tool actuator stroking it forward and reacting the force at the flange. The tool may then be released by the ROV, if required, leaving it engaged on the interface and holding the “pushed” position.

Release of the tool requires firstly the release of the force within the tool holding the stem, allowing the internal fail-safe spring in the valve actuator to return the stem to the original position. The tool is then unhooked and removed.

Dimensions in millimeters (inches)



Key

a angular tolerance

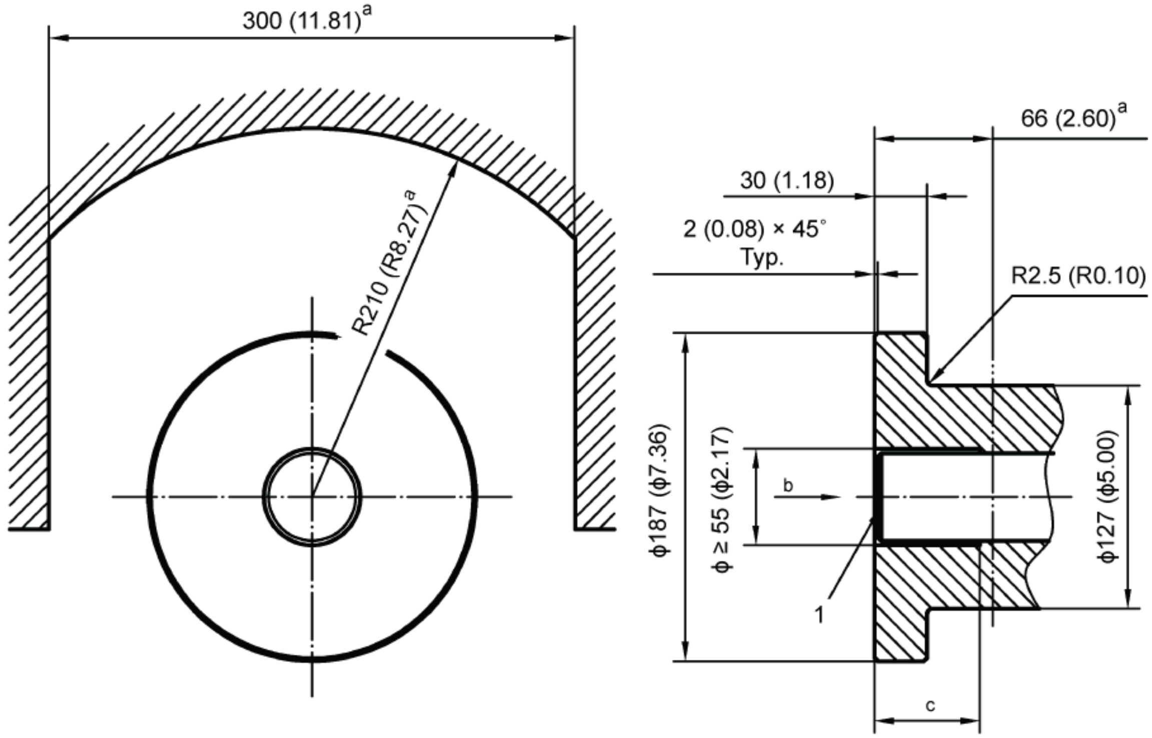
b valve stroke

Nominal linear force exerted by tool = 745 kN (167.5 klbf).

Figure 14—Linear Push Interface Type C

Linear push devices can be operated by manipulator or by TDU. It is important to check the stroke on the TDU to ensure sufficient clearance to fully make up the linear push device, and subsequently remove it. The top of the interface should be located not more than 25 mm (1 in.) below the panel face.

Dimensions in millimeters (inches)



Key

1 valve override stem

a minimum clearance required for tool engagement

b axial force

c valve stroke = 5 mm (0.2 in.)

Maximum linear force exerted by tool = 745 kN (167.5 klbf).

Figure 15—Linear Push Interface Type B

6.9 Hot Stab Hydraulic Connections

6.9.1 Function

The hot stab is a means of making a temporary hydraulic or gas connection to a remote piece of subsea equipment using the ROV as the means of delivery and possibly supply of the fluid.

6.9.2 Application

Hot stabs are normally used to:

a) override existing systems,

b) complement systems such as lower riser packages with locking and unlocking functions,

c) hydraulically activate valves and tools,

d) hydrotesting and pigging,

e) test seals and connections,

f) dewatering of enclosed spaces,

g) flushing of subsea components.

6.9.3 Design

The hot stab design is based upon a section of mandrel being inserted into a pressure balanced receptacle with matching ports, allowing pressurization between the two isolated sections separated by seals.

Sufficient space should be provided around the stab receptacle in order to provide full engagement without clashes.

6.9.4 Design Recommendations

The hot stab receptacle should be designed such that it does not fill with debris while not in use. Debris ingress can be avoided by location, orientation, protection and/or use of a 'blind stab' (sometimes referred to as a blank, blanking plug, blank male stab or passive blank).

The blind stab is removed prior to the insertion of a hot stab. When blind stabs are not inserted into hot stab receptacles, they can be stored in a parking receptacle. All blind stabs should be tethered to the subsea structure so that they are not dropped or lost during subsea operations.

Blind stabs can be of a sealing or non-sealing type depending on the application. Non-sealing blind stabs are generally used for short term blanking applications such as painting, shipping, transportation and, installation. Sealing blind stabs are generally used for the following applications:

a) keep debris and marine growth out of the hot stab receptacle,

b) trap and retain fluid and prevent any further seawater from entering the hydraulic circuit or test port,

c) provide a secondary (elastomeric) pressure barrier to the environment.

Integrated check valves may be used on hydraulic ports to minimize possible water ingress and contamination of fluid system. Hot stabs used in text port applications commonly used an ROV operable isolation valve (needle valve or ball valve) which can be used to provide a hydraulic lock on the hydraulic circuit and prevent seawater ingress.

The hot stab may feature an optional flexible joint between the handle and the stab body to assist manipulator access during insertion or retrieval.

The hot stab receptacle can be mounted prone or flush with an interface panel, but should not be recessed. Appropriate clearance should be provided to allow the mating hot stab to engage the receptacle. Clearance space behind the receptacle should be provided to allow hot stabs from various vendors to interface with the receptacle.

6.9.5 Operations

Hot stabs may be operated by manipulator or by TDU. It is important to check the stroke on the TDU to ensure sufficient clearance to fully make up the hot stab, and subsequently remove it.

A lanyard (or leash) may be attached to the blind stab which connects the blind stab to the subsea structure with a short rope or wire. The purpose of the lanyard is to prevent the blind stab from being dropped or lost during subsea operations.

Parking receptacles may be provided to store Blind stabs when they are not inserted into the hot stab receptacle.

6.9.6 Materials in Design

It is important that the design of the hot stab system ensure that the female part of the stab remains undamaged during the installation and continued use of the male stab. The material selection should also depend upon the intended use of the stab. A once or twice in a lifetime usage of the stab system (e.g. during pile sleeve grouting) might require a lower specification than a frequently used intervention stab.

6.9.7 Hot Stab Hydraulic Connection, Type A

This hot stab connection is a two port taper design. Interface dimensions and features are included in Figure 16 and Figure 17.

All seal bore data shall be toleranced from the face of the coupling to 0.3 mm (0.01 in.). Porting into the bore shall not come within 2 mm (0.08 in.) of the seal groove. Porting diameters are defined by user requirements. Porting locations other than interface location defined in Figure 16 and Figure 17 are defined by user requirements.

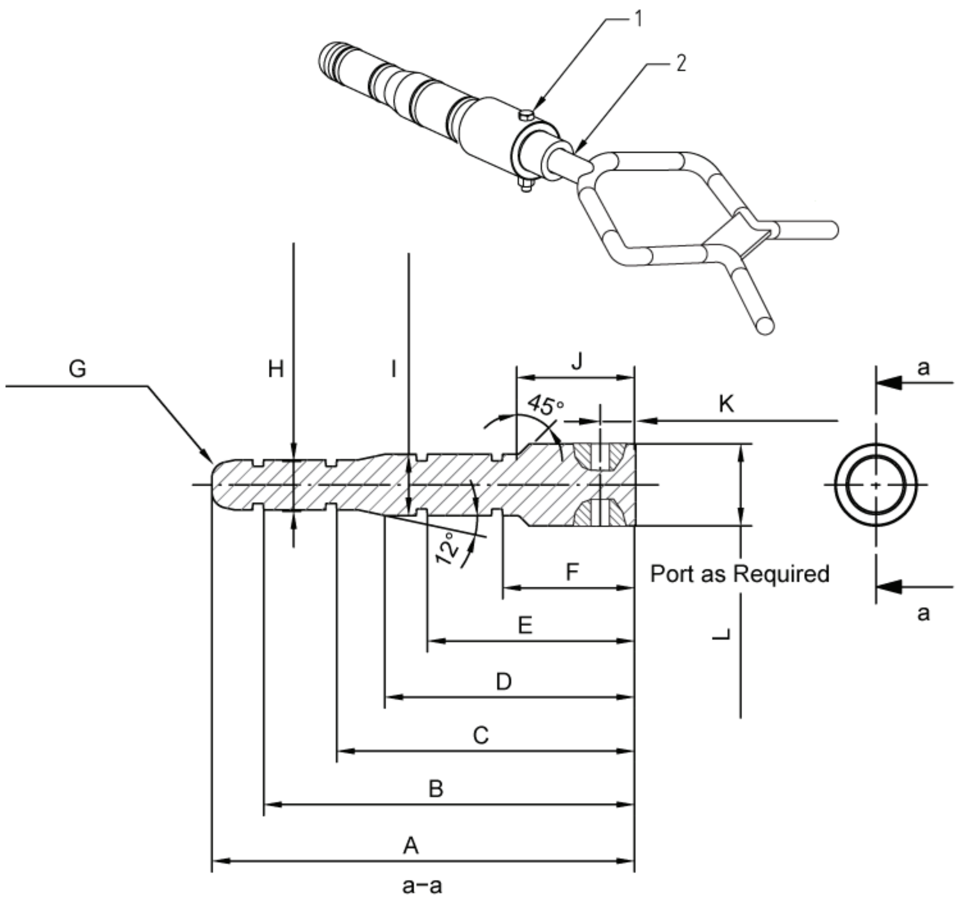
6.9.8 Hot Stab Hydraulic Connection, Type B

This hot stab connection includes the ability to have multiple ports by repeating certain dimensions utilizing a common seal bore. Interface dimensions and features are included in Figure 18 and Figure 19. Hydraulic porting connection type and dimensions are defined by port diameter, pressure rating, and user requirements. Porting locations other than interface location defined in Figure 18 and Figure 19 are defined by user requirements.

NOTE Hot stabs built to these dimensions are not intended to fit or operate properly in older API 17D, First Edition receptacles. Dimensions for the older API 17D hot stab can be found in the first edition of API 17D.

6.9.9 Hot Stab Hydraulic Connection, Type C

This hot stab connection is a large bore connection intended for applications which require larger flow rates such as subsea BOP hydraulic control and flushing operations. Hydraulic porting connection type and dimensions are defined by port diameter, pressure rating, and user requirements. The design of this hot stab connection should include a stab locking mechanism to prevent inadvertent disengagement of male hot stab. Porting locations other than defined interface locations are defined by user requirements. Interface dimensions and features are included in Figure 20 and Figure 21.



Dimensions in millimeters (inches)

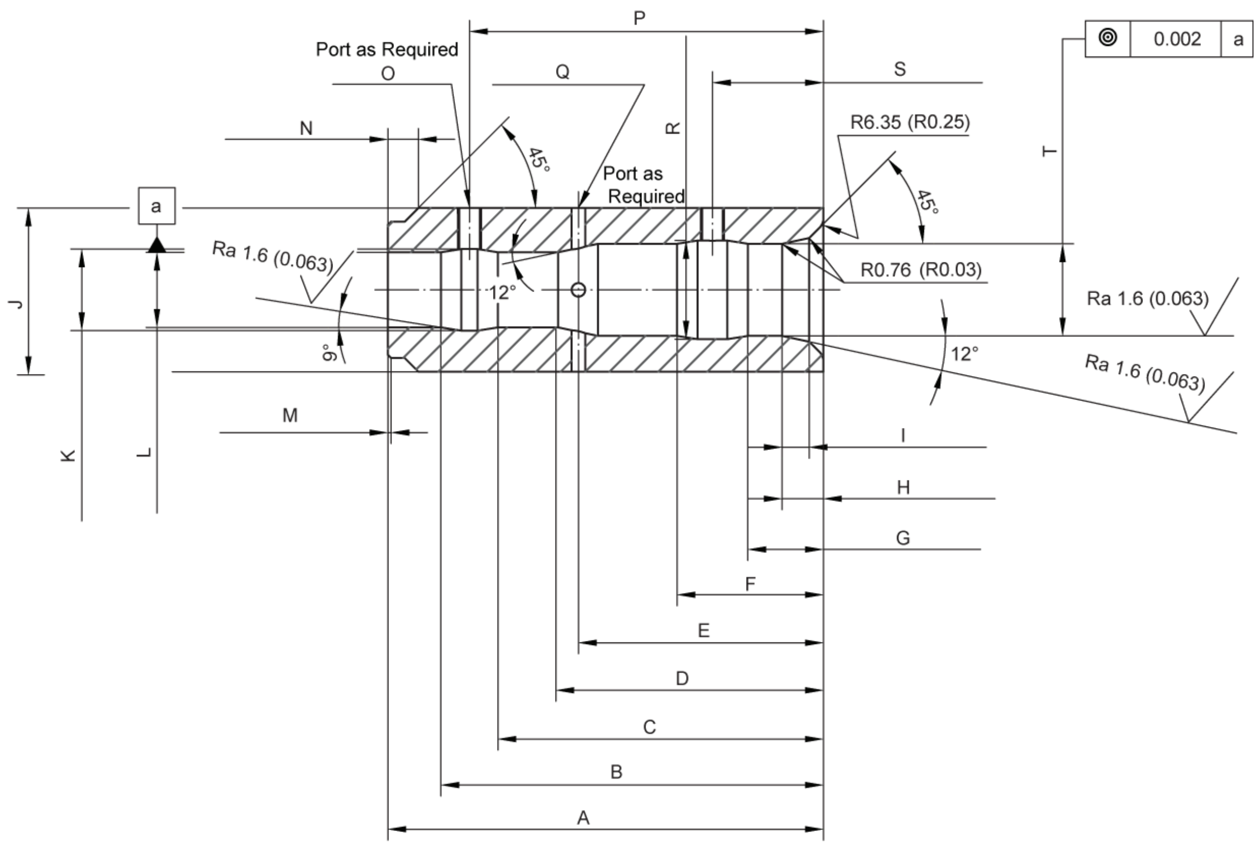
A	B	C	D	E	F	G	H	I	J	K	L
296.46 (11.63)	259.59 (10.22)	208.79 (8.22)	174.75 (6.88)	145.54 (5.73)	92.96 (3.66)	92.96 (3.66)	Ø34.82/ Ø34.85 (Ø1.371/ Ø1.372)	Ø42.77/ Ø42.80 (Ø1.684/ Ø1.685)	81.53 (3.21)	25.40 (1.00)	Ø57.15 (Ø2.25)

Key

1 hydraulic ports

2 flex joint (optional)

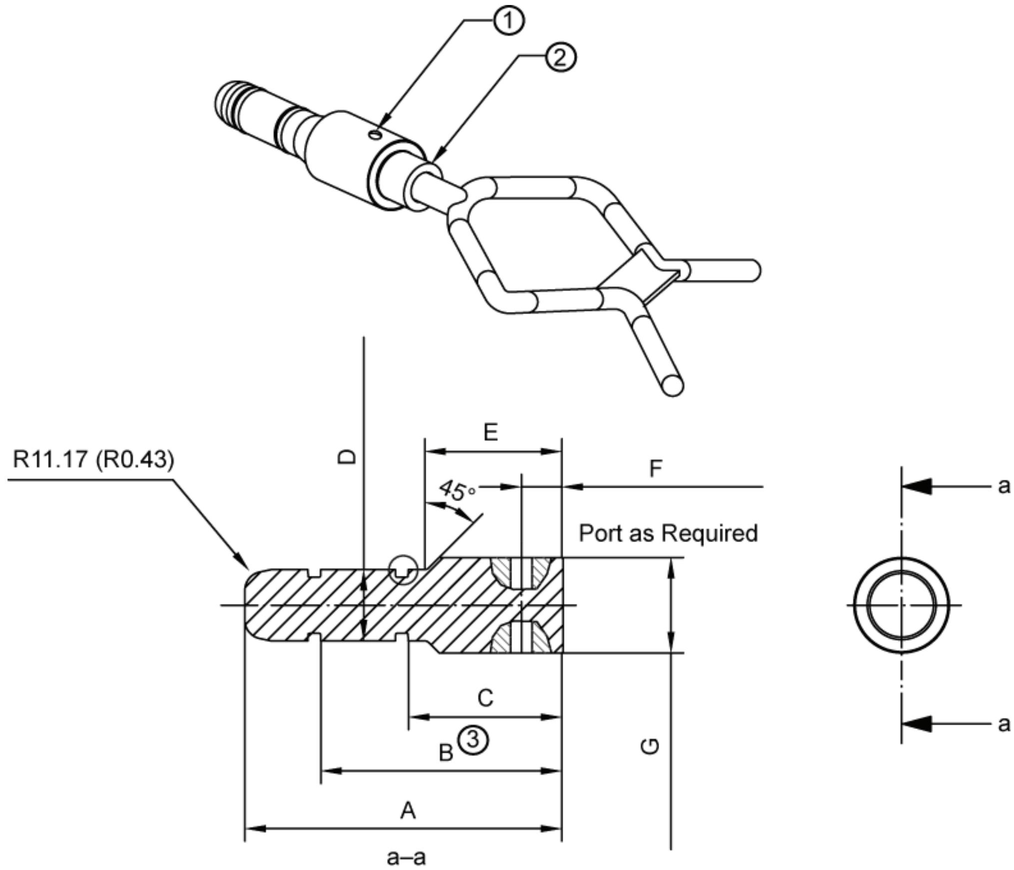
Figure 16—Male Hot Stab Connection Type A



Dimensions in millimeters (inches)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
203.2 (8.00)	178.48 (7.03)	151.82 (5.98)	123.77 (4.87)	114.30 (4.50)	68.27 (2.69)	35.26 (1.39)	19.21 (0.76)	12.55 (0.49)	Ø76.20 (Ø3.00)	Ø37.97 (Ø1.50)	Ø34.92/ Ø34.98 (1.371/ 1.372)	0.06 × 45°	7.87 (0.31)	11.1 (7/16)	165.15 (6.50)	4XØ6.3 (0.25)	Ø45.97 (Ø1.81)	51.77 (2.04)	Ø42.85/ (Ø1.687/ Ø1.689)

Figure 17—Female Receptacle—Type A



Dimensions in millimeters (inches)

A	B	C	D	E	F	G
182.51 (7.18)	145.27 (5.72)	92.67 (3.65)	42.80/ 42.77 (1.685/ 1.684)	81.53 (3.21)	25.40 (1.00)	Ø57.15 (Ø2.251)

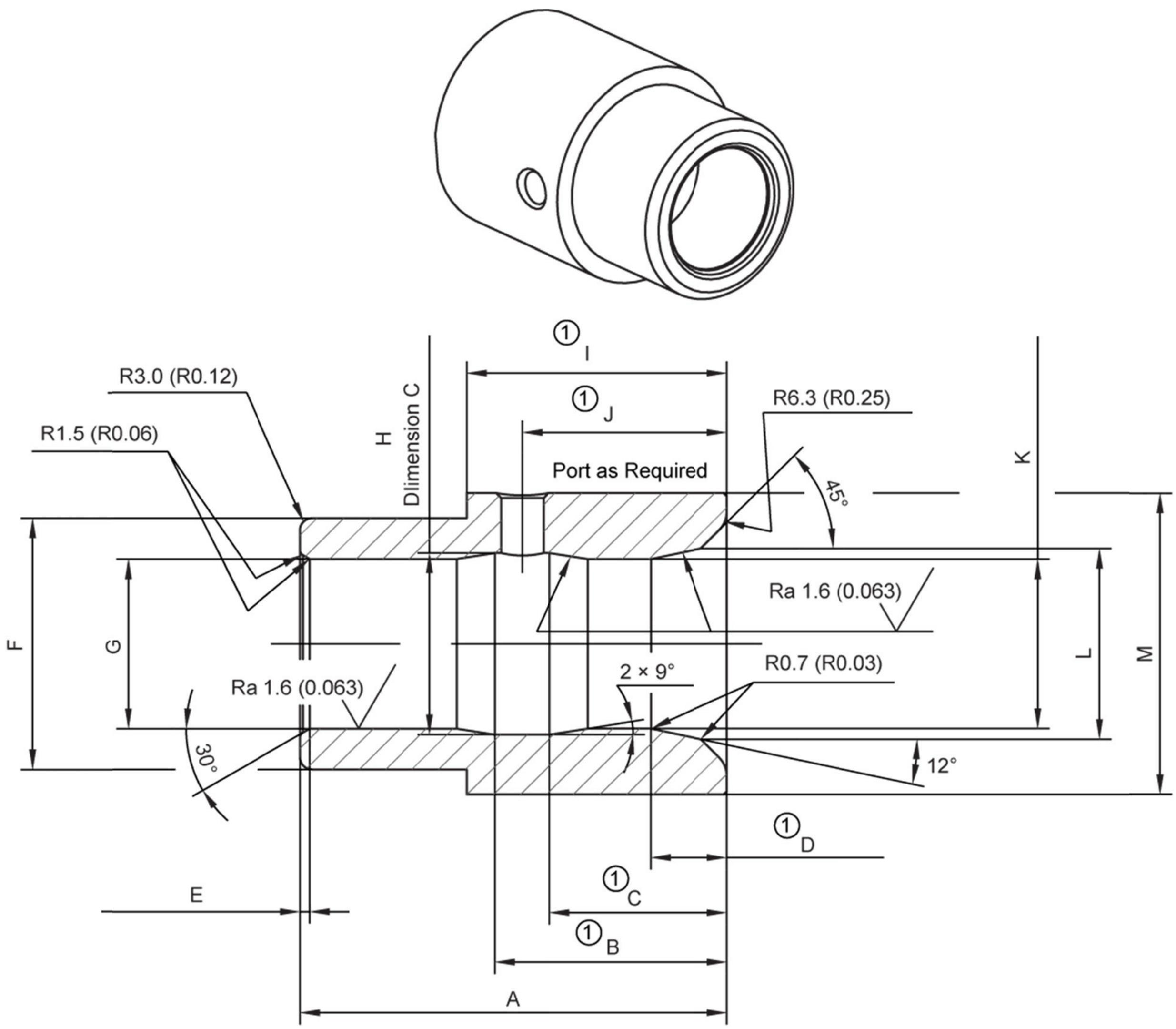
Key

1 hydraulic port

2 flex joint (optional)

3 repeat for multiple port applications

Figure 18—Male Hot Stab Connection Type B

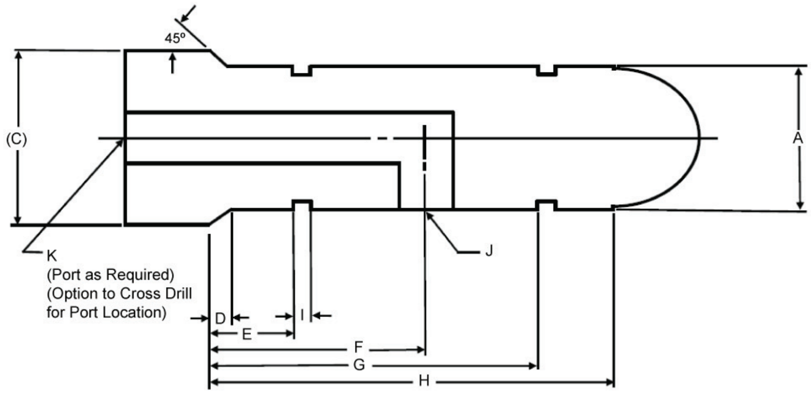


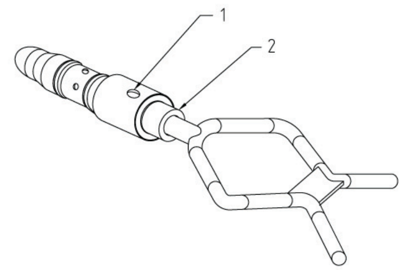
A	B	C	D	E	F	G	H	I	J	K	L	M
108.0 (4.25)	58.7 (2.31)	44.8 (1.76)	19.2 (0.76)	2.44/ 3.20 (0.096/ 0.126)	Ø63.5 (Ø2.50)	Ø42.88/ Ø42.94 (Ø1.688/ Ø1.690)	Ø45.9 (Ø1.81)	65.8 (2.59)	51.8 (2.04)	Ø42.82/ Ø42.88 (Ø1.686/ Ø1.688)	Ø48.2 (Ø1.898)	Ø76.24 (Ø3.00)

Key

1 repeat for multiple port applications

Figure 19—Female Receptacle—Type B





Dimensions in millimeters (inches)

A	C	D	E	F	G	H	I	J	K
42.80/42.77 (1.685/1.684)	63.5 (2.50)	9.65 (0.38)	21.6 (0.85)	51.8 (2.04)	73.4 (2.89)	92.0 (3.62)	Seal groove	4X 12.7 4X (0.50)	17.5 (0.69)

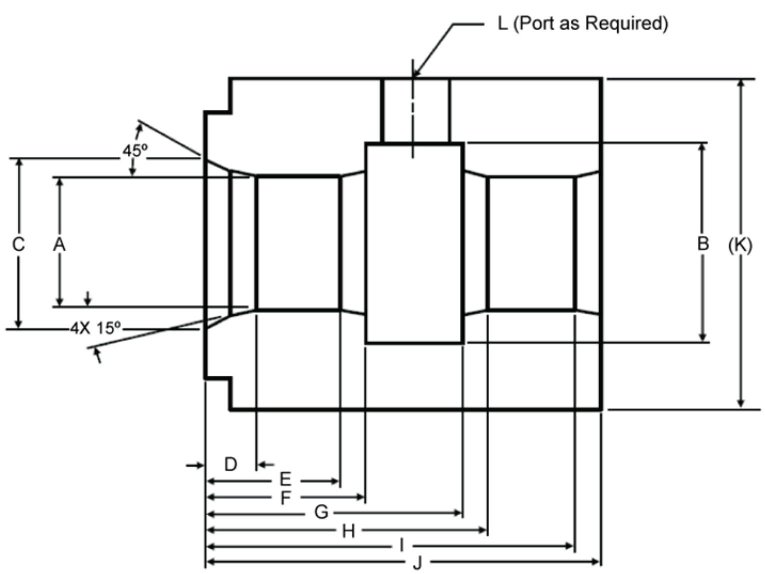
Key

1 hydraulic ports

2 flex joint (optional)

Figure 20—Hot Stab Connection Type C

This hot stab receptacle features a double angled bevel (15/45°) on the hot stab entry side of the female receptacle.

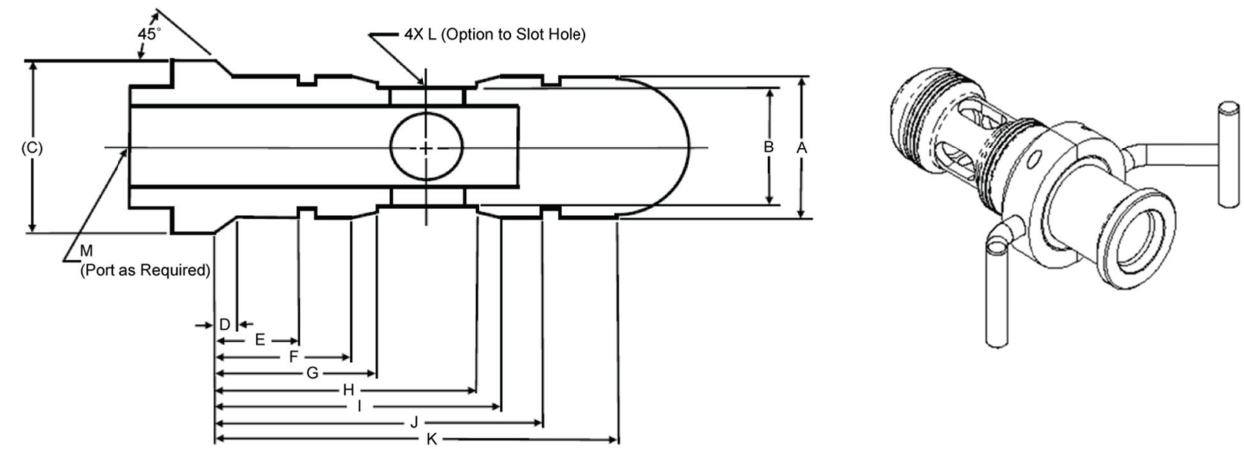


Dimensions in millimeters (inches)

A	B	C	D	E	F	G	H	I	J	K	L
42.90/42.85 (1.689/1.687)	71.0 (2.80)	63.5 (2.50)	19.3 (0.76)	35.3 (1.39)	42.4 (1.67)	61.2 (2.41)	68.3 (2.69)	84.3 (3.32)	92.0 (3.60)	165.0 (6.50)	17.5 (0.69)

Figure 21—Female Receptacle—Type C

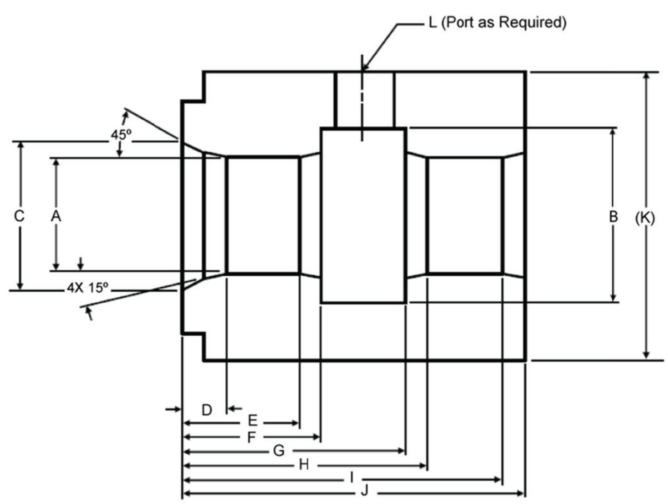
Dimensions in millimeters (inches)



Nominal Size	A	B	C	D	E	F	G	H	I	J	K	L	M
38 (1.5)	53.82/53.90 (2.119/2.122)	50.8 (2.00)	73.1 (2.88)	9.6 (0.38)	21.1 (0.83)	40.6 (1.60)	53.1 (2.09)	100.1 (3.94)	112.5 (4.43)	119.3 (4.70)	133.8 (5.27)	19.0 (0.75)	38.1 (1.50)
51 (2.0)	88.75/88.82 (3.494/3.497)	63.5 (2.50)	113.0 (4.45)	12.2 (0.48)	27.4 (1.08)	50.8 (2.00)	61.0 (2.40)	116.8 (4.60)	127.0 (5.00)	130.8 (5.15)	142.7 (5.62)	25.4 (1.00)	50.8 (2.00)
89 (3.5)	152.25/152.32 (5.994/5.997)	101.6 (4.00)	176.5 (6.95)	12.2 (0.48)	40.6 (1.60)	77.5 (3.05)	87.6 (3.45)	184.9 (7.28)	195.1 (7.68)	199.1 (7.84)	211.6 (8.33)	44.4 (1.75)	88.9 (3.50)

Figure 22—Hot Stab Connection Type D

Dimensions in millimeters (inches)



Nominal Size	A	B	C	D	E	F	G	H	I	J	K	L
38 (1.5)	53.98/54.02 (2.125/2.127)	69.8 (2.75)	73.1 (2.88)	19.3 (0.76)	40.6 (1.60)	53.1 (2.09)	100.1 (3.94)	112.5 (4.43)	133.8 (5.27)	147.0 (5.80)	107.0 (4.20)	38.1 (1.50)
51(2.0)	88.90/88.95 (3.500/3.502)	104.6 (4.12)	113.0 (4.45)	35.0 (1.38)	50.8 (2.00)	61.0 (2.40)	116.8 (4.60)	127.0 (5.00)	142.7 (5.62)	160.0 (6.30)	226.0 (8.90)	50.8 (2.00)
89 (3.5)	152.40/152.45 (6.000/6.002)	165.1 (6.50)	176.5 (6.95)	61.0 (2.40)	77.5 (3.05)	87.6 (3.45)	184.9 (7.28)	195.1 (7.68)	211.6 (8.33)	231.0 (9.10)	259.0 (10.20)	88.9 (3.50)

Figure 23—Female Receptacle—Type D

6.9.10 Hot Stab Hydraulic Connection, Type D

This hot stab connection is a intended for large bore - high circulation capabilities and limited to maximum of 34.5 MPa (5000 psi) rated working pressure. These stabs are commonly used for flowline/pipeline flooding and circulation applications. The design of this hot stab connection should include a stab locking mechanism to prevent inadvertent disengagement of male hot stab. Porting locations other than defined interface locations are defined by user requirements. Interface dimensions and features are included in Figure 22 and Figure 23.

6.10 Rotary Fluid Coupling

6.10.1 Function

To provide multifunction hydraulic stabbing.

6.10.2 Application

Used for multifunction hydraulic stabs for pipeline repair systems and flowline connections.

6.10.3 Design

Basic design considerations of all hot stabs should be as described in 6.9. Use Figure 24 for coupling dimensions.

NOTE Fluid couplings are optional up to eight places as required.

6.11 Component Change-out Interface

6.11.1 Function

This standard interface provides for landing and lockdown of ROV tooling systems for replacement of components on subsea facilities.

6.11.2 Application

The change-out interface for components is used where vertical installation and retrieval can be carried out by ROV tooling systems. Typical components that fall into this category are:

a) chokes,

b) control modules,

c) insert valves,

d) multiphase meters,

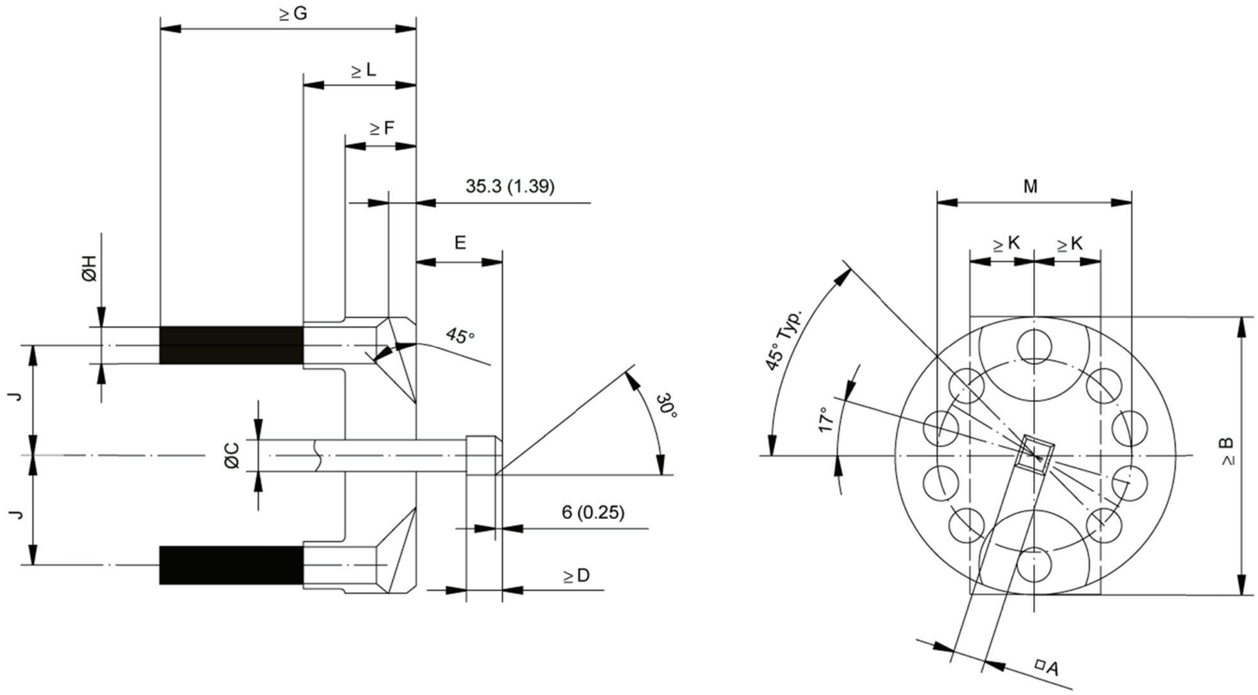
e) pig launchers,

f) chemical injection modules,

g) hydraulic accumulator modules,

h) debris and pressure caps.

Dimensions in millimeters (inches)



Dimensions mm (in.)		
	Class	
	2	3
A	17.3/17.0 (0.680/0.670)	28.6/28.3 (1.125/1.115)
B	164.5 (6.47)	240.5 (9.47)
C	17.0 (0.670)	28.3 (1.115)
D	25.4 (1.000)	31.8 (1.250)
E	57/25.5 (2.25/1.00)	76/32 (3.00/1.25)
F	12.5 (1.50)	62 (2.45)
G	216 (8.50)	222 (8.75)
H	20.6 (0.812)	30.2 (1.187)
J	63.5 (2.500)	95.2 (3.750)
K	50 (1.97)	56 (2.20)
L	82.5 (3.25)	98.5 (3.87)
ØM	—	171.5 (6.750)
Tolerances are: three-place decimal: ±0.2 mm (0.01 in.) two-place decimal: ±0.5 mm (0.02 in.) fraction: ±1 mm (0.04 in.)		

Figure 24—Rotary Fluid Coupling

6.11.3 Design

The interface comprises two identical landing units (see Figure 25 to Figure 29), each with one central lockdown receptacle and two weight receptacles. The weight receptacles may be used in combination with a subsea weight exchange system. Alternatively, cover plates may be positioned over the weight receptacles to enable soft landing dampers to react against.

The landing units should be set at a center pitch of 1500 mm (59.06 in.). This allows components of up to 1100 mm × 1100 mm (43.31 in. × 43.31 in.) plan area to be handled. A nominal height up to 1700 mm (66.93 in.) has been selected as this covers the majority of common components. It is recommended that the height of the interface be designed around the component. The top face of the landing units should be positioned flush with or above the component lifting mandrel. The landing units may be located at a high level, on the tree or manifold, or at a low level provided there is adequate access.

In the event that a component exceeds these sizes the next recommended pitch is 1750 mm (68.90 in.). Components longer than 1700 mm (66.93 in.) can be accommodated depending on tooling capabilities.

The landing units may be structurally supported from either the structural framework or from the component base unit. The support arrangements should take into account the clearance required for weight transfer units.

Design loads for the landing units are particular to the component and should be evaluated on a case by case basis. The interface is designed around a vertical in-water mass of 1200 kg (1.32 t) [3000 kg (3.3 t) in air] that causes a shared maximum vertical load of 200 kN (45 klbf) and bending moment of 60 kN-m (44 klbf-ft). The interface should be manufactured from material with a minimum ultimate tensile strength of 450 MPa (65,300 psi) for these loads and the dimensions provided.

The lockdown receptacle is formed from a post with an internal profile in accordance with the docking probe receptacle profile, as shown in Figure 27. The lockdown post is attached to the bottom plate.

The two weight receptacles, which serve to transmit the weight of the landed object to the host structure, form part of the top plate and are attached to the bottom plate by spacer tubes.

6.11.4 Operation

The removal of a component typically consists of the ROV and tool system landing vertically on the interface and locking down, carrying out some form of weight exchange or buoyancy adjustment, followed by release of the component through the tooling system or operation of ROV torque interface and lifting of the component into the tooling system. The ROV and tooling system with the component, then releases and maneuvers away from the interface. Installation is a reverse procedure.

6.12 Lifting Mandrels

The lifting mandrel designs presented have been developed for use with the CCO tool interface. Two sizes provide for all current subsea replaceable payloads employed with the CCO interface.

Typical examples of such applications are:

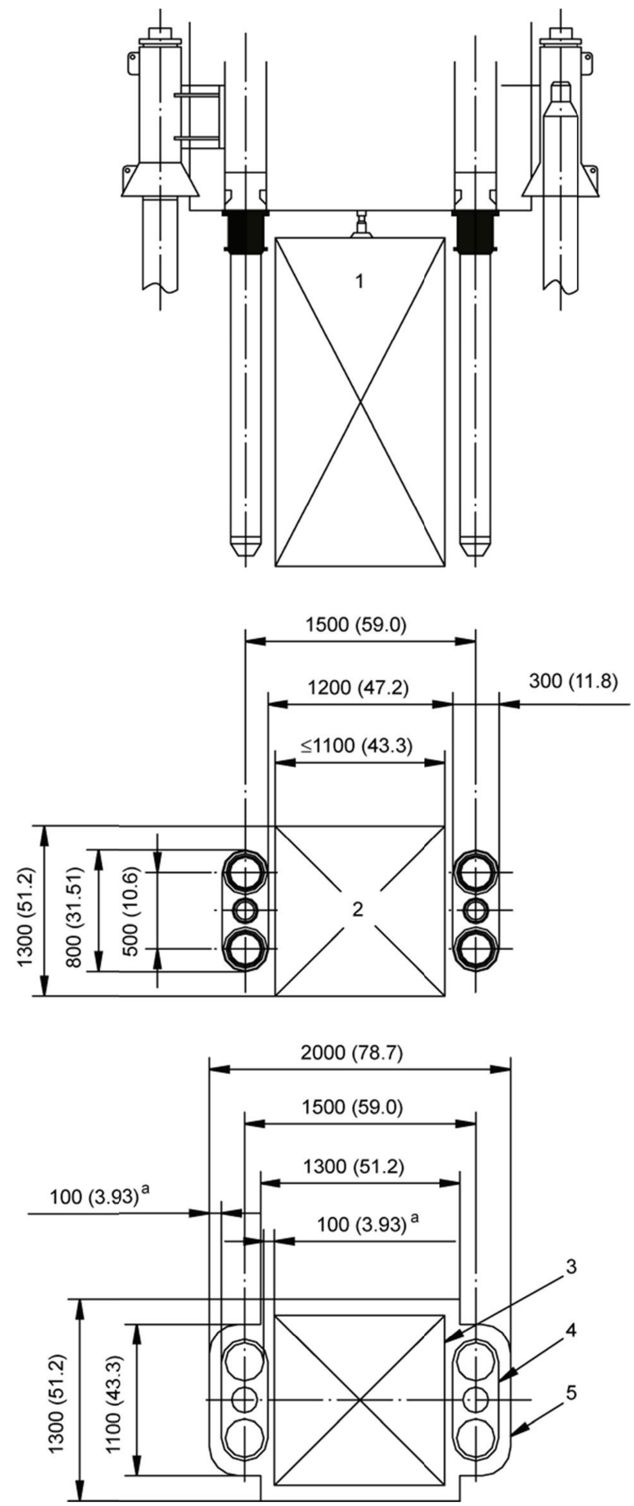
a) subsea control module,

b) subsea choke insert,

c) multiphase flowmeter insert,

d) valve insert.

Dimensions in millimeters (inches)

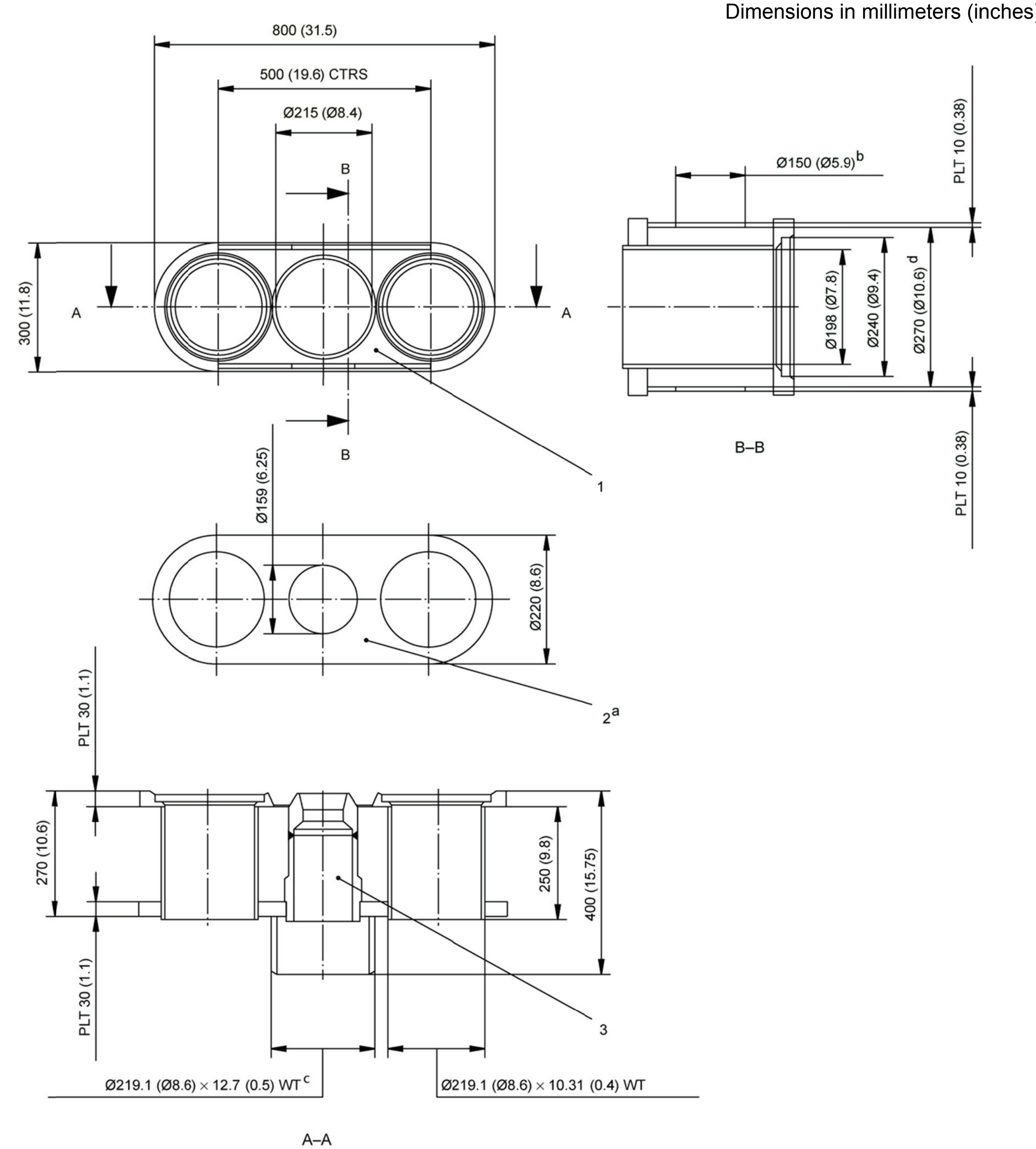


Key

1 component
2 component maximum outline
3 maximum component (1100 × 1100)
4 standard interface
5 minimum clear access outline
a clear all round (typical)

Figure 25—Component Change-out (CCO)

Dimensions in millimeters (inches)



Key

1 top plate

2 bottom plate

3 lockdown post (see Figure 26)

a unspecified dimensions as per top plate

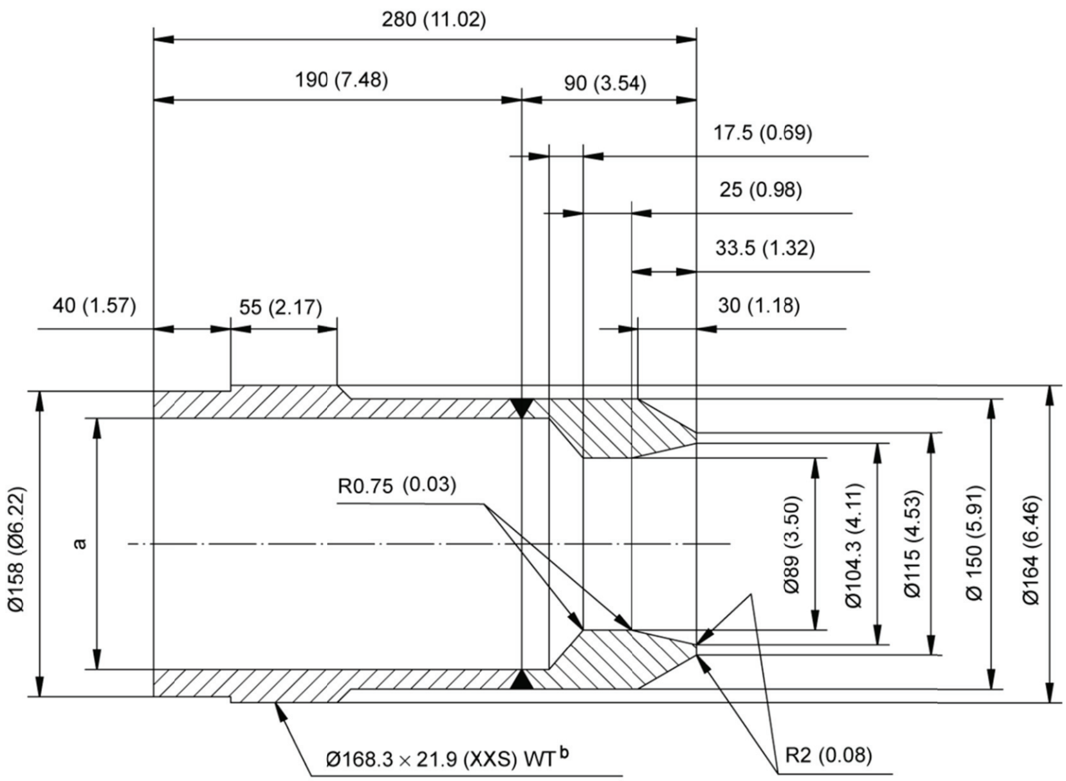
b new hole

c API pipe

d between stiffs

Figure 26—CCO Interface Structure

Dimensions in millimeters (inches)

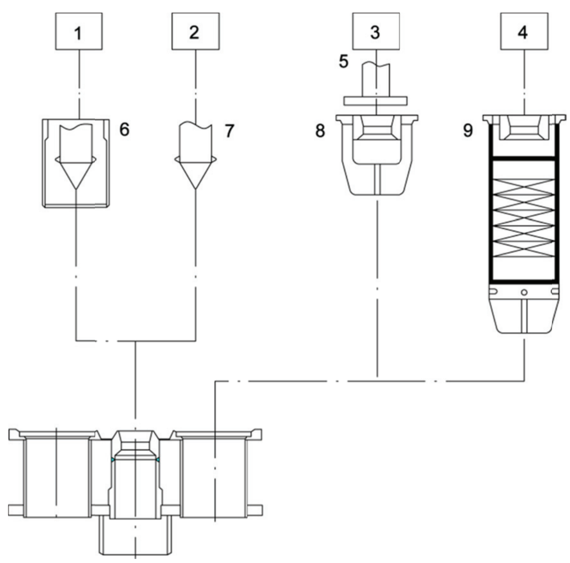


Key

a nominal bore

b API tube or bar stock XXS

Figure 27—CCO Lockdown Post Receptacle Detail



Key

1 high-capacity lockdown tool

2 lockdown tool

3 damped foot

4 weight exchange landing foot

5 landing damper

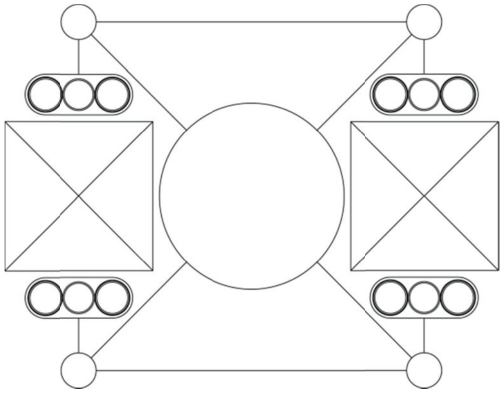
6 alignment panel

7 lockdown probe

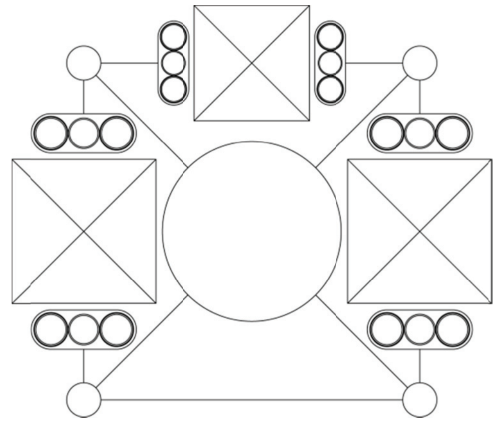
8 cover plate

9 weight assembly

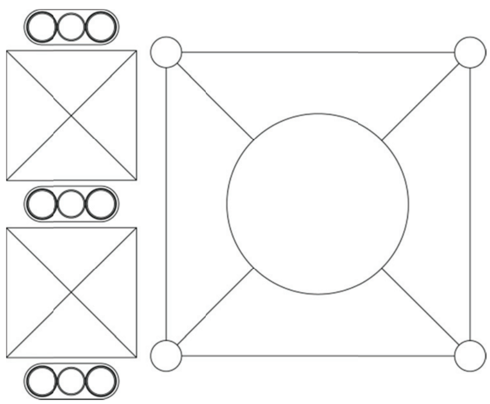
Figure 28—CCO Lockdown and Weight System



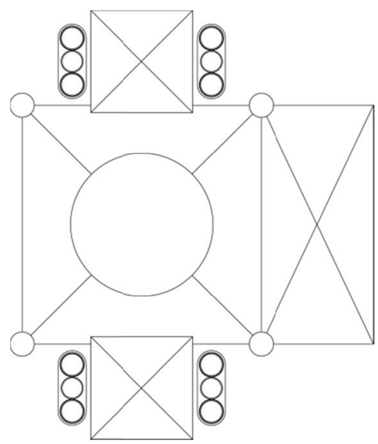
a) Production and Gas Lift Choke



b) Control Module/Production and Gas Lift Choke



c) Shared Interface



d) Horizontal Tree

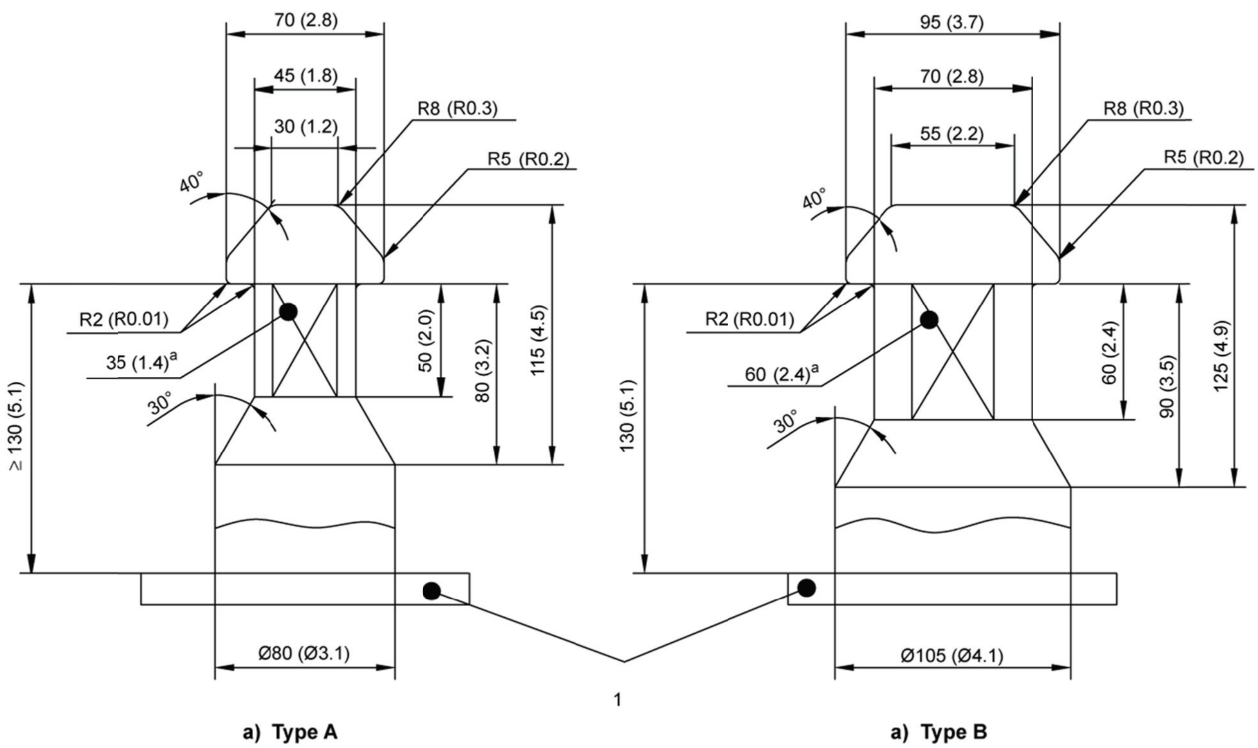
Figure 29—CCO Interface Layout Options

With reference to Figure 30, the Type A mandrel is employed for payloads up to 20 kN (4.5 klbf) gross weight (in air) and the Type B mandrel for payloads greater than 20 kN (4.5 klbf) and up to 50 kN (11.2 klbf).

The mushroom-shaped top has been profiled to facilitate capture using a conical lead-in mechanism. The top of the mushroom is intended to be at the same elevation [or within 51 mm (2 in.)] of the plane surface across the docking plates of the CCO interface. The machined flats are employed as an antirotational mechanism during payload transfer from the CCO tool into the subsea structure interface. These should be aligned such that the flats are transverse when the CCO interface is view as a front elevation (see Figure 31).

The connection interface for the mandrel to the payload is not defined. It can be implemented as a machined/bolted flange, weld socket connection of a threaded and pinned interface. The overall system will be subject to the recognized standard lifting certification testing prevailing within the geographical area of intended use or as specified by the end user.

Dimensions in millimeters (inches)



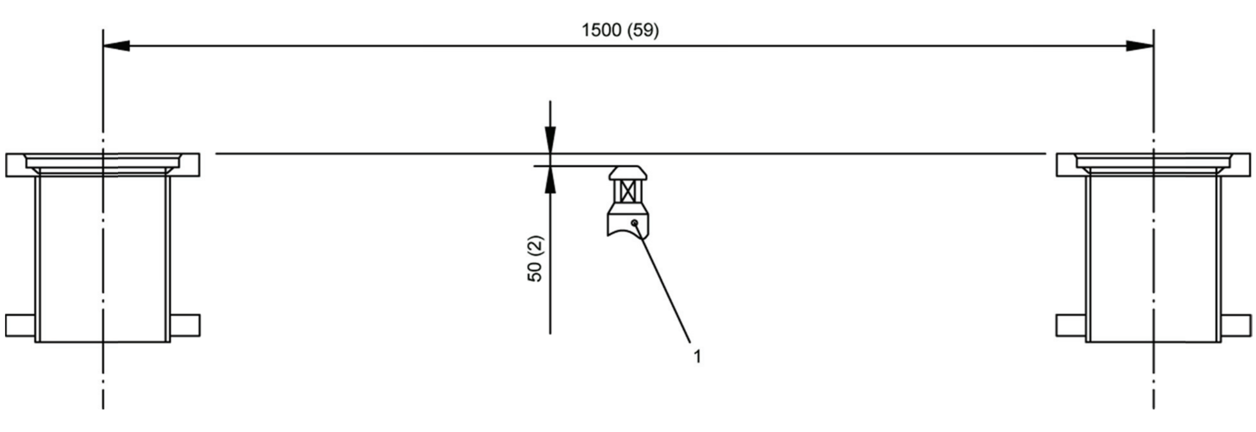
Key

1 attachment (design chosen to suit application)

a across flats

Figure 30—Lifting Mandrels

Dimensions in millimeters (inches)



Key

1 orientation flat/lifting mandrel

Figure 31—Lifting Mandrel in Relation to CCO Interface

6.13 Electrical and Hydraulic Flying Lead Handling

6.13.1 Function

This interface is for transferring or installing, or both, of electrical, hydraulic, or combined electro-hydraulic flying leads associated with the interconnection of subsea production equipment.

6.13.2 Application

This interface can be used for all "fly-to-place" connections/disconnections where the stab plate configuration and weight are with the capacity of the selected ROV.

6.13.3 Design

There is a significant number of subsea connection applications that require the transfer or installation of electrical, hydraulic, or combined electro-hydraulic flying leads associated with the interconnection of subsea production equipment. The length of such flying leads range from a few meters to in excess of 100 m (328 ft). The flying leads are terminated either with a single electrical connector/hydraulic coupling or a number of connections assembled as a stab plate.

Figure 32 shows an electrical connector with an oil-filled hose conduit connection interface suitable for single connection flying leads.

Alternatively, a TDU gripper interface may be mounted to the rear of the connector, which provides an interface for the same connector for TDU operations (see Figure 33).

Whereas single connection interfaces can be implemented for either manipulator or TDU operations, multiquick connector (MQC) stab plates are more easily handled by TDU equipment or a combination of manipulator and tool elevator. The locking system interface should be as shown in Figure 34 and Figure 35.

Where an application requires several connections to be made simultaneously, these are generally mounted onto a support plate, with proprietary subsea-mateable electrical or hydraulic connectors, or both, employed for individual interconnections (see Figure 36).

Such MQC stab plates may be required to provide a mating force against separating influences of mechanical insertion (self-sealing elements) and powered hydraulic supplies, and therefore a positive screw-locking mechanism is required that can generate sufficient force to make and break the connection.

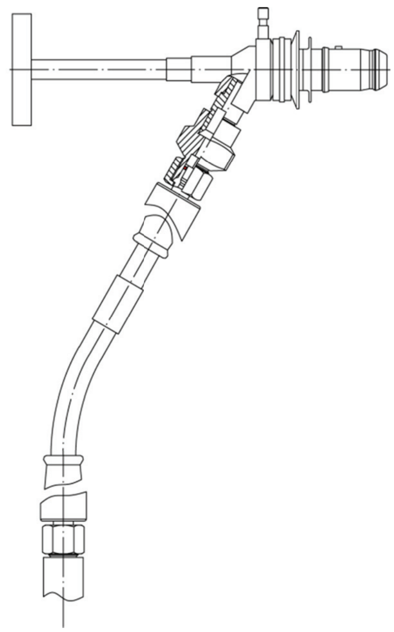
In addition to a combined central locating/locking pin a secondary alignment pin is recommended to provide controlled orientation of the stab plate for makeup. A clamping mechanism for position control and stress relief of the individual conduit hoses or cables or both is also necessary for tooling access and operations.

With reference to the relevant figures in this RP, all numerically dimensioned parameters are proposed as standard, nondefined dimensions and are optional or to suit the application.

Figure 34 shows a termination handling method and offset between the recommended handle and a central locking system. The material specification, plate shape and thickness are dependent upon the forces required. These forces are to be derived from individual application requirements and are outside the scope of this RP. The mechanism for locking is not defined. However, a good practice is to incorporate a release mechanism for the inboard locking assembly in the event of stab plant jamming.

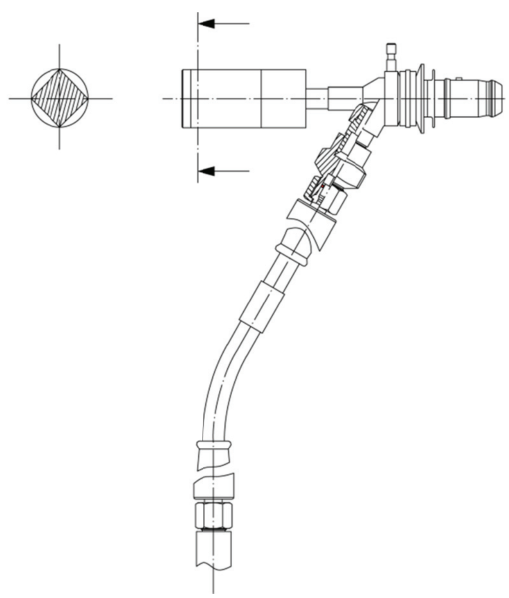
Figure 35 shows a junction plate populated with hydraulic couplings. A similar arrangement could incorporate all electrical or a combination of electrical and hydraulic connections.

The recommended parameters are based upon use of the twin TDU system operating envelope for the case of ROV transfer, which allows for two MQC plates to be designed within a single docking station. This will normally entail a total of five plates, two junction plates, two parking places, and an intermediate part to temporarily place the protective cover plate during the operation. The same parameters will apply to the situation where the flying leads are installed diverless and when the terminations are delivered by a special fly-in tool attached to the host vehicle.



NOTE Handle for use with manipulator; see Figure 9. Handle can also include compliant section; see Figure 16.

Figure 32—Manipulator Connection Operations

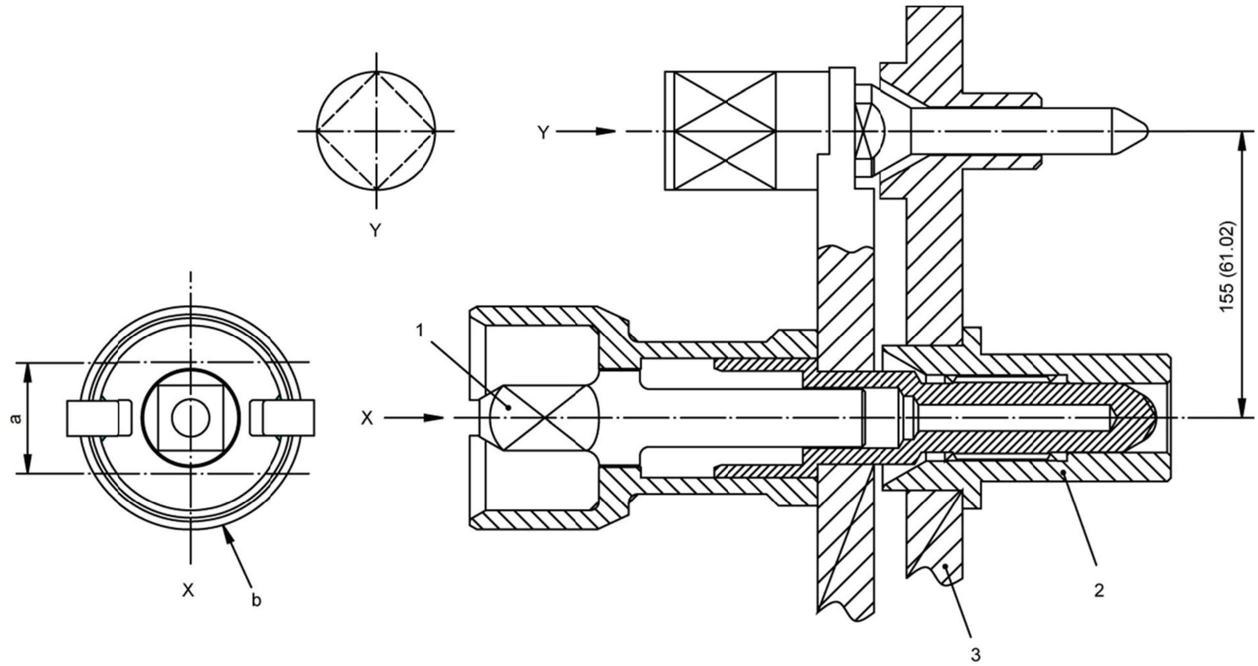


NOTE 1 Handle for use with TDU; see Figure 10.

NOTE 2 Gripper envelope; see Figure 36.

Figure 33—Tool Deployment Unit (TDU) Connection Operations

Dimensions in millimeters (inches)



Key

1 stab plate drive screw

2 locking mechanism (inboard)

3 tree stab plate

a receptacle may be truncated for minor weight-saving

b see Figure 15

Part section shows ROV interfaces only.

Figure 34—Multiple-quick Connection

7 Materials

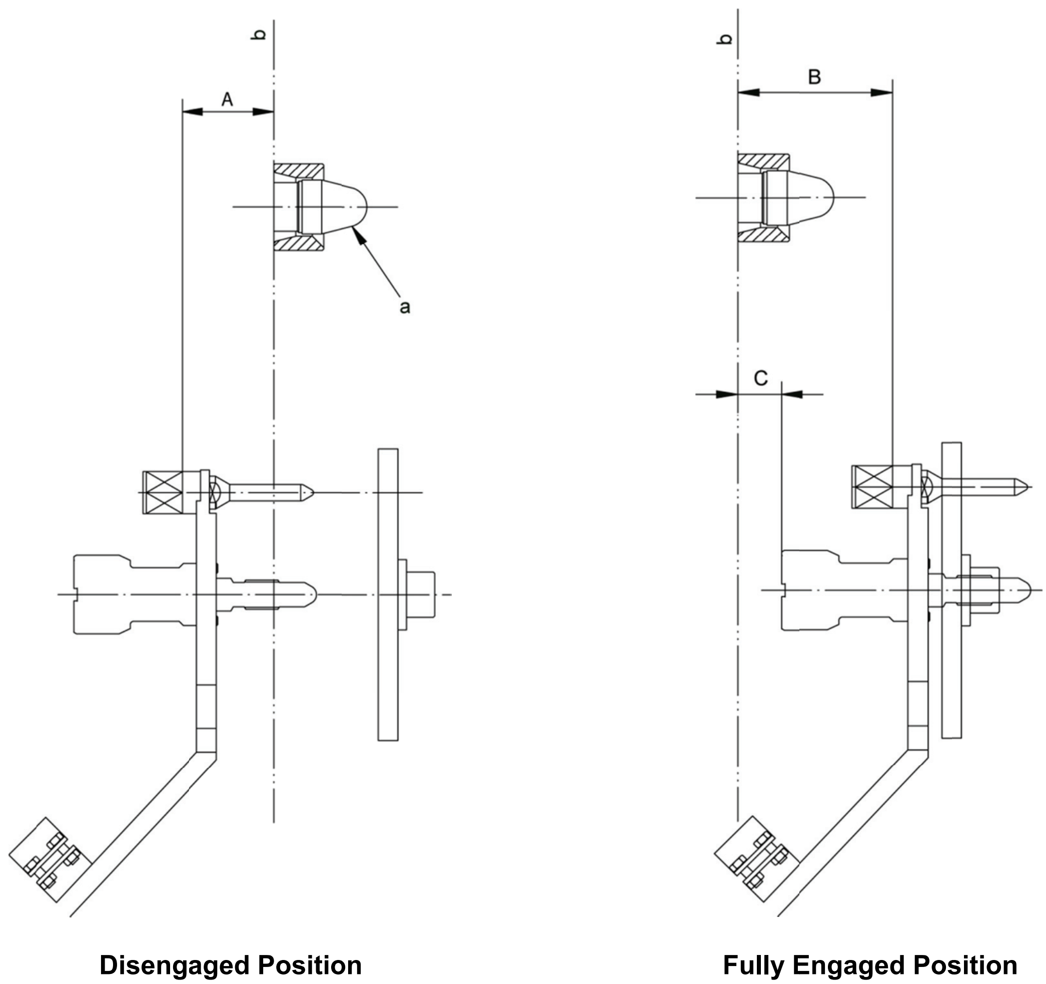
7.1 General Recommendations

The ROV/ROT system should meet the materials selection and materials recommendation requirements of API 17A. Interface designs should be capable of functioning with appropriate materials in accordance with Addendum 1 (2005) of API 17A.

Choosing materials is the ultimate responsibility of the operator/end user. However, the operator/end user may specify the service conditions, leaving the supplier free to recommend a fit-for-purpose solution.

The material of which the interface is manufactured should be fully specified by the designer with responsibility for making the material selection. Generally, the ROV-related interfaces and tools should be designed with materials suitable for frequent use in water.

Dimensions in millimeters (inches)



Dimensions

A = 140 mm (5.5 in.) maximum

B = 90 mm (3.5 in.) maximum

A+B = 230 mm (9.0 in.) maximum = TDU "Z" stroke

C = 270 mm (10.6 in.) maximum

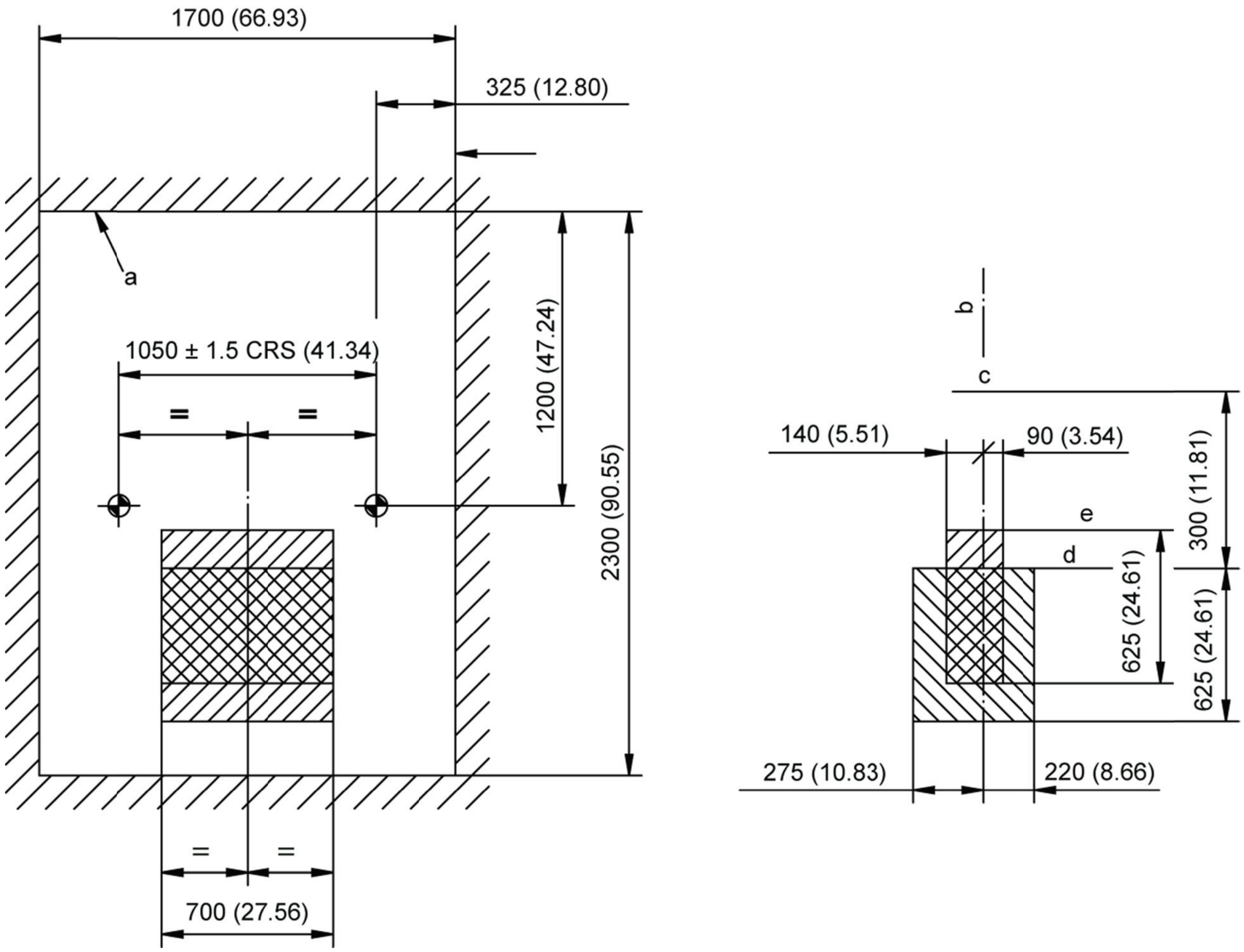
Key

a see Figure 5

b docking face

Figure 35—Typical Flying Lead in Disengaged/Engaged Positions

Dimensions in millimeters (inches)



Key

a recommended clearance area to permit access and allow for cameras, support brackets, etc.

b docking face

c center line of docking probes

d torque tool

e gripper

Figure 36—Combined Gripper and Torque Tool Envelopes for Flying Lead Handling

The designer should clearly differentiate between permanent subsea equipment and equipment used for a short time during intervention operations. Permanent subsea equipment shall be designed in accordance with the appropriate part of API 17A and associated subsea product requirements. Interfaces should cater for:

a) yield stress,

b) ultimate tensile strength,

c) fatigue properties,

d) internal wear of the interface if it is to be frequently used,

e) corrosion,

f) marine fouling.

7.2 Selection Criteria

Key factors to be considered when selecting a material for construction of the interface assembly include the following:

a) the interface mounted on the subsea production system should exhibit greater inherent strength than the interface carried by the ROV/ROT, such that in the event of a mishap during operations the interface cannot be damaged or made inoperable;

b) the interface should be designed to operate correctly throughout the entire period of submersion and should broadly equate to the design life of the equipment to which it is attached;

c) corrosion resistant materials, suitable coatings, and cathodic protection systems to prevent corrosion should be used. Intervention equipment used only a limited number of times throughout the life of the subsea production system may be designed to use materials suitable only for intermittent immersion in seawater;

d) the method of mounting the interface assembly to the subsea structure should be given adequate consideration by the design engineer, to ensure that the interface remains secure during the interface operation.

8 Subsea Marking

8.1 General

Warning—A commonality of abbreviation between subsea facilities and surface-operating equipment is essential. To minimize confusion and enhance safety where the control units are design for multiple applications, it is recommended that functions be identified both on the subsea packages and on their control units, using common abbreviations listed in this document. Where the valve arrangements are unique, the documentation should clearly define the abbreviation used in the marking of equipment.

All equipment on the subsea production systems that is designed for subsea intervention shall have a color and marking system enabling easy and unique identification.

The color and marking system shall act as a guidance map for the intervention operations by:

a) identifying the structure and orientation,

b) identifying the equipment mounted on the structure and intervention interface,

c) identifying the position of any given part of the structure relative to the complete structure,

d) identifying the operational status of the equipment (e.g. connector lock/unlock and valve open/close).

The marking system should enable positive verification of the end stop and/or locked position for retrievable components such as guideposts to lock-down clamps, etc.

When ROV intervention is used, coatings shall have a flat finish. Glare from the ROV lights on a gloss or semigloss finish can cause undue reflective glare into the ROVs low-light-sensitive cameras, causing impaired vision or “ghosting” effects on the monitor.

8.2 Color Design

The main elements of the color design are:

a) object color,

b) background color,

c) foreground color,

d) relative object size.

The colors should be clearly distinguishable at a minimum distance of 10 m (32.8 ft) in air, in artificial lighting, with adjustable intensity, and the red part of the light spectrum with the highest intensity.

The darker color should not be used on large structural parts. White colors on large structural elements should be avoided. Grating (which may be required to see through) should have darker colors [e.g. metallic grey (unpainted)], to avoid light reflection. Furthermore, colors that may be misinterpreted (taken for shadows/bottom, etc.) should not be used. The foreground should appear less bright than the object and background. Elements such as pad eyes, lifting systems, and connectors (i.e. “active” parts during intervention) should be marked with orange color.

The ROV operating spindles (valve spindle/spindle extension) should not be painted because of the tolerance between the spindle and the torque tool.

The colors recommended for use on the subsea production systems, with the equivalent RAL [5, 6], Munsell [7, 8] and U.S. Federal Standard 595A [9] codes, are given in this subsection.

8.3 Marking Guidelines

The marking is divided into primary and secondary marking. Primary marking is defined as marking of major structural members and systems that need to be identified for operational, installation, and retrieval purpose. Recommended height for marking symbols is 170 mm (6.693 in.) to 500 mm (19.685 in.) character size.

Secondary marking is defined as marking used within a major system or location to identify components such as valves, hydraulically operated components, local tapping points used for sensing equipment, probes, etc. Character size of 50 mm (1.969 in.) to 150 mm (5.906 in.) should be used.

Smaller sizes may be used when the specified size is impractical.

The location of the identification marks should be such that they do not obstruct intervention work to be carried out on equipment and components, and such that the risk of damaging or tearing off the marks is minimal.

Antifouling marking signs should be used on permanently installed equipment. The marks should be designed for mechanical attachments to the structure, equipment, or component such that they remain in place and are not damaged during intervention.

Welding attachments to production piping should not be used. If bonding is used, this should be based on thoroughly tested and verified techniques.

The following areas should be considered.

a) *Visibility*—All marks should be designed to be clearly visible in artificial light from a minimum distance of 5 m (16.4 ft) based upon the particle content of the water;

b) *Design Life*—The marks should be protected against marine fouling for the design life of the subsea production system;

c) *Language*—All instructions written on the marks should be in the English language;

d) *Cross-reference*—All symbols, characters, figures, etc. on the marks should be easily identified and cross-referenced with the operational documentation;

e) *Marking of Structures*—The structures should preferably be oriented such that rig headings and template headings are identical during rig operations. The following marking should be used:

   1) front side of the structure: FORE;

   2) starboard side of the structure: STB;

   3) port side of the structure: PORT;

   4) back side of the structure: AFT.

   On the port and starboard sides of the upper structure, main identification marks should be fitted to enable a positive identification of the entire subsea production system. The main identification marks should as a minimum display the field name, block number(s) and name of installation.

   FORE on the protection structure should be defined according to FORE on the rig (i.e. same as the rig heading). For template structures, the numbering of the slots (referring to well slots) can start with slot number one in FORE-STB corner and continue the numbering clockwise. Numbering of other slots, not referring to well slots, follows by starting with slots on FORE side and follows clockwise. It is recommended to use the same method for numbering of well slots and guideposts as for the protection structures. The marks on the sides should be fitted on both top and bottom of the structures, such that they are clearly visible from the outside of the structures. Inside, the structure marks should be fitted to the structural members to enable positive and easy orientation. This should be done by fitting the marks on the vertical members surrounding, for example, a well slot, with the symbols facing towards the center of the slot. The marks should be fitted at an elevation suitable for the foreseen work to be carried out in the respective areas.

f) *Marking of Guideposts*—Guidepost numbering should suit the expected rig heading, and a rig guideline numbering system based on the forward and starboard guideline being wire No. 1 and so on, going clockwise. The posts should be marked with black rings located 200 mm (7.874 in.) below the top and indicating the post number Retrievable guideposts should be fitted with easily readable status indicators showing locked (“L”) and unlocked (“U”) positions of the locking mechanism.

g) *Marking of Manifold Valves*—A unique valve numbering system should be established, providing an easy identification of each valve and its function. All manifold valves should be marked with an “XY”-number where “X” identifies to which slot the pipe is connected or which main line the valve is isolating. The “Y” number should then identify which number of valve from the slot (if several valves in line) and which function the line has. The valves should be marked with a minimum of one mark near the valve body facing upwards. The mark can be fixed on a support plate attached to one of the valve interface flanges between the valve body and bonnet or the near structure.

h) *Marking of Piping System*—As for the manifold valves, a unique numbering system for the piping system should be established. The piping system (inclusive production and injection lines) between the well slots and pull-in porches should be marked to identify each pipe based on the established numbering system.

The piping may in addition be marked with colored strips of antifouling material at different locations in order to facilitate inspection.

i) *Marking of Pull-in Porches*—The pull-in porches should be marked to reflect the type of lines.

The pull-in porches for the electric and hydraulic umbilicals should be marked with “E” or “H” on the upper side.

If combined electric and hydraulic umbilicals are used, the porch should be marked with “E/H.”

Pull-in porches for the flowlines and chemical injection/service lines should be marked as follows:

1) production flowline: P;

2) water injection flowline: WI;

3) gas injection flowline: GI;

4) test line: T;

5) chemical injection: C;

6) methanol injection: M.

In addition to these letters, a number should be added to each funnel reflecting the line or umbilical number.

j) *Marking of Pull-in Ramps*—The pull-in ramps, if fitted, should be marked with a line indicating the ideal centerline of the porch. In addition, a line on each side should be added to indicate the maximum angular misalignment allowed.

Transversal lines every meter from the pull-in funnel entry point should be included on the ramp. The distance should be marked at the side of the misalignment lines, enabling the ROV pilot to record the distance left during pull-in operations.

k) *Status Indicators*—Status indicators should be marked with clearly readable reference points. Symbols “U” = unlock, “L” = lock, “O” = Open, “S” = shut, “B” = bleed should be used to define the reference points.

The distance between the status indicator arrow or marker and the reference points in the viewing direction should be made as short as possible to reduce the sensitivity and effect of ROV viewing position. Direction of operation should be indicated with an arrow.

l) *Marking of Control System Components*—The control system should be marked to provide positive identification of its respective components. The marks should be fitted at regular intervals [e.g. 2 m (6.6 ft)] to enable easy identification of all the control system components.

The control module should be marked with the identification number at a minimum of one location and be clearly visible by ROV when approaching the module. The minimum character size should be 100 mm (3.937 in.).

All the electrical and hydraulic lines should be marked, to allow easy identification of each line. The following guidelines should be used:

1) each individual line should be marked with characters for unique identification of the line and its function at a suitable location close to its respective connection point;

2) lines entering a valve panel should be marked on both panel sides.

m) *Marking of Retrievable ROT Guideposts (if Used)* —

ROT guideposts should be marked with level indicator rings every meter, using the top of the guidepost receptacle as the reference level

n) *Marking of Subsea Tree System*—All the subsea tree valves shall be marked with at least two letters for easy ROV observation with tool in position (e.g. production master valve).

A number shall be fitted on the ROV valve panel providing a unique identification for each subsea tree. Likewise, the subsea tree cap shall be fitted with a unique identification number.

Table 4—Marking Colors

	Black	Red	Orange	Yellow [a]	Unpainted	White [a]	Grey
Paint code: RAL	9017		2004	1004	na	9002	7038
Paint code: Munsell	N 0.5		1.25YR 6/14	1.25Y 7/12	na	10Y 8 5/1	5Y 7/1
Paint code: U.S. Federal Standard 595A	27038	31136	32246	33655 33507	na	27875	26440
a) Structures							
Protective structure	X (text)			X			
Base structure	X (text)			X		X	
Guideposts	X (markings)			X		X	
Pull-in porches (pull-in ramps)	X (markings)			X (ramps)		X (diver porches)	
Anodes or components with a zinc or aluminum treatment					X		
Pad eyes, hinges, ROV attachment/intervention points, etc.		X [b]	X [b]				
b) Process Manifold							
Manifold structure				X		X	
Piping				X		X	
Manifold valves				X		X	
Valve reaction points, ROV attachment/intervention points, etc.			X				
Valve spindle					X		

	Black	Red	Orange	Yellow [a]	Unpainted	White [a]	Grey
Valve status	X (text)			X (back-ground)		X (back-ground)	
Termination hubs		X [b]	X [b]				
Termination hub clamps, protection caps, etc.		X [b]	X [b]				
c) Control System							
Control-pod body			X				
Control-pod ROT hub					X		
Control-module connector clamp					X		
Panels for ROV operation				X			
ROV-operated valve handles, ROV attachment/intervention points, etc.			X				
Control distribution system structure				X			
d) Subsea Tree System							
Tree structure				X		X	
Piping				X		X	
Tree valves				X		X	
Valve reaction points, ROV attachment/intervention points, etc.			X				
Valve spindle					X		
Valve status	X (text)			X (back-ground)		X (back-ground	
Termination hubs		X [b]	X [b]				
Termination hub clamps, protection caps, etc.		X [b]	X [b]				
Connector/termination landing position (swallow) or orientation	X (markings)			X (back-ground		X (back-ground	
e) ROT, ROV, and Replacement Frame System							
Steel structures			X				
ROV-operated handles, ROV attachment/intervention points, etc.			X				

[a] Usually yellow for ROV intervention and white for diver intervention.
[b] Depending on project requirements.

9 Validation and Verification

9.1 Design Verification

9.1.1 General

Design verification should be performed to ensure that the design output, as defined by the design plan, has been met.

All design verification activities should be documented. Nonconformances should be logged, followed up, and closed prior to equipment handover to client.

Design verification is achieved by:

a) operability and access verification;

b) producing design documentation (e.g. drawings, specifications, and procedures);

c) performing calculations;

d) performing design reviews in accordance with latest version of API Q1, ISO 29001, ISO 9001, or another recognized standard;

e) performing qualification testing;

f) performing FAT.

9.1.2 Design Documentation

The design documentation should include, but is not limited to:

a) assembly drawings (including as-built),

b) detail design drawings,

c) structural analysis,

d) piping analysis,

e) pipe wall calculation,

f) specifications and datasheets,

g) design review minutes of meeting,

h) test procedures and records,

i) weight-control reports,

j) access and operability verification,

k) hazardous operations and safe operations reports,

l) operating and maintenance manuals:

    1) storing and preservation procedures,

    2) planned normal operating modes,

3) operating procedures,

4) spare part lists,

5) commissioning procedures,

6) testing reports and records.

9.1.3 Access and Operability

9.1.3.1 General

Access and operability verifications should be performed at various stages during the design of the subsea intervention systems.

The main purpose is to verify the ability of the intervention system to perform its task on the subsea system.

This includes verification of ROV access to the worksite as follows:

a) verification of the location and design of ROV stabilization supports (e.g. grabber bars, landing platforms, etc.);

b) verification that the ROV can perform the task (e.g. weight, size, location of handles of the object to be handled).

Ways to perform the verification include the following:

a) state of the art 3D simulation software—the method provides a realistic, dynamic simulation of the ROV operation in a virtual 3D environment of the worksite. Physical properties of the ROV carried object may be modeled to add to the realism of the simulation;

b) use of 3D CAD drawings;

c) use of mock-up ROVs;

d) use of actual ROVs as part of onshore tests.

9.1.3.2 3D Simulations

The use of 3D ROV simulations should be considered as design verification that can be used throughout the engineering, fabrication, and testing phases. However, 3D simulations cannot be used to replace system integration testing.

The simulations should be performed based on the selected ROV configuration for each project (i.e. normally a left-hand five-function grabber arm and right-hand seven-function manipulator).

Through the various project phases, the simulation/visualization activities should focus on:

a) validation of subsea system layout and equipment packaging through high level access and operability simulations (typical concept development and systems engineering);

b) subsystems, module, and running tool design validation (detailed access and operability validation, typically during detail design, fabrication, and testing phase). These validation activities can include 3D models with built in physical properties (weight, buoyancy, center of gravity, etc.). The validation should focus on identifying the location of stabilizing feature for the ROV (e.g. platform, grabber bar, etc.), marking (status validation and readability), and interfaces to be operated;

c) training and familiarization of personnel and development of animations for the best practice procedure (testing phase and operations preparation);

d) real time operations support during installation and later on IMR activities. This will include both real time ROV navigation support and e-field functionality.

The same software should be used throughout the project and expanded with additional features and details as required. Considerations should also be given to the degree of new technology and concept solutions (e.g. subsea processing systems) being used. An overall program should be prepared prior to project start, and based on the proposed intervention and IMR strategy for the project.

9.1.4 Design Reviews

Design review of the ROV/ROT system and components should be performed in accordance with latest versions of API Q1, ISO 29001, ISO 9001, or another recognized standard.

The design review should include the following elements:

a) review of design inputs,

b) completion of ROV friendliness review,

c) establish design outputs,

d) material selection and review,

e) review conformance to customer requirements,

f) shop handling and fabrication,

g) review internal interfaces,

h) review external interfaces,

i) establish design verification requirements,

j) establish design validation requirements,

k) review safety and environmental considerations,

l) ease of maintenance and operation.

9.1.5 Factory Acceptance Testing

A comprehensive acceptance test program should be undertaken by the manufacturer to ensure that components have been manufactured in accordance with specified requirements. The test should be performed to a predefined and approved procedure.

Any failure occurring should be repaired and analyzed to find reason for the failure and/or result in a review of the calculated reliability of the system to determine if the deviation can be accepted.

FAT is generally a multitiered approach, involving individual component checks, subsystem checks (i.e. control system), interface checks, and unitized system checks. Modifications and changes to the equipment during testing and manufacture should be formally documented.

A typical format for a subsea equipment FAT procedure could include the following:

a) purpose/objective;

b) scope;

c) requirements for fixtures/setups, facilities, equipment, environment, and personnel;

d) performance data;

e) acceptance criteria;

f) reference information.

FAT typically covers the following items:

a) individual component testing;

b) assembly fit and function testing:

  — use actual subsea equipment and tools where possible;

c) interface checks:

  — use actual subsea equipment and tools where possible;

d) interchangeability testing;

e) hydrostatic testing;

f) structural load testing:

  — simulation of all loads subjected during installation and operation;

g) submerged tests (optional).

9.2 Design Validation

9.2.1 General

Design validation is achieved by:

a) performing first article testing,

b) performing qualification testing,

c) performing system integration testing.

Design validation is performed to ensure that the specific operational requirements have been met. In certain cases, it is necessary to perform wet-simulation testing in order to prove center of buoyancy, correct functioning of components and systems underwater.

Tests should include simulations of actual field and environmental conditions for all phases or operations, from installation through maintenance. Special tests may be needed for handling and transport, dynamic loading, and backup systems. Performance tests may be appropriate and can supply data on response-time measurements, operating pressures, fluid volumes, and fault-finding and operation of shutdown systems.

9.2.2 Qualification Test

Individual components (e.g. valves, actuators, fitting, and control system components) should be qualified independently of the manifold/template system. The ROV/ROT system should be subjected to a preapproved qualification test that is defined by the operational limits.

9.2.3 System Integration Test

A system integration test should be performed that includes tooling, vehicles, and control systems. The different tests performed during integration testing should be used to check reliability and should demonstrate tolerance requirements and correct functioning of the complete system.

The purpose of the test is to simulate all operations that could be performed offshore, to the extent practical, and verify all equipment/systems and procedures related to operation of the ROV/ROT system.

Training of personnel, including familiarization with equipment and procedures, is an important factor during integration test activities. This aspect is particularly important in order to promote competence, safety and efficiency during installation and operation activities.

System integration testing typically contains the following activities:

a) a documented integrated function test of components and subsystems;

b) a final documented function test, including bore testing and leak testing;

c) a final documented function test of all electrical and hydraulic control interfaces;

d) documented orientation and guidance fit tests of all interfacing components and modules;

e) simulated installation, intervention, and production mode operations as practical in order to verify and optimize relevant procedures and specifications;

f) operation under specified conditions, including extreme tolerance conditions, as practical, in order to reveal any deficiencies in system, tools and procedures;

g) operation under relevant conditions as practical to obtain system data such as response times for shutdown actions;

h) testing to demonstrate that equipment can be assembled as planned (wet conditions as necessary) and satisfactorily perform its functions as an integrated system;

i) filling with correct fluids and lubricated, cleaned, preserved, and packed as specified;

j) functional test of control system.

9.2.4 Shallow Water Test

A shallow water test can be performed that includes tooling, vehicles, and control systems. The different tests performed during integration testing should be used to check reliability and should demonstrate tolerance requirements and correct functioning of the complete system.

The purpose of the test is to simulate all operations that could be performed offshore, to the extent practical, and verify all equipment/systems and procedures related to operation of the ROV/ROT system.

Training of personnel, including familiarization with equipment and procedures, is an important factor during integration test activities. This aspect is particularly important in order to promote competence, safety, and efficiency during installation and operation activities.

System integration testing typically contains the following activities:

a) a documented integrated function test of components and subsystems;

b) documented orientation and guidance fit tests of all interfacing components and modules;

c) simulated installation, intervention, and production mode operations as practical in order to verify and optimize relevant procedures and specifications;

d) operation under specified conditions, including extreme tolerance conditions, as practical, in order to reveal any deficiencies in system, tools and procedures;

e) operation under relevant conditions as practical to obtain system data such as response times for shutdown actions;

f) testing to demonstrate that equipment can be assembled as planned and satisfactorily perform its functions as an integrated system;

g) filling with correct fluids and lubricated, cleaned, preserved, and packed as specified.

9.2.5 Deep Water Test (DWT)

A deep water test can be performed that includes tooling, vehicles, and control systems.

The test should be performed as an addition to the system integration test, and should focus on verifying the subsea intervention system functionality at the specified working depth. The different tests performed during the DWT should be used to check reliability and should demonstrate tolerance requirements and correct functioning of the complete system during operation.

The purpose of the test is to simulate all operations that could be done offshore, to the extent practical, and verify all equipment/systems related to operation of the ROV/ROT system.

Training of personnel, including familiarization with equipment and procedures, is an important factor during DWT activities. This aspect is particularly important in order to promote competence, safety, and efficiency during installation and operation activities.

DWT testing can include the following activities:

a) documented orientation and guidance fit tests of all interfacing components and modules;

b) simulated installation, intervention, and production mode operations as practical in order to verify and optimize relevant procedures and specifications;

c) testing to demonstrate that equipment can be assembled as planned and satisfactorily perform its functions as an integrated system.

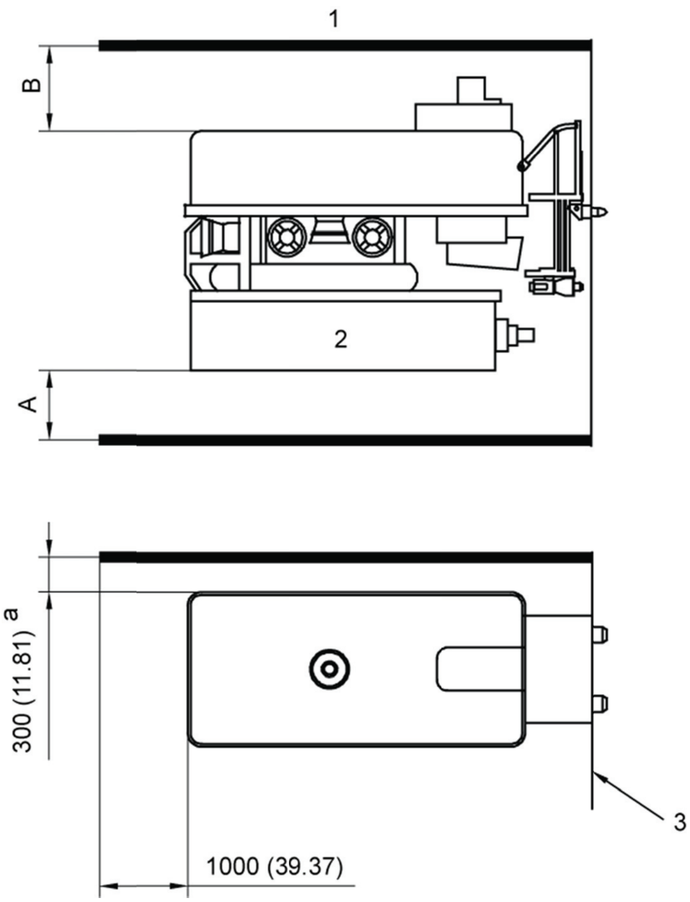
Annex A
(informative)

Access

Typical clearances required for vehicle operations are shown in Figure A.1.

Where the recommended clearances cannot be achieved, care shall be taken to avoid damage to the ROV or equipment.

Dimensions in millimeters (inches)



Key

1 structure

2 tooling package

3 face of structure

a typical

A clear distance to the bottom of the ROV or underslung tooling package of 500 mm (19.68 in.) min. is recommended. Clearance above the ROV should take account of the umbilical connection.

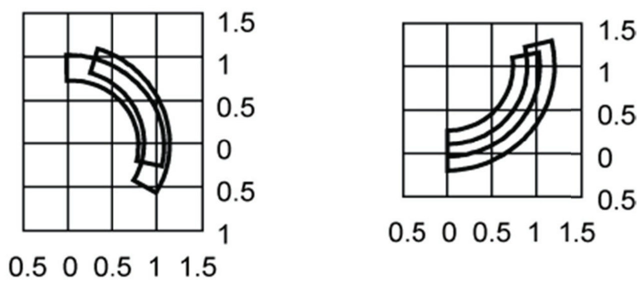
Figure A.1—Clearances

Annex B
(informative)

Manipulator Operating Envelopes

The operating envelopes for a normal range of standard manipulators are shown in Figure B.1 and Figure B.2.

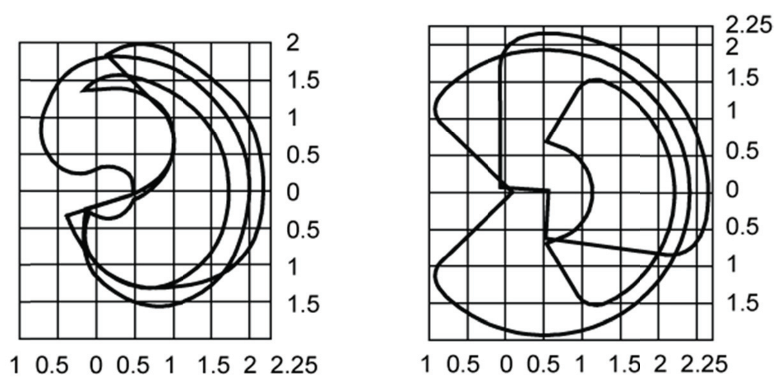
Scale in meters



a) Side View **b) Plan View**

Figure B.1—Typical Five-function Grabber Envelopes

Scale in meters



a) Side View **b) Plan View**

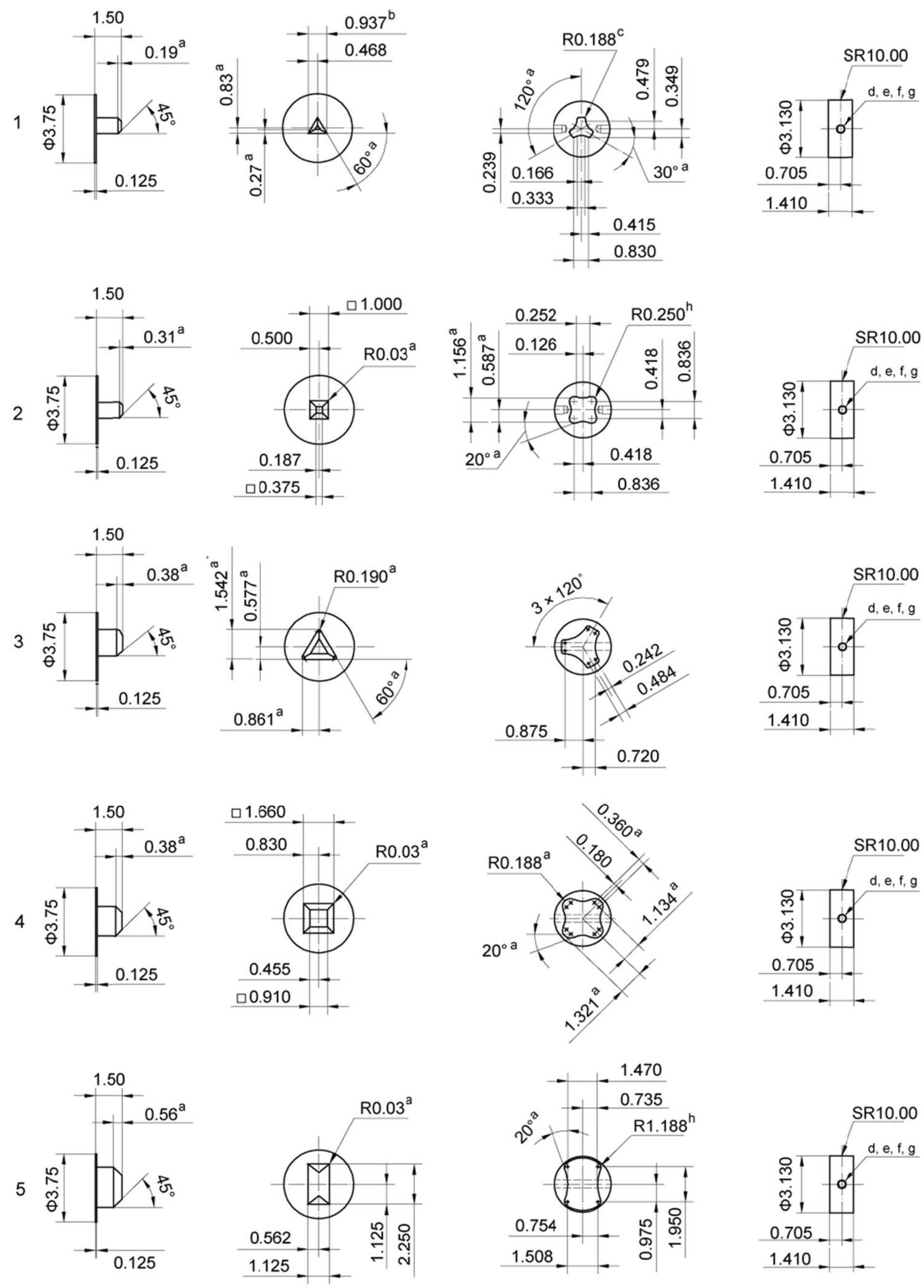
Figure B.2—Typical Seven-function Manipulator Envelopes

Annex C
(informative)

Alternative Designs for End Effectors

There are cases where there might be a requirement to ensure, in a positive manner, that valves cannot be subject to overtorque. To achieve this, a series of end effectors have been developed, applicable to the full range of torque values from 0 kN·m to 2.71 kN·m (0 lbf·ft to 2000 lbf·ft). Their designs are shown in Figure C.1.

Dimensions in millimeters (inches)



Key

1 $^{15}/_{16}$ in. triangle to 50 lbf·ft
2 1 in. square, 51 lbf·ft to 200 lbf·ft
3 2 in. triangle, 201 lbf·ft to 500 lbf·ft
4 1.66 in. square, 201 lbf·ft to 500 lbf·ft
5 (1 $^{1}/_{8}$ × 2 $^{1}/_{4}$) in. rectangle 851 lbf·ft to 2000 lbf·ft

a typical
b before radius
c three places
d $^{27}/_{64}$ drill × 0.75 DP
e 0.781 C bore × 0.10
f $^{1}/_{2}$-13 UNC-2B × 0.60 DP
g two places, 180° apart
h four places

Figure C.1—Alternative Profiles for End Effectors

Annex D
(informative)

Flowline Tie-in Systems

D.1 General

Flowline connection without the use of divers has been in use for a significant number of years. Connection and tie-in by diverless systems of flexible or rigid flowlines, umbilicals, or all these is a prerequisite for deepwater developments.

A typical connection system would consist of the inboard hub (mounted on the subsea tree or manifold), the outboard hub (connected to the end of the flowline), a seal plate, clamp, and the connection tooling.

The inboard hub normally has minimal movement in the horizontal plane and the flowline (outboard) hub is normally pulled in towards the inboard hub, where it locates onto the seal plate. The system is typically finally connected by clamp using the ROV tooling, which activates one or two jackscrews or a collet connector.

D.2 Connection Method

Pull-in of hubs can be in the horizontal plane, with or without buoyancy, or of a hinge and lockdown type assembly.

Hot stabbing for seal tests and also operation of jackscrews is normal.

A seal assembly and connection can also include hydraulic couplings.

The connector should:

— achieve a reliable diverless connection that is capable of being tested for its integrity (sealing will be either metal-to-metal or a combination of metal and elastomeric sealing),

— achieve a short-stroke connection minimizing hub movement and residual stress, and

— allow seal replacement.

Bibliography

[1] AIA National Aerospace Standard 1638 [5], *Cleanliness requirements of parts used in hydraulic systems* (superseded by SAE AS4059)

[2] ISO 4406 [6], *Hydraulic fluid power—Fluids—Methods for coding the level of contamination by solid particles*

[3] SAE AS4059 [7], *Aerospace—Cleanliness classification of hydraulic fluids*

[4] ISO 11218, *Aerospace—Cleanliness classification of hydraulic fluids* (DRAFT replacement for SAE AS4059)

[5] RAL color chart (www.ralcolor.com)

[6] Reichsausschuβ für Lieferbedingungen und Gütersicherung (RAL) (State Commission for Delivery Terms and Quality Assurance), 1927

[7] Munsell, A. H., *A Color Notation*, G.H. Ellis Co., Boston, Massachusetts, 1905

NOTE Munsell's original description of his system, *A Color Notation*, was published before he had established the irregular shape of a perceptual color solid, so it describes colors positioned in a sphere.

[8] Munsell, A. H., A Pigment Color System and Notation, *American Journal of Psychology* (University of Illinois Press), vol. 23, pp. 236–244, 1912

[9] U.S. Federal Standard 595:1989 [8], *Colors used in government procurement*

[10] DNV Standard for Certification No. 2.22 [9], *Lifting Appliances*

[11] IMCA AODC 035 [10], *Code of practice for the safe use of electricity under water*

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5 Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, Virginia, 22209, www.aia-aerospace.org.

6 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

7 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

8 General Services Administration, 1275 First Street, NE, Washington, DC 20417, www.gsa.gov.

9 Det Norske Veritas, Veritasveien 1, 1322 Hovik, Oslo, Norway, www.dnv.com.

10 International Marine Contractors Association, 52 Grosvenor Garden, London SW1W 0AU, United Kingdom, www.imca-int.com.

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