

Remotely Operated Tools and Interfaces on Subsea Production Systems

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Introduction

This Recommended Practice provides general recommendations and overall guidance for the design and operation of remotely operated tools comprising ROT, ROV and AUV tooling, used on subsea production systems for the petroleum and natural gas industries worldwide.

The third edition of this document incorporates the content of API 17TR15 and the Autonomous Underwater Vehicle (AUV) Interfaces in a Subsea Production Environment Recommended Practice produced by DeepStar® Phase XI.

This RP provides guidance when designing for subsea operations to interact with (or near) subsea production systems. The framework and specifications set out will enable the user to design the appropriate interface for a specific application.

Technical Report 17TR15 clarified and defined the most commonly used hot stab types, as well as documented some obsolete sizes. The goal of the technical report was to increase standardization, and to maintain backward compatibility and interchangeability with existing installations and with previous publications (API 17H, API 53, and API 16D).

Specific recommendations are provided where a standard design or operating principles has been adopted and are accepted as standard industry practice. 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

API Recommended Practice 17H provides recommendations for development and design of remotely operated subsea tools and interfaces on subsea production systems 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 ROV/ROT/AUV interfaces are covered by this standard. It is applicable to the selection, design and operation of ROTs, ROVs and AUVs including ROV tooling, hereafter defined as “subsea intervention systems”.

This Recommended Practice (RP) provides functional requirements and guidelines for ROV/ROT/AUV interfaces in subsea production fields for the petroleum and natural gas industries. It is applicable to both the selection and use of ROV/ROT/AUV interfaces related to subsea production equipment and provides guidance on design as well as the operational requirements for maximizing the potential of standardized equipment and design principles. This RP identifies the issues to be considered when designing for ROV/ROT/AUV operations to interact with (or near) subsea production systems. The framework and specifications set out enables the user (whether they may be on the ROV/ROT/AUV side or production facility side) to design the appropriate interface for a specific application. These interfaces include subsea docking, recharging, data transfer, data harvesting, and mechanical intervention.

It is anticipated that in the future, resident ROVs/AUVs near the seabed can provide high value for oil and gas inspection, monitoring, and maintenance and repair activities. The benefits of employing ROVs/AUVs in such situations include reduced operating costs and improved safety. The guidelines established in this RP leads to efficient development and deployment of ROV/ROT/AUV systems, providing clarity for operators, contractors, and developers. Recommendations have been provided in a flexible manner to accommodate a wide variation of AUV styles and applications, while maintaining an appropriate level of interface commonality for specification.

This document defines four major categories of hot stabs and describes the geometry to maintain compatibility across all manufacturers. The categories were first introduced in Technical Report 17TR15 which described several common or previously used hydraulic hot stab and receptacle configurations. The approach is to ensure backward compatibility of the hot stabs described in API Recommended Practice 17H, 2nd Edition and to align API RP 17H with API S53 and API 16D.

This RP is not intended to replace sound engineering judgment as to when and where its provisions are to be used. Users need to be aware that additional or differing details may be required to meet a specific service or local legislation.

This document is not intended 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 re-use intervention tooling in the interests of minimizing life-cycle costs and increasing the use of proven interfaces.

2 Normative References

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

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

API Specification 16D, *Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment*

API Recommended Practice 17A: *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 17F, *Specification for Subsea Production Control Systems* (2006)

API Standard 53, *Blowout Prevention Equipment for Drilling Wells*

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

ANSI C84.1, *For Electric Power Systems and Equipment—Voltage Ratings (60 Hertz)* (2011)

EEMUA Publication 194, Guidelines for materials selection and corrosion control for subsea oil and gas production equipment

IEEE 802.11b/g/n (*Wireless Local Area Networks*)

IEEE STD C62.41, *Recommended Practice Surge Voltages in Low Voltage AC Power Circuits* (1991)

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

autonomous underwater vehicle

AUV

Free-swimming submersible craft used to perform tasks such as inspection, data collection and transfer, and other general IMR tasks.

3.1.2

data harvesting

Methodology employed by an AUV and its associated equipment to capture and/or store data in a subsea environment.

3.1.3

data transfer

Methodology employed by an AUV and its associated equipment to allocate or relocate data in a subsea environment.

3.1.4

deployment system

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

3.1.5

design 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 or System Integration testing, or both.

3.1.6

design 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.

3.1.7

docking base

Bottom-founded structure (either gravity-based or installed with a suction pile or similar technique) or a feature that is structurally integrated with the subsea facility that is cabled either back to the subsea facility or connected to shore.

3.1.8

docking structure

Replaceable feature that is fitted with guide cones to accept the guideposts on the docking base and connectors on cables to mate with those on the docking base.

3.1.9

guideline

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

3.1.10

heave-compensated system

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

3.1.11

hot stab

Pressure balance coupling used for making temporary and permanent subsea fluid connections.

3.1.12

independent sensor

Any sensor which is not typically integrated into the rest of the subsea facility's customary sensing system and could include accelerometers, temperature sensors, strain gages, acoustic sensors, or others.

3.1.13

manufacturer

Company responsible for the manufacture of the equipment.

3.1.14

operator

Company which physically operates the subsea vehicle (delivery system).

3.1.15

payload

Amount of additional tooling weight carried on the vehicle when it is trimmed neutrally buoyant in seawater.

3.1.16

pull-in head

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

3.1.17

recharging

Methodology employed by an AUV or resident subsea vehicle and its associated equipment to replenish its onboard power source(s).

3.1.18**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.

3.1.19**observation ROV****OBSROV**

Small IMCA class I and II vehicles fitted with cameras/lights used for inspection and monitoring, that may carry sensors or inspection equipment and may have basic manipulative capability.

3.1.20**working ROV****WROV**

Large IMCA class III vehicles normally equipped with a five-function grabber and a seven-function manipulator and typically have multiplexing controls capability allowing for additional sensors and tools to be operated without the need for a dedicated umbilical system.

NOTE 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.

3.1.21**resident ROV**

Any sized IMCA class I, II, and III vehicles with various capabilities, distinguished as an ROV/AUV which is parked subsea for extended periods of time.

3.1.22**ROT system**

Dedicated, unmanned, subsea tools used for installation and 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.

3.1.23**ROV toolskids**

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

3.1.24**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.

3.1.25**subsea vehicle**

Generic term which refers to an ROV, AUV, UUV or ROT.

3.1.26**termination head**

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

3.1.27

tie-in system

Integrated or separate pull-in and connection related equipment.

3.2 Acronyms and Abbreviations

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

AC	alternating current
ANSI	American National Standards Institute
API	American Petroleum Institute
AUV	autonomous underwater vehicle
BOP	blowout preventer
BSP	British Standard Pipe
CCO	component change-out
CoB	center of buoyancy
CoG	center of gravity
EEMUA	Engineering Equipment and Materials Users Association
EMI	electromagnetic interference
FAT	factory acceptance test
FMECA	Failure Mode Effect and Criticality Analysis
HAZOP	hazardous operations
HIPPS	high integrity pressure protection system
HPU	hydraulic power unit
ICS	intervention control system
IEEE	Institute of Electrical and Electronics Engineers
IMCA	International Marine Contractors Association
IMR	Inspection, Maintenance and Repair
ISO	International Organization for Standardization
LARS	launch and retrieval system
MILSPEC	military specification
MPFM	multi-phase flow meter
MQC	multi quick connector
MTBF	mean time between failures
NAS	National Aerospace Standard
NPT	national pipe thread
Ø	diameter
OBSROV	Observation class ROV
OEM	original equipment manufacturer
PLEM	pipeline end manifold
PLET	pipeline end termination

ROT	remotely operated tool
ROV	remotely operated vehicle
RP	recommended practice
SAE	Society of Automotive Engineers
SAFOP	safe operations
SPS	subsea production system
TDU	tool deployment unit
TMS	tether management system
TR	technical report
USC	United States Customary (units)
UUV	unmanned underwater vehicle
WROV	work class ROV

4 Subsea Facilities Design

4.1 Intervention Philosophy

This RP is intended to take a system wide approach to the design and implementation of subsea interventions. When designing subsea vehicle interfaces for use on subsea systems, an interface and/or intervention philosophy, should be established. This philosophy should address the activities to be performed, the method of interfacing for each task, the type of tooling required, the method of stabilization of the vehicle by docking or positioning for the effective performance of its interfacing tasks, and access requirements. The interface philosophy should take into account the various interface tasks, rationalizing them so that a consistent method is adopted, as several tasks may be performed consecutively.

The design, configuration and operation of the subsea intervention system directly impacts on the lifecycle cost for the entire subsea production system.

The optimum design of subsea systems and associated remotely operated tooling system is achieved by utilizing a system design approach. The principle focus areas are the standardization of interfaces, equipment and intervention methods. Subsea intervention systems should be designed in parallel with subsea production systems to allow for efficient intervention solutions for the life of the field. This recommended practice addresses tooling design, design of intervention interfaces on the subsea equipment, and guidelines for implementing intervention systems.

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

The primary impact on the system design is to provide access for the interface for subsea vehicles and applicable tooling or interfacing hardware. Depending on the interface and/or intervention method and interface location, access requirements can vary significantly and therefore should be addressed early in the design and clearly documented in the interface and/or intervention philosophy. Equipment designed under this recommended practice should conform to the requirements of subsea facilities of which they form an integral part.

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 specific 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, as are the associated evaluation criteria used in selecting the interfaces incorporated into these recommendations.

4.2 Intervention Strategies

An intervention strategy is key to the development of an overall field architecture. The intervention strategy should be determined based on a multidisciplinary systems approach at an early stage of system engineering.

The intervention strategy selection may be based on use of a combination of tooling including ROT technologies.

NOTE ROVs can 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.

Equipment and intervention methods should be selected when establishing the intervention strategy.

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

Equipment should be designed for effective execution of the intended purpose under the anticipated environmental operating conditions. Simplifying interfaces and reducing transit hazards (entanglement, collisions) reduces the required complexity, reduces cost, and increases reliability.

The following issues should be addressed when developing an intervention 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 back-up 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) multi-purpose tools versus dedicated tools;
- k) the selection of mechanically operated tools versus hydraulically or electrically operated tools;
- l) reuse of intervention systems;
- m) wet storage of tools;
- n) categorization of critical and non-critical 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.

4.3 Intervention System Design

4.3.1 Subsea Intervention System Development

Subsea intervention systems should be designed 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).

The subsea intervention systems operating philosophy should be developed with the following design inputs:

- 1) availability requirements (logistics and mobilization time for equipment);
- 2) field-specific parameters (water depth, wave, current, seabed conditions and surface conditions);
- 3) intervention vessel requirements and interfaces (deck space requirement and deck layout);
- 4) vehicle requirements, including the number and class of ROV/AUV required to perform the various intervention tasks;
- 5) intervention task-specific parameters (planned versus unplanned operation, complexity, frequency and subsea interfaces).

4.3.2 Fail Free Interfaces

Interfaces for AUVs and their associated operating equipment should be designed so devices are released from the subsea equipment in the event of a power failure. This allows the AUV to be retrieved to the surface.

4.3.3 Minimizing Damage Potential

Interfaces should be designed so that the potential for damage is minimized during the positioning, docking, and operation of interface and/or intervention equipment. Any retrievable portion of the interfacing, including the part(s) attached to the vehicle, should yield before damage occurs to the subsea equipment.

4.3.4 Load Reaction

Loads imposed on the interface by the interface and/or intervention equipment should be used in the design. Generally, interfaces where the loads are transmitted directly into the structure are preferred where complex load paths through the equipment/structure are required.

4.3.5 Minimizing Interference

Interfaces should minimize potential entanglement and snagging with interface or intervention equipment, or both.

4.3.6 Positioning Control

In performing tasks on subsea equipment, a positive means of stabilization should be provided (see 6.3), minimizing the need for the subsea vehicle or intervention tooling thrusters to be used for positioning control while physically in contact with the equipment. This does not preclude the use of a constant horizontal or vertical thrust to ensure interfaces remain in contact throughout the interfacing or intervention operation, or both.

4.3.7 Temperature Requirements

Subsea equipment should be designed and rated to operate throughout a temperature range of 5 °F to 113 °F (−15 °C to 45 °C). For specific geographical areas where lower temperatures can occur (e.g. arctic areas), these should be considered in the equipment design.

4.4 Typical Components

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) subsea vehicle spread interface with equipment and tools.

4.5 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) subsea vehicle assisted guidance.

4.5.1 Hot Stab Operations

Hot stabs may be operated by a manipulator, deployment tool or diver. 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.

Grab bar positioning relative to stab interface can influence risk of seal damage. A linear action by the manipulator reduces risk of seal damage.

4.6 Typical Subsea Vehicle Configurations

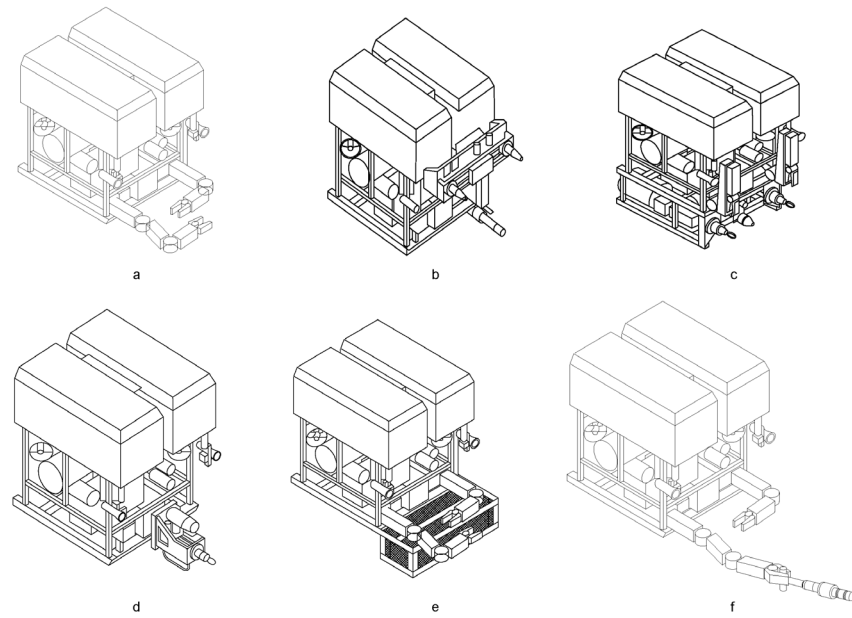
Subsea vehicles are essentially configured for carrying out intervention tasks in six ways (see Figure 1):

- a) with manipulators for direct operation of the interface (Figure 1a);
- b) with TDUs (Figure 1b);
- c) with toolskids mounted on the external surface of the vehicle, either underslung, rear, front or side mounted (Figure 1c);
- d) with single point docking tool (Figure 1d);
- e) with support by an external underslung basket which is used to store commonly used 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 normally have a base configuration consisting of a left hand, five-function grabber arm and a 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 subsea vehicles and intervention vessels of opportunity. For the purpose of securing access for safe and efficient intervention operations, a dimensional envelope, representing the majority of subsea vehicles in the market is specified (see 6.2.1).

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



Key

- a ROV/AUV with manipulators
- b ROV/AUV with twin-point docking tool delivery system
- c under-slung tool skid and front-mounted frame
- d single-point docking tool delivery system
- e ROV/AUV with external basket
- f ROV/AUV with external handheld tooling

Figure 1—Typical Work Class ROV/AUV Operationally Configured

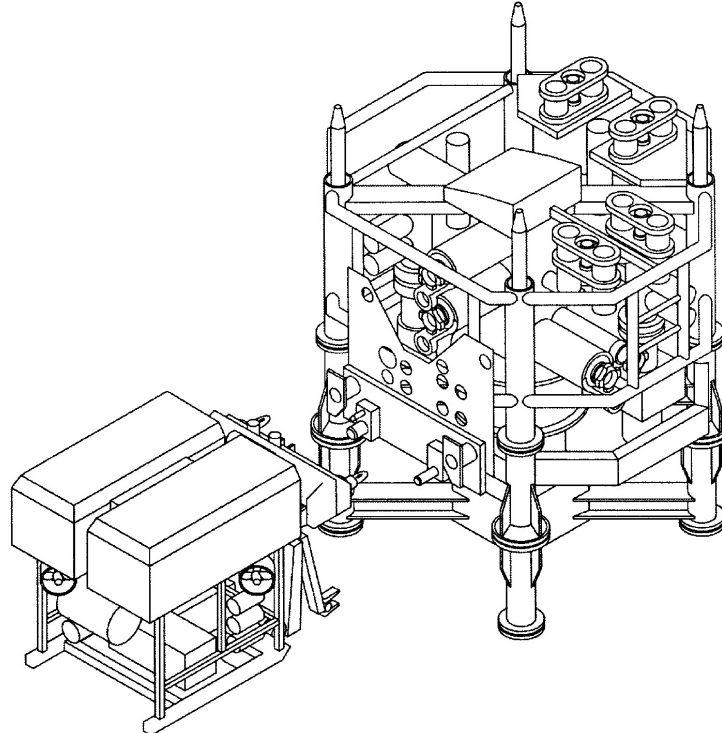


Figure 2—Typical Interfaces on a Subsea Tree

4.7 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, inspection, vessels equipped with moon pools and dedicated handling systems, have been used extensively to allow for year-long operations, while other areas less exposed to wind and sea have used standard supply vessels.

4.8 Component and Module Intervention

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

A lift line or drill pipe can be used to deploy subsea components and modules which are too heavy to be carried by a subsea vehicle.

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 which are initially deployed subsea by a crane or winch. The tool could then be used and manipulated by ROV/AUV and flown to the working location.

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

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

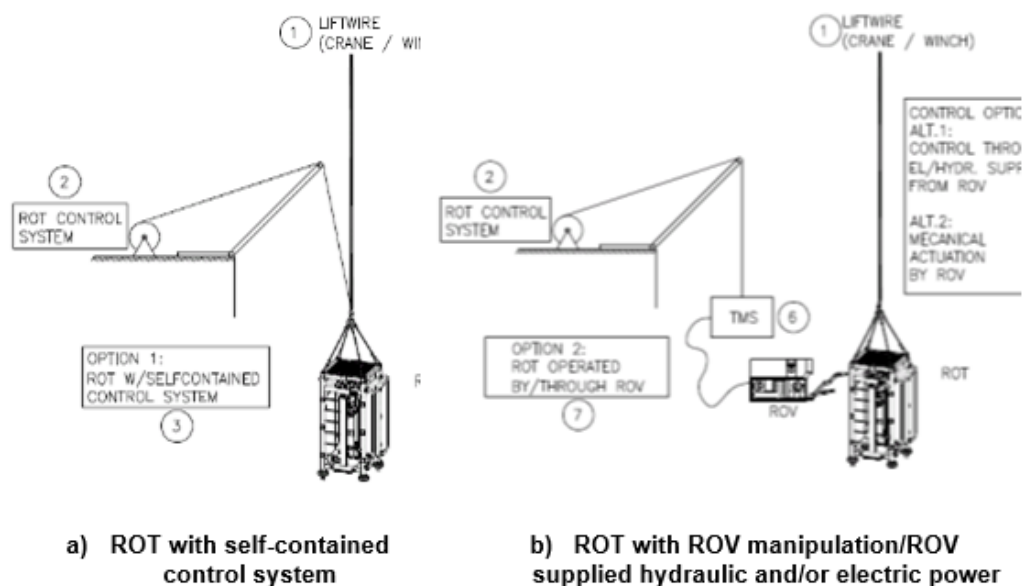


Figure 3—Typical ROT Configuration

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.

4.9 Tie-in Systems

Diverless tie-in systems are used for connection of rigid flowlines, flexible flowlines, and umbilicals to subsea equipment. Tie-in systems may require the use of ROV/AUV/ROT or a combination of these to complete the connection and testing of the tie-in hardware. The tooling involved may range from a simple hydraulic hot stab or torque tool through to an integrated bolt/nut handling mechanism.

Typical operations that may need to be completed during tie-in include:

- Assistance with alignment;
- Installation or replacement of a seal plate;
- Actuation of a clamp or collet;
- Actuation of connection/pull-in tooling;
- Installation or removal of pull-in heads, pressure caps, debris caps etc.;
- Testing of pressure/seal;
- Actuation of locking mechanisms;
- Inspection of connector status.

4.10 System Interfaces

4.10.1 General

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

4.10.2 Equipment

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

- Equipment performance data
 - specific utility requirements (e.g. air, water, electricity, fluids);
 - specific communications protocols with control system;
 - video and data output capabilities;
 - equipment dimensions; operational footprint (e.g. ROV/AUV panel docking);
 - depth rating;
 - Center of Gravity (CoG) and Center of Buoyancy (CoB);
 - weight in water/in air.
- Interface data
 - electrical and hydraulic connections (including electrical supply requirements);

- hydraulic requirements (e.g. fluid, flow, torque, number of turns, pressure, cleanliness);
- deployment and handling requirements.
- Transport data
 - dimensions, footprint, inclusive transport container etc.;
 - seafastening and deck load distribution;
 - utility requirements (e.g air, water, electricity, fluids);
 - subsea vehicle topside equipment interface requirements;
 - system layout drawings/equipment drawings/pictures;
 - contact information.

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

- handling and operation instruction including maintenance and preservation;
- technical description and component identification including pictorial representation (for spare part ordering);
- interface data;
- equipment performance data;
- lifting certificates;
- outline operation procedure;
- hydraulic schematics and electrical wiring diagrams;
- maintenance, preservation and storage program;
- drawings.

5 Design Recommendations

5.1 General

5.1.1 Conceptual Design

5.1.1.1 Assessment of Requirements

During subsea production equipment design, all the operational tasks required for installing, operating, inspecting, maintaining, repairing, and recovering interface elements of the subsea production system should be identified and assessed.

The following issues should be addressed as a minimum:

- a) The need for deployment of a subsea vehicle services, and if the requirement can be met using non-interfacing means;

- b) The frequency of the operation/task;
- c) The sensitivity of the operation (e.g. critical/highly desirable/helpful);
- d) Subsea facility abandonment;
- e) Subsea vehicle access requirements;
- f) The expected field life of the overall subsea system;
- g) Planned (primary) intervention task;
- h) Unplanned task (contingency).

5.1.1.2 Failure Mode Effect and Criticality Analysis (FMECA)

It is recommended that an FMECA of the system installation be performed for operations contemplated to be performed by subsea vehicles. The FMECA should address all phases of the system's lifetime, ranging from installation to recovery. It should determine the relative criticality of the subsystems/components, based on the effect of a failure and the expected mean time between failures (MTBF).

5.1.1.3 Method of Interfacing/Intervention

Examine the method of solving the identified tasks using a subsea vehicle-based system, or tooling systems, or both. By classifying the subsea interfacing and/or intervention requirements/applications, the alternative means of conducting the interfacing and/or intervention can be evaluated and the most appropriate method selected for simplification and ease of execution.

5.1.1.4 Frequency of Interfacing/Intervention

Frequent interfacing and/or intervention could depend on many factors but is driven by the need to replace components due to their reliability or performance and frequency of adjustment or actuation.

If a case is made for frequent interfacing and/or intervention, the selection of interfaces should be based on simplicity and reusability.

5.1.1.5 Standard Tooling

Where there are large numbers of items for which interfacing and/or intervention could be conducted by a similar method, a standard interface or tool should be used where possible, to avoid frequent tooling re-fitting.

5.1.1.6 Loading

5.1.1.6.1 General

The design shall address the various loading conditions that subsea vehicles impart during subsea operations. These loads may act individually or concurrently and should be included during the design phase.

Loads are applied to the subsea vehicle and equipment interface by:

- a) Tooling engagement and reaction;
- b) Environmental forces (current and, in exceptional circumstances, waves);
- c) Installation/removal forces;
- d) Interface/tooling forces;

- e) Impact due to collision between a subsea vehicle and subsea equipment;
- f) ROV/ROT tether (if required).

5.1.1.6.2 Design for Loading

The following approaches to interface loading design are available:

- a) Design of the interface to accommodate all loads described in 5.1.1.6.1;
- b) Limiting of the forces that can be applied to the interface (e.g. limiting maximum thruster forces);
- c) Accepting that damage occurs under certain load conditions.

The combination of loads should be analyzed, and the maximum combined load should be identified; it may not be necessary to design the interfaces to accommodate the maximum sum of all loads.

5.1.1.6.3 Tooling Forces

Subsea vehicle interface or tooling forces should be limited so that under normal operation they cannot damage the equipment tool interface being operated. Where provisions on the tool exist to permit "overload" forces to be applied, there should be a mechanism other than operational procedures to prevent this (e.g. simple cover over operating switches, function interlocks, or software control, etc.).

5.1.1.6.4 Currents

Currents inherently act on any subsea vehicle. The following loads should be addressed:

- a) Drag force on vehicle hull (or tethers etc.) thus affecting vehicle maneuverability in the areas of interfacing or intervention, or both;
- b) Drag forces on vehicles carrying equipment or equipped with tooling packages or payloads;
- c) Current affecting visibility and navigational instrumentation during near-seabed operations;

Adequate clearance in the areas of interfacing and/or intervention should be provided.

5.1.1.6.5 Collision

Unprotected subsea facilities and components which may be physically impacted by a free-swimming subsea vehicle should resist collision damage when the vehicle (typically a vehicle with associated entrained water) is traveling, at a minimum, at 5 ft/s (1.5m/s).

However, the impact velocity may be reduced if the subsea vehicle is maneuvering within a structure or is anticipating docking. Subsea vehicle velocities should not exceed 1 ft/s (0.3 m/s) when operating near or inside infrastructure. An impact analysis is recommended during the design process.

5.1.2 Detailed Design

Following the assessment of the requirements for vehicle interfacing and/or intervention (see 5.1.1.1), an interface and/or intervention philosophy for the subsea system should be established to reduce the number of different intervention techniques and interfaces required. Design inputs include the following:

- Definition of intervention tasks;
- Compilation of specification(s) for interfaces, generally in association with the relevant subsea vehicle contractor and subsea equipment supplier;

- Choice of docking and interface/tool deployment philosophies;
- Definition of interfacing and/or intervention (at this point the interfaces should be identified, addressed and specified at system, sub-system, and component level and, once specified, their use and incorporation in the design rigorously monitored throughout the construction and installation phases);
- Definition of the host subsea facility detail design for subsea vehicle interfaces for tool operation;
- Definition of the intervention tooling, interfaces, onboard power storage, and controls;
- Documentation (design, maintenance, and operating philosophies);
- Ensuring sub-system suppliers are providing equipment which supports operation and interface and/or intervention requirements and techniques are in accordance with the overall design philosophy for the subsea installation;
- The effort in the design phase should be focused on those areas of the subsea system that are the most susceptible to failure. Those assemblies should be thoroughly examined and designed for simplicity, durability, and redundancy or ease of replacement;
- During the design phase of the subsea production equipment, the location and running of control lines/cables should be planned to ensure avoidance of interference with subsea operation. This design input is particularly important when these items are to be site run during the construction phase.

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 following guidance outlines those features of the system which should be included at the design stage.

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.

Design functionality includes:

- a) a means of moving subsea intervention equipment on deck (skid systems versus use of intervention vessel cranes);
- b) a means of deploying and landing subsea intervention systems (winches and simple mobile A-frames versus use of complex purpose-made, heave-compensated systems);
- c) a 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 conditions affecting the operation and time available to carry out operations.

The following recommendations apply:

- 1) Skids and baskets for the various tools and the involved modules should provide safe and efficient transportation and deck operations.
- 2) Lifting points should be designed according to a recognized lifting standard (e.g. API 17D, BS 7121–2).
- 3) each tool, including the tool skids, 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.
- 4) The tool skids and baskets should be balanced for safe lifting and handling with the dedicated tool and, when applicable, with the replaceable module installed.
- 5) 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.
- 6) When required, tool skids 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 equipment and tools used during the deployment and landing phases during an intervention.

The following recommendations apply:

- a) Operations in which sensitive components, as part of the subsea system, are involved should be performed in a two-step sequence. The ROT should be landed and sufficiently secured prior to manipulation of sensitive components, e.g. hydraulic lines.
- b) 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 include emergency operations, for example 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 the subsea area in which sensitive components are exposed at the same level as the ROT.
- f) 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 clearance while on guidelines and 0.2 m while on guideposts should be provided. Cursor systems, guidecones and guideposts should be secured to avoid movements above the tolerance limits [1.0 m topside and 0.2 m subsea]. Running clearances for guidelineless systems needs to be defined. Protection of surrounding equipment by use of bumper bars may be used.

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

- 1) Winch load calculations shall be in accordance with the relevant standards and regulations such as DNVGL-ST-0377 and DNVGL-ST-0378;
- 2) Constant-tension winches should allow for instant and direct switchover from normal operation to constant tension;
- 3) As well as local control, the winches should be equipped with a mobile remote operation to ensure a safe and well-monitored operation;
- 4) The lifting winch or deployment system should include a facility for depth display during operations;
- 5) An overload protection system should be incorporated when selecting winches.

5.2.3.2.2 Guideline Winch System

The following recommendations apply:

- 1) Guideline winches should include an adjustable constant-tension mode, with the capacity to operate with the guideline in tension during maximum design operation condition;
- 2) The guideline winches should have a defined operational tolerance (e.g. +15 % to –30 % of set value);
- 3) 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);
- 4) 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:

- 1) 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.
- 2) Umbilical winches should include an adjustable constant-tension mode, with the capacity to operate with the umbilical in tension during maximum design operation condition.
- 3) Umbilicals should have a system for easy attachment to the lift wire, when applicable.

- 4) 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:

- 1) a low-grease and torque balanced design of lift wires;
- 2) 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 and deployment subsea, should be developed with the following inputs:

- 1) safe handling of equipment in the work area;
- 2) intervention vessel facilities (a vessel typical for the geographic area used as a basis, if no specific intervention vessel has been selected);
- 3) intervention system design (size, weight, and shape);

The following apply:

- a) Manual handling of equipment should be limited to 53 lb (25 kg). 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 tool skid systems are given in 5.2.2.
- c) Access to the master link for lifting should be from deck level.
- d) During the design phase, the placement of access aids such as ladders, footrests, handholds, temporary gratings and attachment points for safety lines and fall-arrest systems shall be included in the design.
- 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 addressed. 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) Dedicated sea-fastening attachment points should be clearly marked "For sea-fastening only", Each sea-fastening point should be designed 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 Intervention Tools

5.3.1 General

Size, shape, CoG of intervention tools, and equipment should allow for safe and efficient operations by use of a subsea vehicle.

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

If the weight limit must be exceeded, special handling procedures should be developed.

ROV/AUV operated tools should have the ability to visually monitor their actions through the subsea vehicle in case of a control system malfunction (e.g. hot stab pressure gauge port, torque tool turns counter).

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

5.3.2 Subsea Vehicle Mounted Skids

The height, width, and overall length of the tool skid package and its mounting position on the vehicle should be designed for any space restrictions in the launch and recovery system, particularly for moon pool or hanger deployed systems.

The recommended size for an under-slung tool skid is less than 20 in. (0.5 m) in height, length, and width in accordance with the subsea vehicle envelope.

Weights of the skids should be checked versus through frame lift capacity of the selected vehicle.

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

The center of buoyancy and center of gravity should allow the skid to maintain operational orientation without requiring correction, such as ballast or thrust from the ROV.

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

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

The global weight of the subsea vehicle including the skid and the TMS shall not exceed the safe working load of the LARS.

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 between steps 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, to recover the tool.

5.5 Subsea Intervention Tooling Control and Actuation

5.5.1 General

A variety of control systems and actuation principles for the tools have been established for ROT and tooling systems.

This section addresses recommendations for control and actuation of ROT or subsea tooling within the following main categories:

- a) self-contained intervention control system;
- b) control systems controlled via the subsea vehicle control system;
- c) mechanical actuation; and
- d) deck pack for testing, cleaning, removal of water and replacement hydraulic fluid.

5.5.2 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 operating parameters such as:

- a) pressure;
- b) flow;
- c) position indicators;
- d) self-diagnostics;
- e) interlocks;
- f) data logging; and
- g) operating parameters as applicable (e.g. torque etc.).

5.5.3 Self-contained Intervention Control Systems

5.5.3.1 General

Self-contained intervention control systems (ICS) may be used for the control and monitoring of ROTs. The independent control system configuration may include one or more of the following systems:

- a) surface control system;
- b) surface/subsea communication;
- c) subsea control system.

Functional requirements for the ICS should include:

- 1) Hydraulic control components should meet standardized pressure classes.
- 2) The capacities of the electrical and hydraulic systems in the ICS should provide for some increase in the number of functions.
- 3) 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.
- 4) When selecting the hydraulic fluid, compatibility with interfacing equipment, i.e. subsea vehicle control systems and workover systems, shall be evaluated. If required qualification and compatibility verification should be conducted.
- 5) Separate purifier drain and fill connections should be fitted to all hydraulic reservoirs.
- 6) All electrical equipment should be water-ingress-protected and have active electrical insulation monitoring. (For example, in accordance with "IMCA AODC 035, *Code of practice for the safe use of electricity underwater*").
- 7) The equipment should be supplied complete with all necessary interface piping, instrumentation, cabling and deck jumpers to avoid on-site installation, except for connecting the units.
- 8) 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.
- 9) 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.
- 10) Multi-connectors should be evaluated to reduce hook-up time.
- 11) The same type of fitting should be used for the same pressure classes.
- 12) The number of different types of fitting should be minimized throughout the system.

5.5.3.2 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 subsea 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.

5.5.3.3 Surface/Subsea Communication

The following recommendations apply to an ICS with a dedicated umbilical.

The umbilical may be clamped to or wrapped around a lift wire or designed with armoring to provide lifting capability without transmitting unwanted loads to individual internal umbilical tube/conductors or to the connections to the ICS.

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/liftwire can be used. The combined umbilical/lifting wire shall be certified according to an applicable standard such as DNVGL-ST-0377 and DNVGL-ST-0378.
- d) Umbilicals 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) Umbilicals containing hydraulic lines and which include a hydraulic return line, should always have a pressure higher than ambient pressure in the return line to prevent seawater ingress. Alternatively, other suitable seawater ingress-prevention facilities may be used.
- 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. (For example, in accordance with “IMCA AODC 035, *Code of practice for the safe use of electricity underwater*).

- 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 subsea vehicle/ROT in case of intervention vessel drift-off.

5.5.3.4 Subsea Control System

The following recommendations apply:

- a) The subsea intervention system may be operated by use of a subsea HPU, either subsea tool-mounted or via a subsea vehicle.
- b) The HPU installed should be mounted on a sub frame 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 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.
- h) When interfacing with a subsea hydraulic control system, fluid compatibility should be addressed to prevent contamination.

NOTE It is best to use the same working fluid or a fluid which is compatible. Alternatively, a hydraulic motor/pump unit placed in the subsea vehicle skid can be used to avoid interference of hydraulic fluid between the subsea vehicle system and the subsea intervention system.

5.5.4 Vehicle-based Control Systems

Subsea vehicle control systems may be used for the control and monitoring of ROT. The vehicle-based control system falls within the following main configurations:

- a) hydraulic power supply from dedicated umbilical from surface and control signals from a subsea vehicle;
- b) hydraulic power and control signals supply from a subsea vehicle.

5.6 Indicator Systems

Remote interface operation may require supplementary feedback by a video camera or other instrumentation on the subsea vehicle to verify proper operation. This indication can be achieved by various means, but the indication system should conform to the following guidelines.