SPECIFICATION, SUBSEA - INTERVENTION/TIE-IN, ROV INTERFACE HANDBOOK - DESIGN GUIDELINES

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	6147725	26-SEP-2013	Aamodt, Oyvind	Youkhana, Roni Khamo	RELEASED

Summary:

This document will give the guidelines to design subsea intervention equipment, ROV tooling and interfaces for easy operation by any ROV.

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ABBREVIATIONS

The following abbreviations are used throughout this document.

Abbreviation	Description
API	American Petroleum Institute
COB	Centre of Buoyancy
COG	Centre of Gravity
DNV	Det Norske Veritas
DWG	Drawing
EQ	Equipment Number
HPU	Hydraulic Power Unit
ISO	International Standards Organization
MQC	Multi Quick Connector
N/A	Not Applicable
NORSOK	Norsk Sokkels Konkurranseposisjon
Obs ROV	Observation ROV (Class I and II)
OMM	Operation and Maintenance Manuals
P/N	Part Number
ROT	Remotely Operated Tool
ROV	Remotely Operated Vehicle
SIT Camera	Silicone Intensified Target (Low Light) black & white video camera
SWL	Safe Working Load
TMS	Tether Management System
TST	Test Procedure
WROV	Work ROV (Class III and IV)

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1.0 INTRODUCTION

1.1 GENERAL

Remote Operated Vehicles (ROV) has been used in the subsea oil industry since the middle of the 1970's. But it is only recently that these vehicles have performed extensive intervention tasks. The success of an ROV operation is fully dependent on three major factors. These are:

1. The ability to design and arrange the subsea equipment for easy ROV access and operation

2. The ability to design the ROV tooling and interfaces for easy operation by any ROV

3. The ROV operators and pilots ability to easily understand and operate our equipment

This document shall focus on the two first factors, while the Operation and Maintenance Manuals (OMM) shall cover the third factor.

1.2 PURPOSE

The purpose of this document is to define all standard interfaces related to ROV's and ROV Intervention on FMC Subsea Equipment.

1.3 SCOPE

The scope of this document is to give the designers at FMC a common understanding of how to design interfaces related to ROV operations, and to ensure that the limitations and capabilities of ROVs are fully taken into account during the design process.

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1.4 REFERENCES

Source of information is referred in brackets [API, ISO, FMC, etc.].

NOTE

All places where API is mentioned in this document we refer to API 17 D and/or H, (Ref. section 1.7)

1.5 FMC ROV INTERVENTION PHILOSOPHY

1. ROV Intervention equipment shall be designed to minimize potential damage to and/or entanglement to or with

   a) Subsea equipment

   b) Intervention tooling

   c) ROV

   d) Wires and umbilicals

   e) Operating personnel and the environment,

   [API, ISO, FMC, NORSOK, etc.]

2. Retrievable parts of the intervention interfaces shall be designed to yield before damage occurs to the portion fixed to the subsea equipment. (API)

3. All equipment must be designed so that in the juncture of a power failure to the ROV or the intervention equipment, all devices which could attach the ROV to the subsea equipment is released in a reliable manner allowing the ROV to be retrieved to the surface. (API)

4. ROV Tools shall be delivered as complete stand-alone units, requiring no extra parts except power supply. (NORSOK).

5. All ROV tools shall be delivered in dedicated transportation boxes suitable for offshore handling. The boxes shall include a user manual for the equipment. (NORSOK)

6. Interfaces that comprises rotary action shall use (ISO13 628-8 (API 17 H) wherever practical possible. (FMC)

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1.6 FLOW DIAGRAM FOR ROV INTERFACES AND TOOL

Activity	Design review	Check questions
Define ROV Interface Tool		
Make Interface Data Sheet and Technical Data Sheet (if applicable)		
	DR 2	
	Design Review on Interface Data Sheet and Technical Data Sheet with ROV specialist	• Specific requirements from project • Demands in standards • Interface standardization • Demands on force in operation • Demands on ROV forces • ROV access demands • Lifetime • Etc.
Check if existing design can be used (in cooperation with product team)		
Establish GA and Interface drawings		
	DR 3	
	Design review of assy towards Interface Data Sheet and Technical Data Sheet with ROV Spec	Demands for / on: • Qualification testing • FAT • OMM • Calculations • Total weight • Packaging • Etc.
	Freeze Interface	
	Release Interface Data Sheet	

to be continued

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Activity	Design review	Check questions
Make detailed drawings		
	DR 4	
	Design Review of detailed drawing with ROV specialist	
	Release Drawings	
	Release Technical Data Sheet	
Write FAT/input to FAT procedure		
Final documentation		

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1.7 REFERENCES

Document	Title
AODC 051	Guidance Note on Safe and Efficient operation of ROV's
API 17D	Design and Operation of Subsea Production Systems-Subsea Wellhead and Tree Equipment
API 17H	Remotely Operated Tools and Interfaces on Subsea Production Systems
ISO 11218	Fluid cleanliness
ISO 13628-1	Colors and Markings
ISO 13628-8	ROV tooling Interfaces
ISO 13628-9	Remotely Operated Tooling (ROT) (Subsea Intervention Systems)

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NOTE

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1.8 DEFINITIONS

1.8.1 General

Expression	Explanation
Subsea Intervention	Installation / Retrieval of sea lines, modules and components, inspection and survey, maintenance and repair work carried out subsea. Vertical wellbore intervention and internal flow line inspection are excluded.
IMR	Intervention, Maintenance & Repair
Subsea Intervention System	All equipment involved in the intervention task
ROV Intervention System	Buoyant intervention system where the primary intervention tasks are performed by a standard Work ROV.
ROT System	Remote Operated Tool system is dedicated, unmanned subsea tools used for installation, inspection, maintenance and repair tasks that require lift and/or handling capacity beyond that of free swimming ROV systems.
Primary Intervention tasks	All scheduled intervention tasks
Back-up Intervention tasks	Prepared intervention task used when primary intervention method failed
Contingency Intervention task	Performance of a prepared but unscheduled intervention task.
Shallow Water (diver depth)	Down to 180 meter (diver depth)
Deep Water	Down to 1 000 meter as the limit for guidelines
Very Deep Waters	Below 1 000 meter water dept

1.8.2 ROV Classification

Class	Use
Class I	Pure Observation (Obs ROV)
Class II	Observation with payload option (Obs ROV)
Class III	Work Class Vehicles (WROV)
Class IV	Towed or Bottom Crawling Vehicles (WROV)

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1.8.3 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:

- Surface guideline systems
- Guideline less systems
- Subsea deployed guideline systems
- Thruster assisted systems
- ROV assisted guidance

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2.0 ROV CAPABILITIES

2.1 GENERAL

Although some manufacturers of ROV's claim they produce them in series, ROV's are almost always different from one another. This means that the general Data Sheet may not be correct. A consequence of this is that it is difficult to establish standard values on the performance of ROV's. Below is given some information as a design guideline for those who are interfacing ROV's and ROV operations.

As the newer generation ObsROV and Work Class ROV's (WROV) contains a lot of nice new features, the values given below may be conservative. It is however FMC philosophy to design equipment that can be operated by almost all ROV's available on the market.

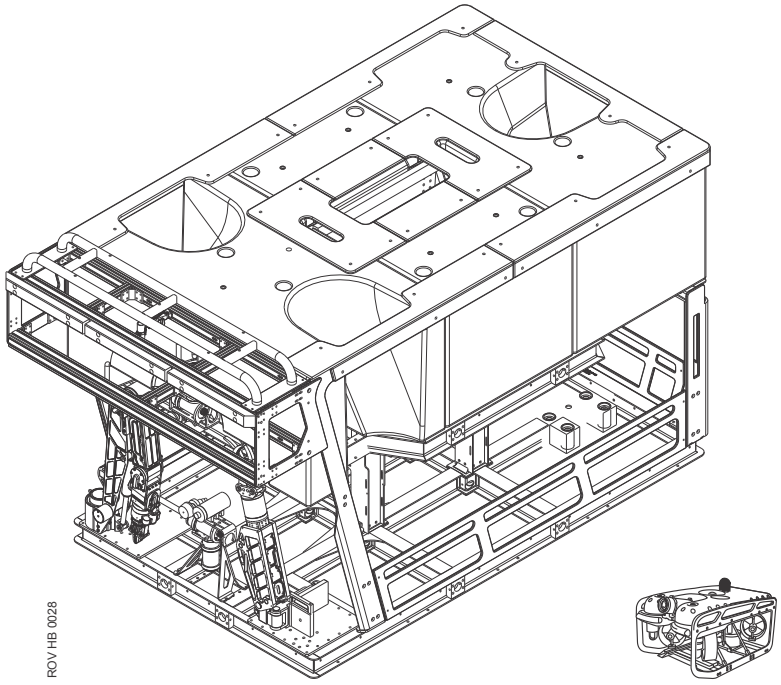

Figure 1: Examples of a WROV (left) and an ObsROV (right) in the same scale

Table 1: Examples of ROVs size and weight

	Length	Height	Width	Weight
WROV	3 000 mm	1 800 mm	1 500 mm	3 200 kg
ObsROV	1 000 mm	500 mm	600 mm	50 kg

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2.2 OBSERVATION ROV (CLASS I AND II)

The ObsROV is an electrical vehicle and is normally equipped with one or two video cameras, scanning sonar and lights. These types of ROVs are mostly used for observation and documentation purposes.

Some ObsROV models can be equipped with one manipulator and a range of small capacity hydraulic tools.

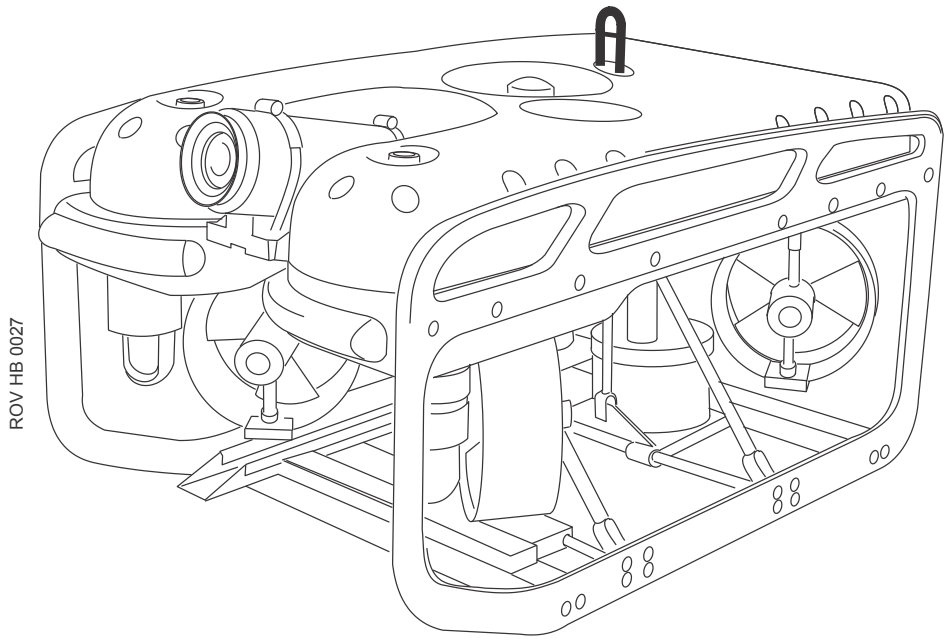

Figure 2: Observation ROV with a single camera and lights

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2.3 WORK CLASS ROV (CLASS III) TYPICAL VALUES

The Work ROV is a large vehicle with 5 to 9 hydraulic thrusters, several video cameras and one or two manipulators.

Specifications will vary from the older to the newer types. Information's given here are typical values and should only be used for general information.

ROV	Data
Left Hand Manipulator, common configuration capacity (e.g. Shilling Robotics "RigMaster")	• 4 or 5 function grabber arm with approx. 0.5 to 1.3 meter reach. • Gripper opening may vary from approx. 100 mm to 300 mm. • Claw rotate torque, 50 -200 Nm • Wrist rotate: Continuous (typical on modern units)
Right Hand Manipulator, common configuration capacity (e.g. Shilling Robotics "Atlas")	• 7 function manipulator with approx. 0.3 to 1.7 m reach • Gripper opening, max nominal 200 mm • Claw rotate torque, 50 -200 Nm • Wrist rotate: Continuous (typical on modern units)
Video cameras	• Several separate Video channels and One Color and one SIT camera mounted on a pan and tilt unit in front of the ROV between the manipulators. • Some vehicles carry a manipulator camera in addition.
Lights	• 4 x 600W switch and dim channels (typical)
Speed performance	• Approx. 2 to 3,5 knots in horizontal plane using 4 thrusts • Approx. 2 knots vertical movement, using 3 thrusts **NOTE!** Subsea current, ROV's mass and dimensions will influence speed and performance.
Payload	• Typical 200 kg or more, but may only be 50 kg on some old ROVs
Hydraulic Output Pressure	• 140 to 207 bar / 2 030 to 3 000psi (typical) • ROV Hydraulic circuit will always give 1-5 bar over - pressure to avoid water ingress
Hydraulic Supply Flow	• Typical flow 15-20 l/min
Spare Valve functions	• Minimum two

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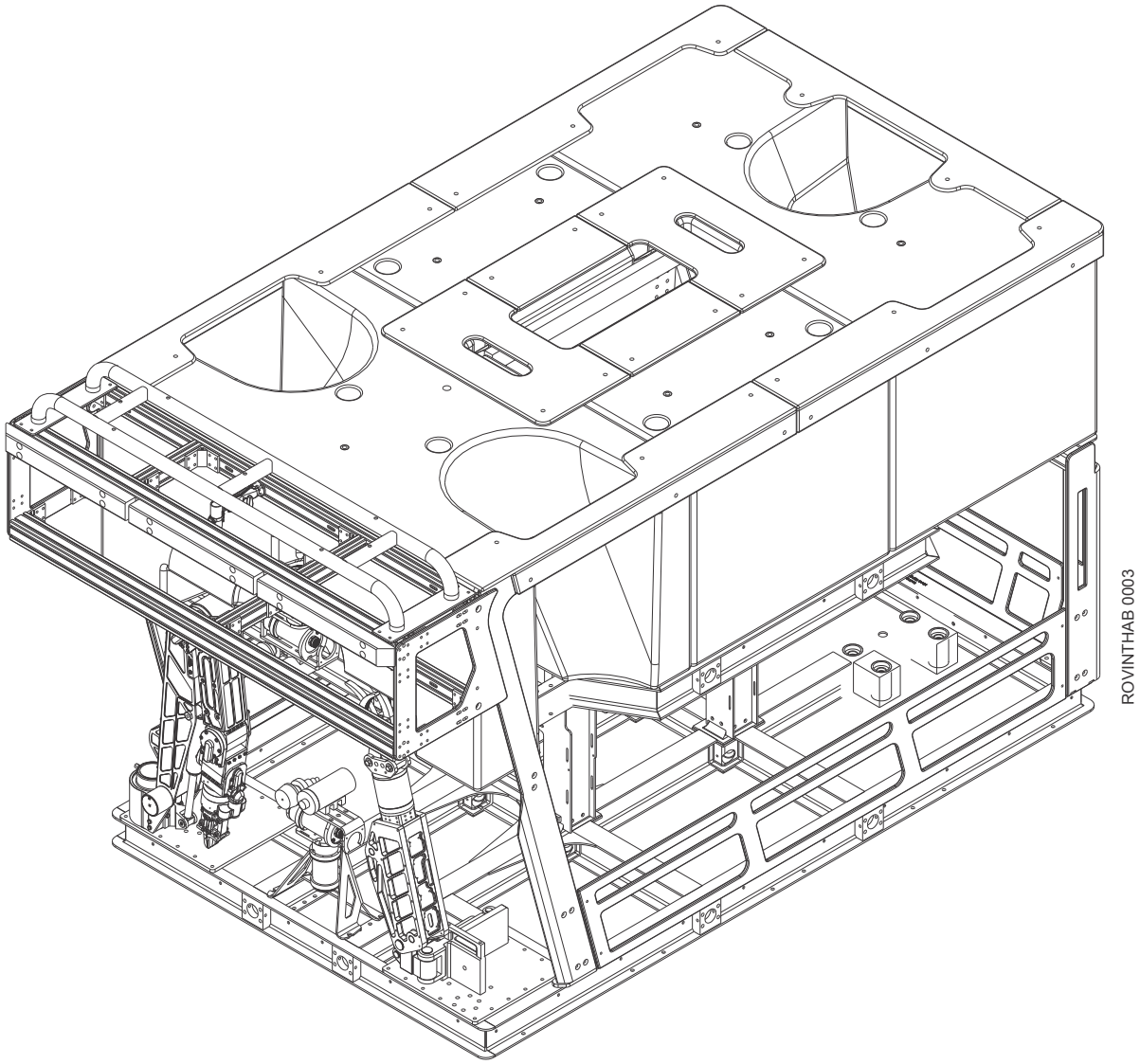

Figure 3: WROW with one 4-function manipulator (left) and one 7-function manipulator (right)

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2.4 ROV MANIPULATORS

2.4.1 Manipulator Operation area

Range of manipulators varies depending on number of functions, see examples in Figure 4 and Figure 5.

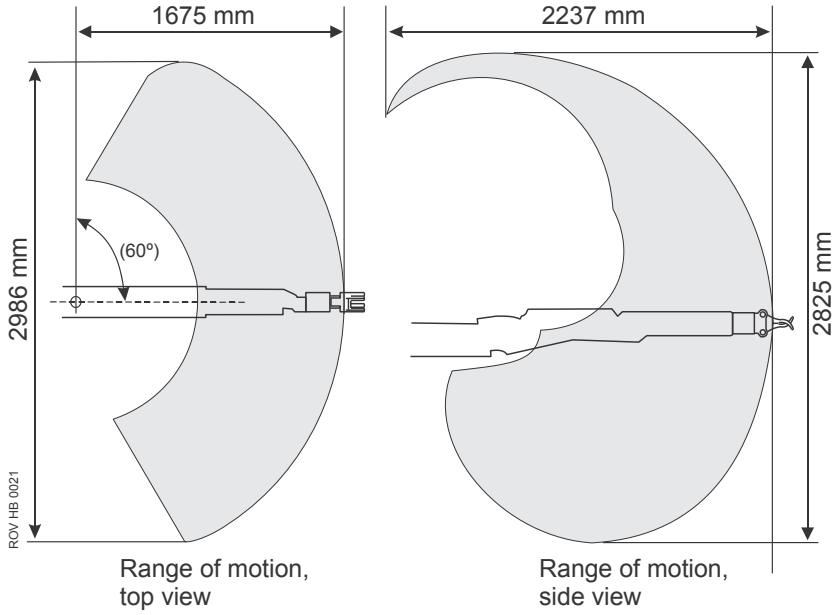

Figure 4: Range of motions for a 7-function ROV Manipulator, example

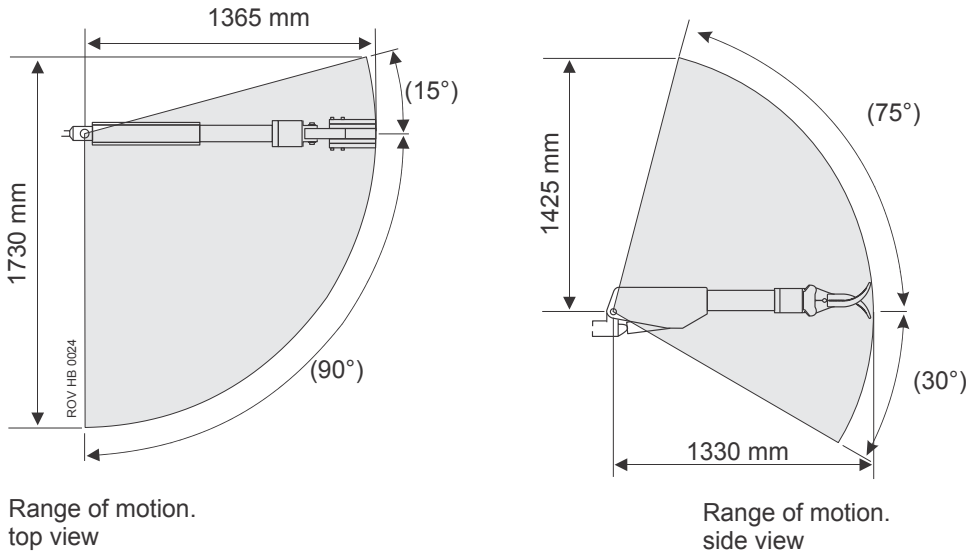

Figure 5: Range of motions for a 5-function ROV Manipulator, example

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2.4.2 Manipulator functions and Grippers

Manipulators with Grippers are delivered with several functions. The 4, 5 or 7 function manipulators are most common.

The functions on a 7-functions manipulator can be: Azimuth; Shoulder pitch; Elbow pitch; Wrist pitch; Wrist yaw, Wrist rotate and Gripper open / close.
In addition the grippers come in several models, see Figure 6, for some examples. The parallel gripper and the 3-finger gripper are most common.

The ROV always grabs with the left manipulator (4 or 5 functions) to keep it in a steady position during operation.

The ROV's right hand is always used to operate ROV tools, handles, valves, etc.

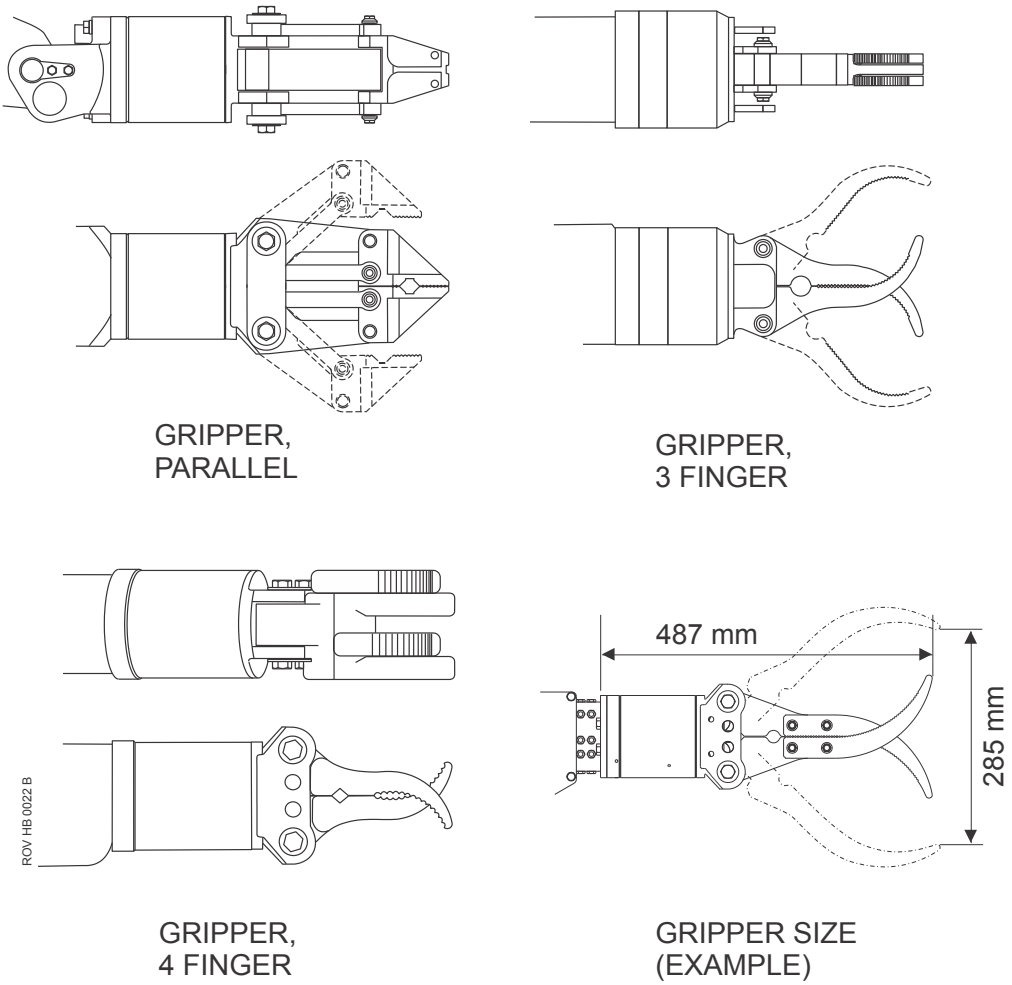

Figure 6: Gripper types for manipulators, examples

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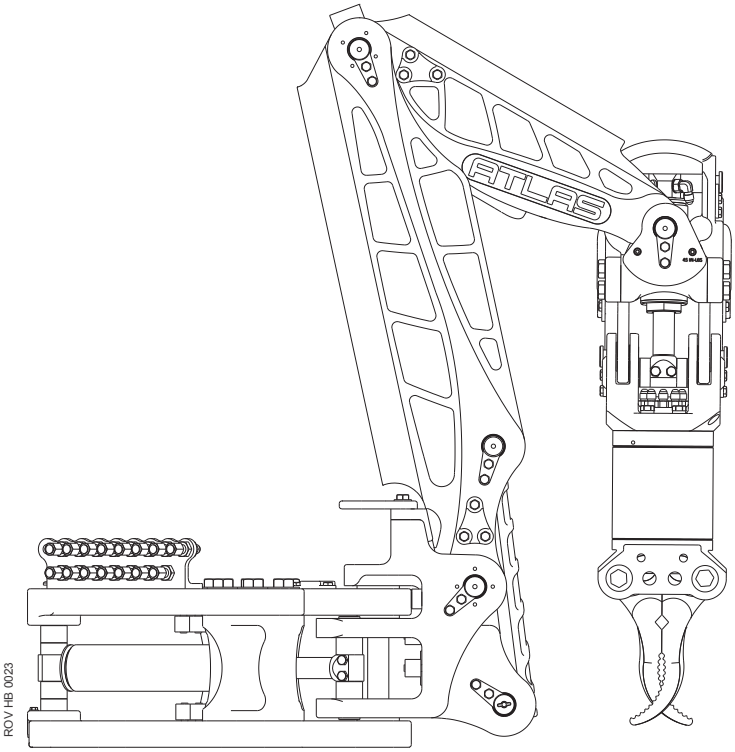

Figure 7: 7-function ROV arm, in stowed position

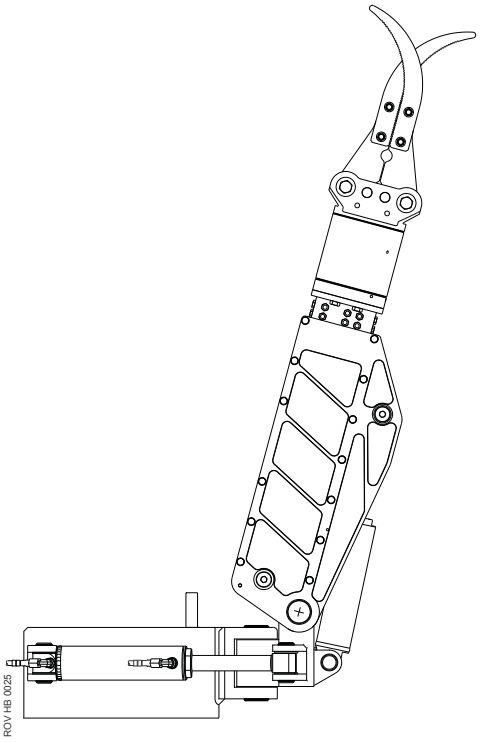

Figure 8: 5-function ROV arm, in stowed position

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3.0 ROV ACCESS REQUIREMENTS

3.1 GENERAL

3.1.1 Design recommendations

The ROV is linked to the Tether Management System (TMS) / Garage or directly to surface by a neutral buoyant Umbilical.
The Umbilical shall be designed to prevent operational problems for the ROV and risk of entanglements with wires or subsea equipment is minimized.

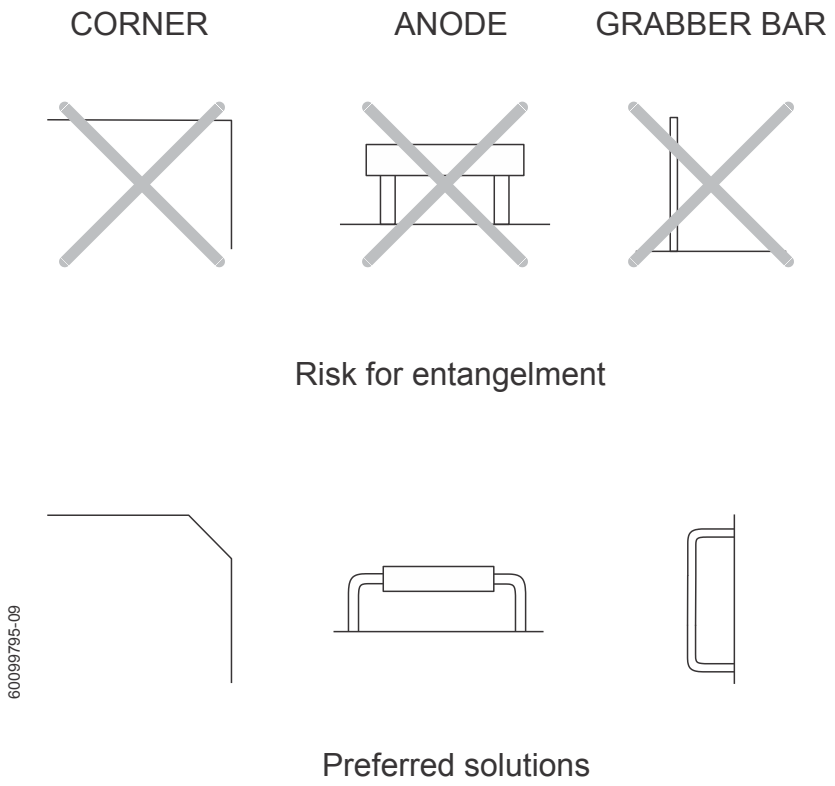

Figure 9: ROV friendly design

3.1.2 Protection

Fragile items such as hydraulic piping, electrical cabling, hydraulic test ports, visual position indicators etc, should be protected by bumper bars, grating or equivalent to avoid damage from the ROV.
The bumper bar shall be identical to the one used as a grabber bar, and identified by Orange colour.

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3.2 OBSERVATION ROV (ObsROV)

The access envelope required for the ObsROV is smaller than for the Work ROV. The consequence of this is that it may not be possible for the WROV to access an ObsROV work site either for inspection or operation.

3.2.1 ObsROV Size

The physical size of the ObsROV shall not exceed the following dimensions:

Length	1.4 m
Width	1.0 m
Height	1.0 m

3.2.2 ObsROV Access Envelope

The ObsROV need approx. 0.5 meter free space in all directions to be able to maneuver freely (ref. NORSOK):

Length	1.9 m
Width	1.5 m
Height	1.5 m

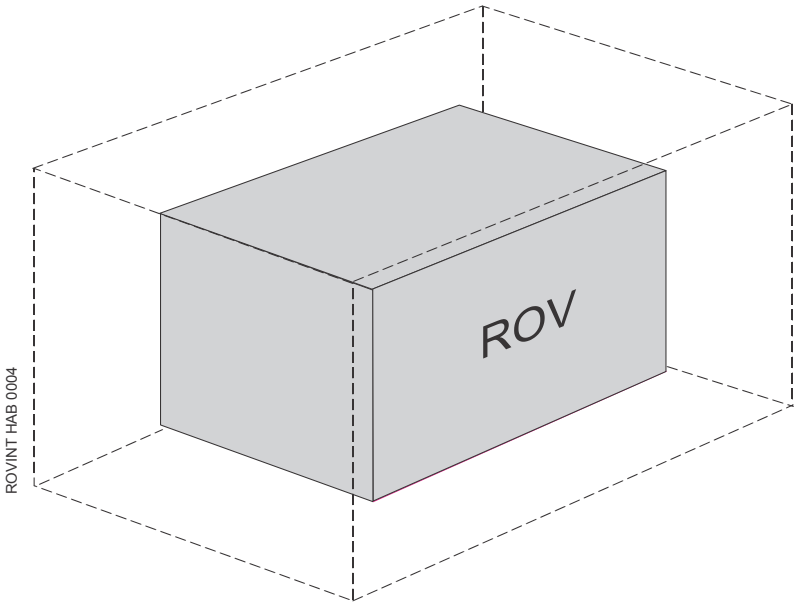

Figure 10: Obs ROV Access Envelope

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3.3 WORK CLASS ROV

The access envelope required for the Work Class ROV is consequently larger than for the ObsROV, see Figure 12.

3.3.1 Work ROV Size

The physical size of the WROV shall not exceed the following dimensions:

Length	2.5 m
Width	1.9 m
Height	1.9 m

3.3.2 Work ROV Access Envelope

The Work ROV needs approx. 1 meter free space in all directions to be able to maneuver freely (ref. NORSOK):

Length	3.5 m
Width	2.9 m
Height	2.9 m

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3.4 HORIZONTAL ACCESS

Intervention or inspection points less than 2 meters inside the structure may only require the minimum access envelope (0,25 m for ObsROV and 0,5 m for WROV)..

Intervention or inspection points located further inside the structure require access for the ROV to turn around and fly forwards out of the structure.

The horizontal distance from the front of the ROV to the work site shall be minimum 0.5 m and maximum 1.0 m.

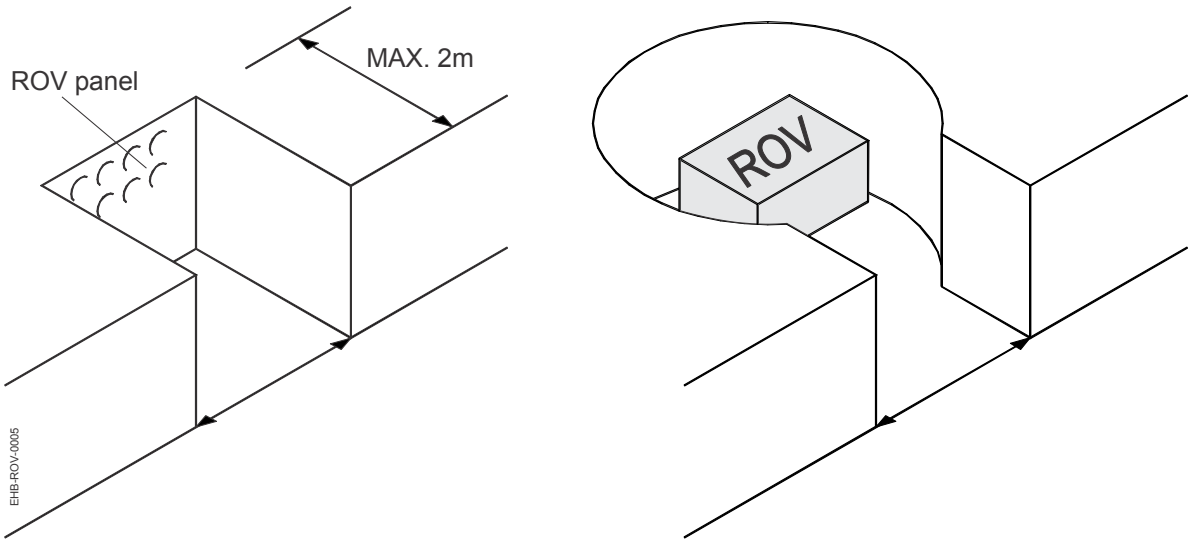

Figure 11: Horizontal ROV Access

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3.5 VERTICAL ACCESS

Work sites with vertical entry require additional ROV access space, depending on the dept to the site.

The vertical distance to the lowest point on the ROV frame down to the site of the intervention (inspection, cleaning or tool interface) shall not be more than 0.3 meter (NORSOK), see Figure 12.

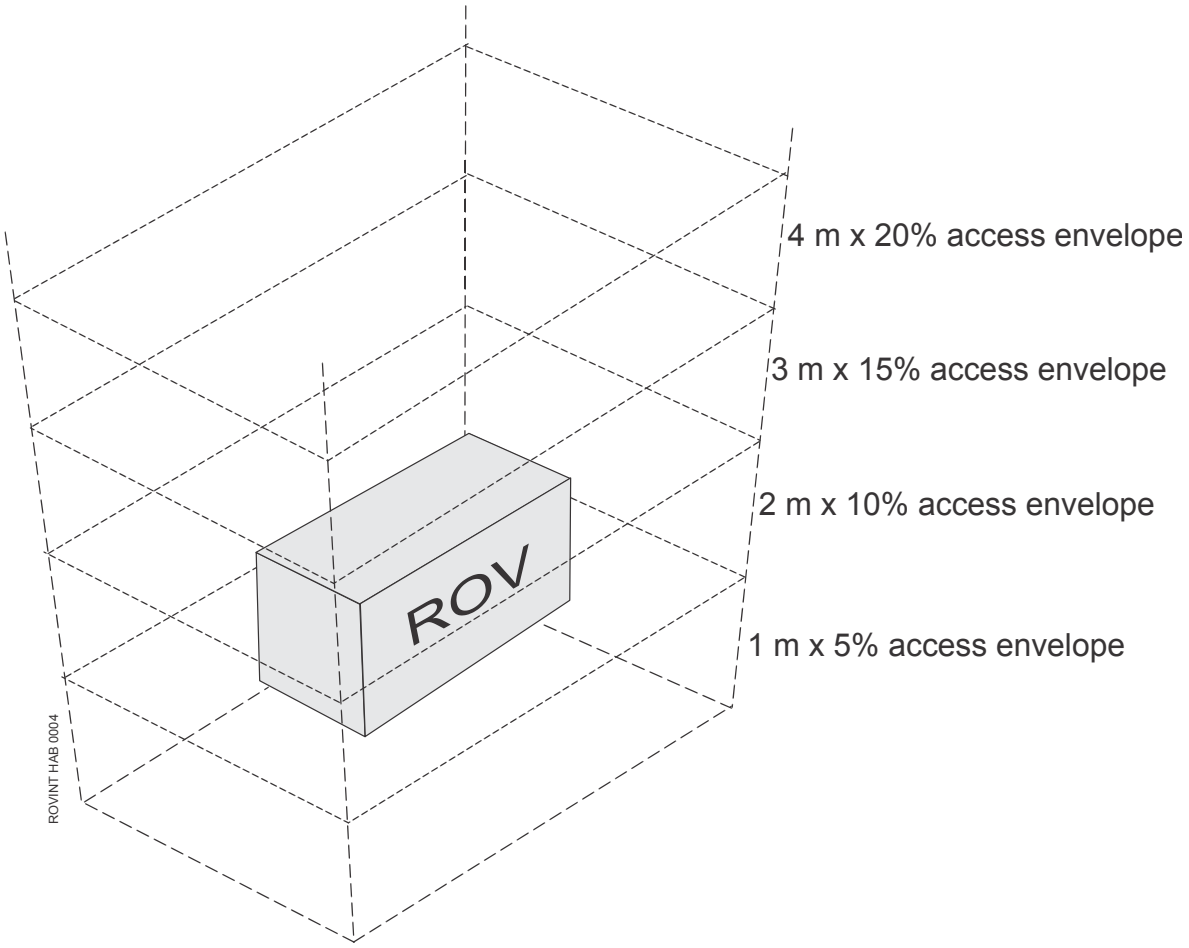

Figure 12: Vertical ROV Access Envelope

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3.6 DEVIATIONS

FMC shall in general design subsea systems according to ISO, NORSOK and other relevant standards. Deviations shall be avoided where practical possible. The designer is however obliged to use common sense when the standard dimensions are impractical to obtain.

The following questions shall be asked when considering deviations:

- Is this a frequent task, a back-up operation or is it a one in a lifetime operation?
- Is this a typical observation task, or does it require a WROV?
- What is the criticality if this task takes longer time than "normally" expected?
- Is this tasks a part of the yearly inspection program?
- What are the chances of unexpected interventions in the surroundings of this work site?

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4.0 STANDARD ROV INTERFACES

4.1 GENERAL ROV TASK INTERFACES

NOTE

Follow the instructions given in ISO 13628-8 ROV tooling Interfaces (API 17 H), as much as practically possible.
Always use the latest revision of any document.

Depending on the task to be performed, special ROV interfaces should be prepared at the subsea intervention site.

To perform safe and stable manipulative tasks, the ROV needs either:

- a docking point
- a suitable working platform
- a grabber post or grabber bar (grasping)

Special attention should be given to the location of the interfaces relative to the ROV position during operation, and the need to space around the interface for easy access with the ROV manipulator or grabber (ref Figure 11Figure 12).

Tools shall be designed in such a way that it the ROV can be stationary at the intended intervention point during ROV use of the tool.

This includes also inspection or observation tasks that require use of a manipulator mounted camera. Inspection sites should be prepared with bumper bars for the ROV to lean on.

No extra stabilization aids (platform or grabber bar) are required where the ROV tool is mounted/fixed to the ROV frame and the tool docks into a receptacle at the work site.

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4.1.1 Docking Points for ROV Stabilization

When performing Manipulator tasks, manipulator held tool tasks, or long term observation at one location, a Docking point may be the most practical solution. The docking point may be bolted or welded to the nearest structural member. It requires that the ROV carries a Torque Tool or a Docking Probe (Dummy Torque Tool) mounted in front of the ROV. This solution leaves the ROV stabilized in one dedicated position only by a slight forward thrust preset by the operator.
Both manipulators are then free to be used for the primary task. See Figure 13: ROV Docking Point.

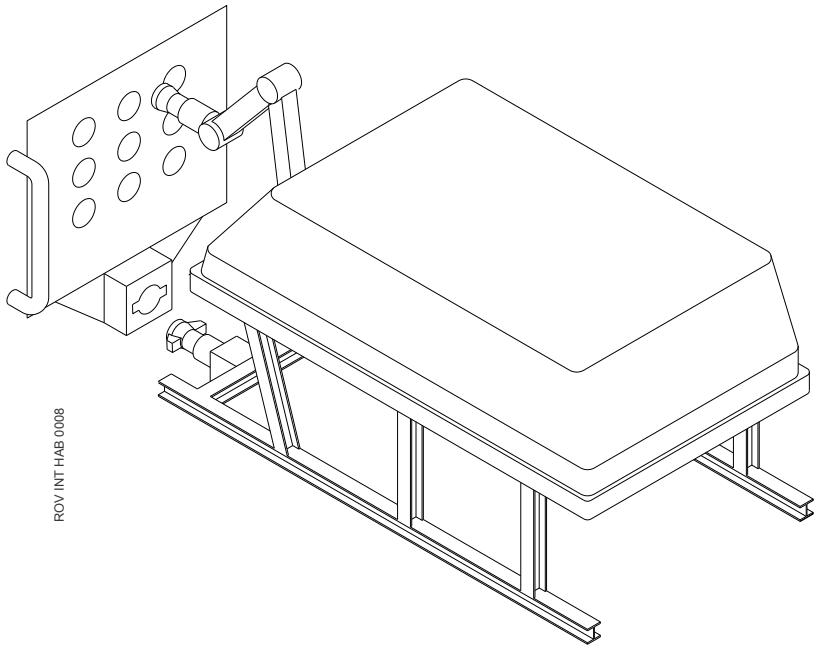

Figure 13: ROV Docking Point

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4.1.2 ROV Working Platforms

Working platforms may be the best solution for stabilizing the ROV if the task to be performed requires that the ROV may move around the work site.
The advantage of making Platforms is the fact that if often can be combined for general protection purposes and make life safer for the workers during the construction phase. ROV platforms should be flush with the surroundings (NORSOK), see Figure 14: ROV Working Platform.

ROV Platforms should be avoided where they need to be removed, (opened and closed) for other primary work tasks performed frequently.

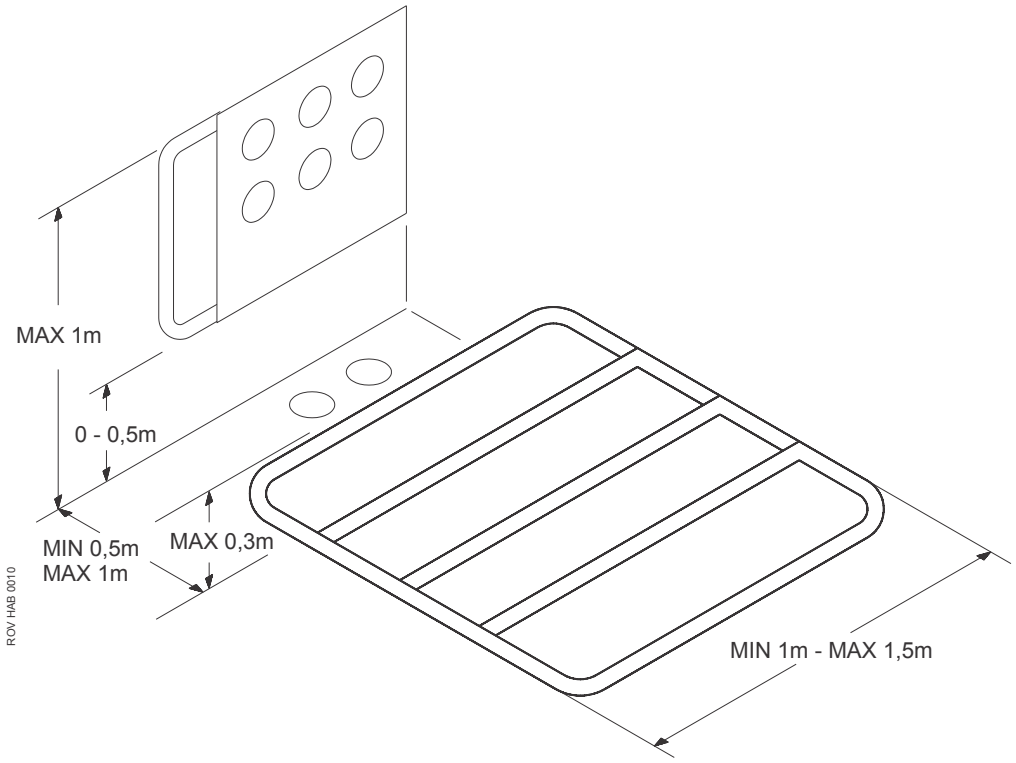

Figure 14: ROV Working Platform

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4.1.3 Grabber Bars (Grasping)

Grabber bars/Grabber posts shall be used as ROV stabilization aids when operating a ROV panel, a pedestal or other vertical interfaces. The Grabber bar should be designed both for grabbing and as a bumper bar for protection purposes.

The vertical part of the grabber bar should include mechanical stops every 0,5 m for avoiding unintentionally sliding of the ROV.

See Figure 15: Examples of ROV Grabber Bars / Grabber posts for Manipulator for details.

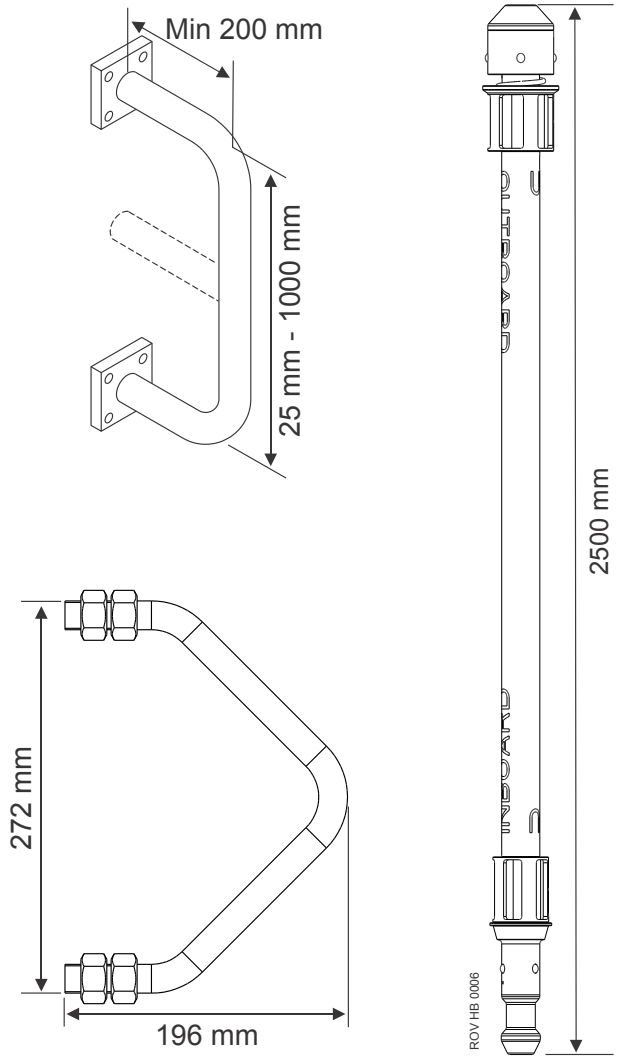

Figure 15: Examples of ROV Grabber Bars / Grabber posts for Manipulator

Measurements only for illustration

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4.2 ROV TORQUE TOOL INTERFACES

FMC has standardized on the ISO 136280-8 (API 17H) should be used where practically possible, 0-2700 Nm, (4500 Nm break-out force optional). Class 5 and 6 shall be used for higher torque values. See Figure 16: Examples of ROV Torque Tool Interface

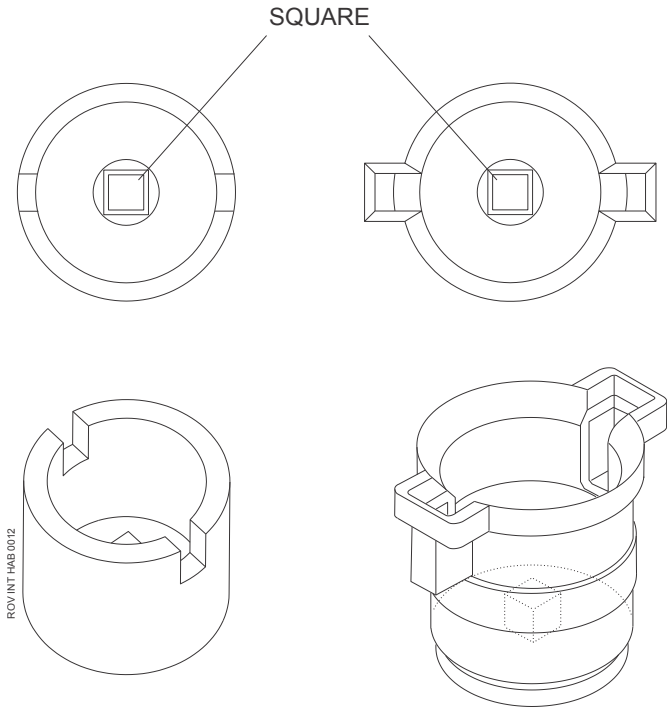

Figure 16: Examples of ROV Torque Tool Interface

NOTE

This is not according to NORSOK.
NORSOK values, 1700 Nm for medium torque tool may be used for Norwegian customers.

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4.3 ROV MANIPULATOR OPERATED INTERFACES

FMC has standardized the Fishtail handle and the D-type handle and also use ISO standard "A" handle (see Figure 17), for manipulator operated interfaces.
The handles may vary in size depending on the task requirements.
The handles shall be designed for easy replacement if other interfaces are required.

- The "D" shaped handle is welded to the mounting bracket two places.
- The "D" handle may be used by all common manipulator claws on the market.
- The "A" handle may be used in different ways:
  - the main grip over both horizontal bars,
  - holding only in the top horizontal bar to make gravity aligning the equipment,
  - and to use both sides as a traditional "T" bar.
- The conventional "T" bar may act as a hook for ROV umbilical, wires, handling ropes etc. and shall be avoided.
- For small equipment, electrical connectors etc. the "A" handle is proposed to be made of solid bar. For larger equipment like ROV tools, it is proposed to make the "A" handle out of thick-walled pipe.

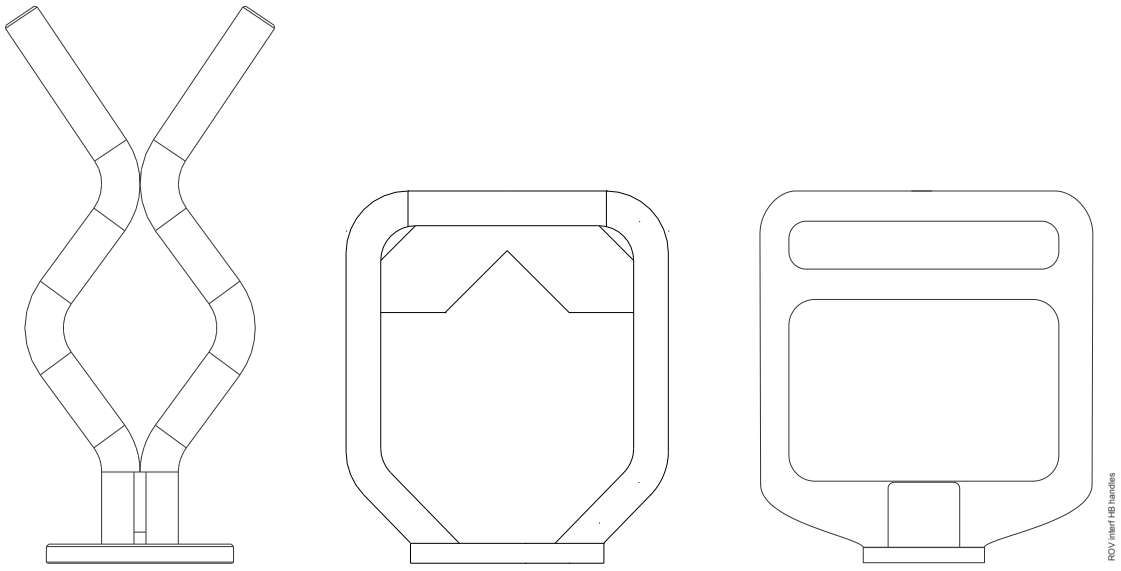

Figure 17: Standard ROV handles

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4.4 MANIPULATOR OPERATED VALVE INTERFACES

FMC has standardized on two manipulator operated interfaces for small 1/4 turn Ball Valves. One interface is designs for operation of torque values from 0 to 75 Nm, while the other is from 0 to 200 Nm torque at full operating pressure.
Both interfaces incorporate adjustable end stops.

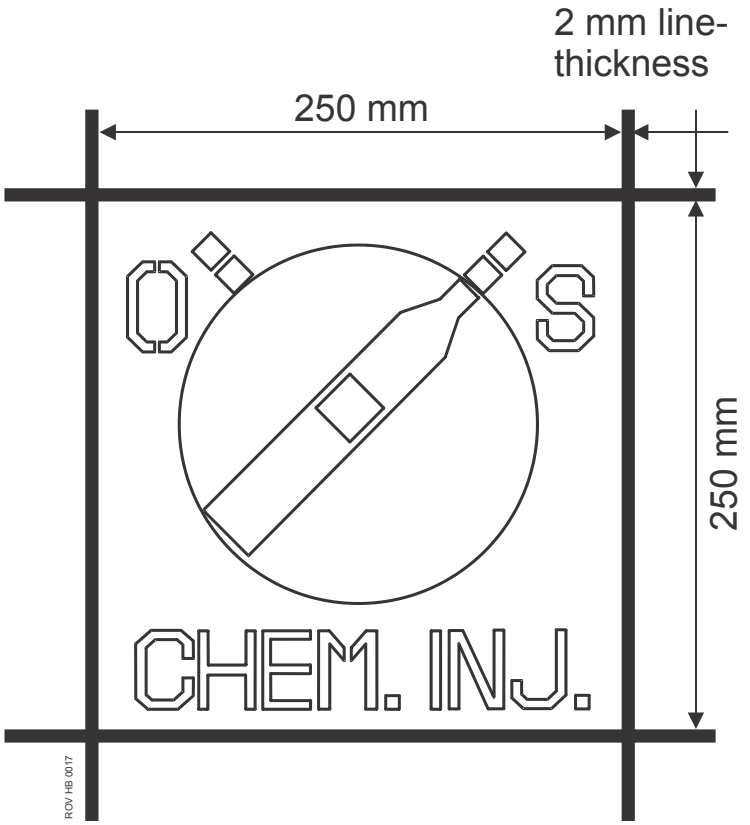

Figure 18: ROV Panel Marking (example)

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4.5 ROV OVERRIDE TOOL INTERFACES

FMC has standardized on one interface (mushroom) for Mechanical Override of critical functions on intervention tools. Two sizes are defined with two ROV tools. Pure mechanical functions may be override directly by the Override tool, while hydraulic functions must be ventilated (cutting of hydraulic hoses) prior to operation.

Description	Interface / Equipment
Universal Override Jack	Mushroom Interface
MFM Override Jack	MFM Connector
Single, Override Jack	KC4, PLM
Dual, Override Jack	KC4, PLM
Type 3, Override jack	KC4-3
Tubing Hanger O-pin Override Jack	TH orientation Pin
Linear Actuator Override Tool	LAOT (STD 5" 10K)
HD Linear Actuator Override Tool	Heavy Duty LAOT 7"
MQC Override Jack, MK2, with 4L stab Receptacle	MQC
Mechanical Override Tool	KC4-10, EH XT

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5.0 ROV TOOL DESIGN REQUIREMENTS

5.1 GENERAL

1. ROV Tools shall be designed to be fully compatible and operable with any deepwater WROV,

2. Where multiple tools are used during one operation, the tools shall be designed for subsea tool replacements in order to avoid retrieval of the ROV to surface.

3. Tools shall have possibility to release from the Subsea Production equipment in case of ROV electrical or hydraulic power failure.

4. Tools operated in areas with vulnerable equipment such as sealing areas, shall be designed of, or alternatively protected by use of a non metallic material.

5. ROV handles should be located in the same axis as movement / force direction; i.e. offset handles shall be avoided.

6. The tool shall be designed to operate using nominal pressure (207 bar / 3000 psi) and delivery of the standard ROV auxiliary hydraulic power pack. If tools are required with higher pressures than ROV power pack can deliver, a pressure intensifier shall be supplied as part of the tooling.

7. Weight of ROV manipulator carried tools and equipment should not exceed 50 kg in fresh water. Equipment and tools with weighs >25 kg in air shall be prepared for safe lifting by use of strops or other suitable lifting equipment.

8. All ROV tools shall be delivered in dedicated transportation box/skid suitable for offshore handling. The box/skid shall include a user manual for the equipment. (NORSOK)

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5.1.1 Torque Tools Interfaces

The torque tool shall provide a torque minimum 30% higher than the maximum required operation/break out torque value. For small valves up to 3" bore, the valve design torque shall be minimum 100% greater than the maximum required operation torque. (NORSOK)

The torque tool system used within classifications given in ISO 13628-8 shall include the following equipment:

- Torque tool
- Tool Control Unit
- Calibration equipment

Torque Tool shall include a turn counter that can be reset, which shall be visible by ROV during operation and indicate the digital number of revolutions in either direction of operation.

Torque tool s shall have incorporated a torque limitation device to avoid SPS equipment damage.

The tool shall be designed with a square drive socket according to ISO13628-8. Also should be designed with a soft start feature to avoid excessive dynamic forces, and for high accuracy and repeatability of output torque.

A latch mechanism may be included in the tool depending on project specific requirements.

5.1.2 Hub Inspection Tool / Hub Cleaning Tool

The Hub Cleaning and Inspection Tool (HCIT) shall include a mechanical cleaning device; i.e. rotating brushes. The tool shall enable visual verification of tool rotation during operation.

An inspection camera with lights, covering the entire seal area(s) shall be supplied as an integrated part of the HCIT or as a separate tool.

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5.1.3 Guidewire anchors

When needed Guidewire anchors shall be standard WEPCO and shall use the WEPCO interface.

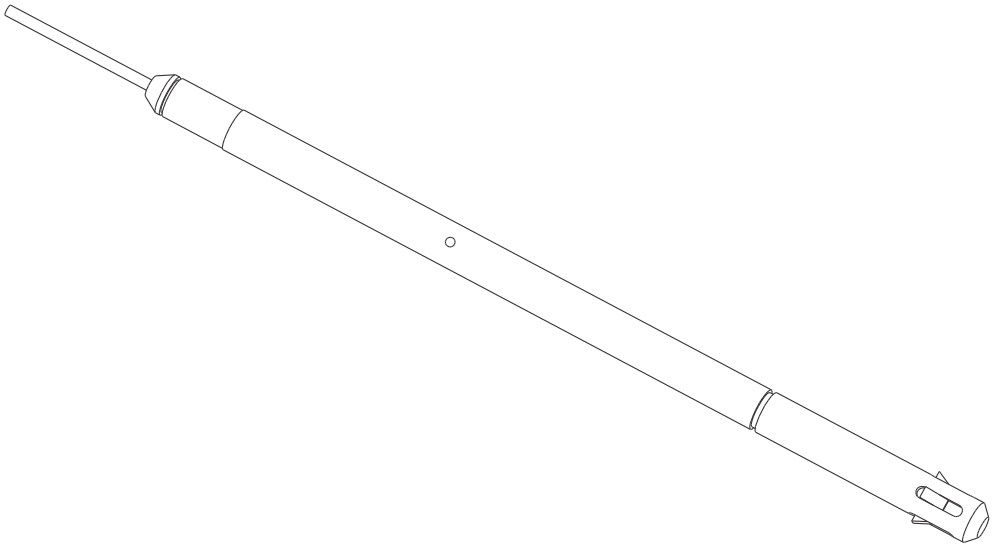

Figure 19: WEPCO anchor, example

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5.2 DESIGN LOADS

Impact Load

Sensitive equipment/components shall be protected against ROV impact of 1000 kg at 0.5 m/s. (NORSOK) i.e. 125 J.

Valve Handles

Valve handles shall be designed to take (NORSOK):

- Torque 400 Nm
- Bending Moment 1000 Nm (400 Nm according to ISO)
- Axial Force 5000 Nm
- Force from the ROV manipulator shall not be transferred into the Valve spindle or body. (NORSOK)

5.3 QUALITY ASSURANCE

- All new designs shall be evaluated with respect to requirement for qualification and wet testing
- All ROV Tools shall be tested according to written FAT procedures
- All ROV Tools shall have provisions for surface testing prior to use subsea
- The tool stability (COG / COB) shall be verified in water and on land
- All ROV equipment shall be stamped with a specific weight in water and on land

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6.0 ROV MARKING, VISUAL INDICATORS AND COLOUR CODING

6.1 GENERAL

Marking on subsea equipment can be divided in three main groups. These are:

1. Global Marking (see section 6.2)

2. Module Marking (see section 6.3)

3. Visual Indicators (see section 6.4)

The material, paint or coatings should provide a clear and visible identification for a ROV mounted video camera and should not reflect light in a manner which may prevent the video camera from reading the identification.

Marking by water cutting onto the ROV panel is recommended.

Extensive subsea marking is time saving during operation and consequently cost saving. Extensive marking is also beneficial for the visual documentation such as ROV Videos and Still Photos.
The visibility on seabed can vary and can in worst cases be less than 0.5 meters. Consequently, the ROV operation is extremely difficult when navigating the ROV from one intervention site to another. The need for subsea marking as frequently as possible is therefore practical.

All Subsea Equipment shall therefore be clearly marked to ensure safe and efficient identification, operation, intervention and Inspection by ROV or ROT.

All equipment on the subsea production systems that is designed for subsea intervention shall have a color and marking system (see Table 2: Marking colors (extract)) enabling easy and unique identification.

Color coding is used for general identification while **marking** is used for specific identification. The two types will in combination give the best result with respect to an optimized subsea operation.

The color and marking system shall act as a guidance map for the intervention operation by: The marking system shall enable positive verification of the end stop and/or locked position for retrievable components such as guidepost to lock-down clamps, etc.

- All text, symbols, figures, abbreviations etc. shall be easily identified and in strict accordance to the written procedures and documentation.

- All marking shall be in English.

- Identifying the structure and orientation of the subsea equipment

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- Identifying the equipment mounted on the structure and intervention interface
- Identifying the position of any given part of the structure relative to the complete structure
- Indentifying the operational status of the equipment, e.g. connectors lock / unlock and valve open / close.

Transportation devices, lifting points and sea fastening points shall be clearly marked with function and rating to prevent incorrect use.

Elements such as pad eyes, lifting systems, connectors, i.e. "active" parts during intervention shall be marked with orange color.

The ROV operating spindles (valve spindle / spindle extension) shall not be painted due to the tolerance between the spindle and the torque tool.

6.2 GLOBAL MARKING

Global Marking shall be used on Templates and large modules. This identification is mending to define the installation and location and assist the ROV in global navigation. (N-S-W-E).

1. Marking must be located easy visible for the ROV from several angles.
2. Each corner of the structure should have the geographical location (NE, SE, NW, SW, etc.)
3. Transponder receptacles need unique identification (e.g. T 01, T 02, etc.)
4. Each Well slot needs identification. (E.g. WS 01. WS 02 etc.)
5. The centre of the template should be identified
6. Each hatch in the roof needs individual identification corresponding to the Well slot or equivalent
7. Each Tie-in area needs individual identification
8. Each Guide Post Receptacle needs individual identification
9. Each Mini Post needs identification to the corresponding intervention task

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6.2.1 Marking of structures

The structures should preferably be oriented such that rig headings and template headings are identical during rig operations. The following marking, with its abbreviations, shall be carried out:

- Front side of the structure: FORE
- Starboard side of the structure: STB
- Port side of the structure: PORT
- Back side of the structure: AFT

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

FORE on the protection structure shall be defined according to FORE on the rig, i.e. identical to the rig heading. For template structures, the numbering of the slots (referring to well slots) can start with slot number on in the FORE-STB corner and continue the numbering clockwise.
Numbering of other slots, not referring to well slots, shall follow by starting with slots on the 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 shall 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 shall be fitted to the structural members to enable positive and easy orientation. This shall be done by fitting the marks on the vertical surrounding members (e.g. a well slot), with the symbols facing the centre of the slot.

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6.3 MODULE MARKING

Module marking shall be used on all individual modules and components. This identification shall at least give the operator information on the following

- FMC Module/Component Name (Full Name)
- FMC Module/Component Part No.
- FMC Module/Component Serial No.
- Guide Post Receptacle No.

All override points shall be identified by text and numbers according to the override procedure.

Marking must be located easy visible for the ROV from several angles after installation of the all subsea equipment.

6.3.1 Marking of subsea Hoses

All hoses shall be identified by a unique identification number. Letter size should be minimum 20 mm high, 10 mm wide and with a line thickness of 3 mm.

6.3.2 Marking of Guide Posts

The Guide Posts shall be marked with black rings located 200 mm (7.874 in) below the top and indicating the post number.

Retrievable guideposts shall be fitted with easily readable status indicators showing locked (L) and unlocked (U) positions of the locking mechanism.

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6.4 VISUAL INDICATORS

All valve, connector, cylinder, elevation and position indicators on the individual modules or components shall have Visual Indicators. The Visual Indicators shall be designed to:

- Give the operator a clear indisputable picture of the status
- Contain positive visual indication that functions have been successfully operated.
- Be easy readable from different angles
- Be easy readable from at least 0.5 meter in normal visibility
- Be of a Non-fragile construction
- Are self protected against Umbilicals, wires, etc.

Black lines, minimum 10 mm wide and minimum 50 mm long shall be the basis for all position indicators. The background shall be light, preferable white, but not darker than orange. Larger size indicators are preferable if possible.
Where black is the primary background color, the position indicates shall be white (10 mm wide, min. 50 mm long)

The position indicator must be located easily for the ROV's Pan/Tilt camera located in the centre of the ROV.

The visual indicator must not be exposed to potential structural damage during operation.

The visual indicator must not be placed as a potential climbing stair or eq.

All large items, plates etc. moving slowly (typical template foundation skirts) shall have longitudinal black lines 25 mm wide, minimum 1 meter long. Each line shall have a reference depth or height according to the datum line.

The visual position indicator must be assembled and mounted so that they can easily be adjusted during testing.

The distance between the moving / rotating part and the reference point shall not be more than 5.0 mm in the typical viewing direction.

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6.4.1 Marking of status indicators

Status indicators shall be marked with clearly readable reference points.
Symbols "U" or "UL" = Unlock, "L" = Lock, "O" = Open, "S" = shut, "B" = Bleed shall be used to define the reference points.

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

Following rules apply for marking of an indicator:

- Rotating markers shall have a painted stripe according to Figure 20
- Linear indicators (rising stems) shall have zebra stripes acc. to Figure 20

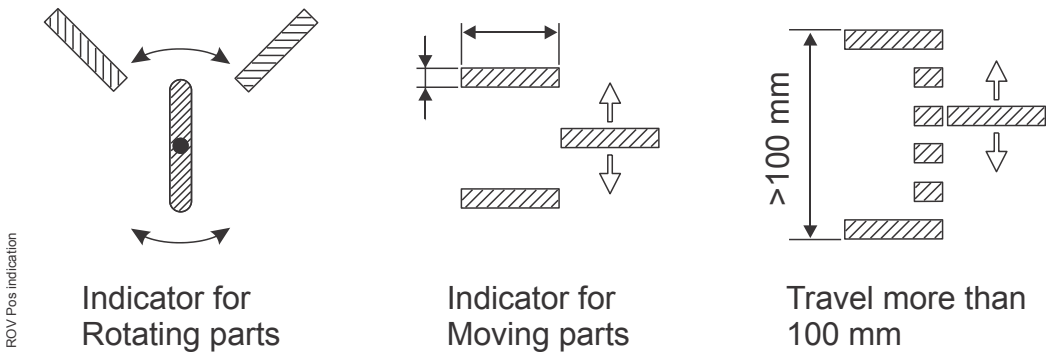

Figure 20: Position Indicators for moving parts

- Open (O) and Shut (S) shall be used instead of Open /Close on valves
- Locked (L) and Unlocked (U) shall be used instead of open / close on connectors and locking mechanisms.
- Extend (E) and Retract (R) shall be used instead of Upper / Lower on cylinder positions.

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6.5 MARKING SIZES

The figures given below are defined as the minimum criteria's. Larger letter sizes are easier visible in low visibility environment and should therefore be used wherever possible.

Category	Minimum Height	Minimum Width	Minimum Thickness
Global Marking	150 mm	100 mm	20 mm
Module Marking	80 mm	40 mm	10 mm
Visual Indicators	50 mm	25 mm	10 mm

6.6 MARKING COLOUR

General Color coding shall be in accordance with project and client specifications. Recommendations below shall be used when in doubt, or if other specifications are missing.

- All large permanent subsea elements such as templates and modules shall be colored in a light but not white or orange color, typical Yellow.
- All ROV Interfaces such as grabber bars, valve handles, docking receptacles, attachment points, tool interfaces etc. shall be orange.
- All indicators shall be by a black minimum 10 mm wide line on a light background (preferably white) or by a white line on black background.

Table 2: Marking colors (extract)

	Black	Red	Orange	Yellow [a]	Un-painted	White [a]	Grey
Paint code: RAL	9017		2004	1004	n/a	9002	7038
Paint code: Munsell	N 0,5		1,25 YR 6/14	1,25 Y7/12	n/a	10Y 85/1	5Y 7/1
Paint code: US federal Standard 595A	27038	31136	32246	33655 33507	n/a	27875	26440
a) Structures							
Protective structure	X (text)			X			
Pad eyes, hinges, ROV attachment / intervention points etc.		X [b]	X				

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	Black	Red	Orange	Yellow [a]	Un-painted	White [a]	Grey
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		
Valve status	X (text)			X (back-ground)		X back-ground)	
c) Control system							
Control-pod body			X				
ROV-operated valve handles, ROV attachment / intervention points, etc			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)	
e) ROT, ROV and Replacement Frame System							
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

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7.0 MATERIALS

7.1 GENERAL

All ROV related interfaces and tools shall be designed with materials that possess adequate strength, toughness and corrosion resistance for frequent use in water. Commercial aspects shall be given due consideration, but shall not put the functional requirements in danger. Materials with well-documented merits from manufacturing, fabrication and relevant service shall be the preferred choice.

The designer shall clearly deviate between **permanent subsea equipment** and equipment used **submerged for a short time** during intervention operations. Permanent subsea equipment shall be designed of materials according to standard part specification or relevant project and company specifications. Intervention equipment used subsea only a number of times a year or in back-up operations, shall be designed with this in mind.

Electrical discontinuity between components shall be considered to prevent galvanic corrosion.

Tooling interfaces shall be designed to prevent the possibility of galling between the mating components.

Materials to be used in ROV related interfaces and tools shall be discussed and approved by Product Responsible Engineer and Material Engineer before manufacturing and application.

7.2 MATERIALS IN ROV TOOLS

7.2.1 Steel material

Carbon steel, low alloy steel and stainless steel are materials that are commonly used in ROV related interfaces and tools.

Fittings and solid hydraulic piping shall have a corrosion resistance similar to Stainless Steel AISI 316L or better.

Nuts and Bolts shall have a corrosion resistance similar to Stainless Steel AISI 316L or better.

7.2.2 Aluminum

Aluminum is a light weight metallic material with low strength and low corrosion resistant properties.

Aluminum alloys shall be used where weight savings are needed.

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7.2.3 Titanium

Titanium shall be used where weight saving combined with high strength is required.

Titanium Grade 5 (TiAl6V4) is commonly used where the combination of high strength and low weight is required.

7.2.4 Elastomeric materials (Non-metallic material)

Elastomeric materials is a common name for plastic and rubber materials, i.e. thermoplastic material, rubber seals etc.).

Elastomeric materials are light weight material with excellent corrosion properties. The strength properties are low, and thus elastomeric material shall only be used for non-critical parts.

The designers shall be aware that elastomeric materials within the same group, i.e. material group named POM, may vary in properties like compatibility and water absorption.

7.3 SURFACE TREATMENT

The following is valid for surface treatment:

- Parts made of aluminum shall be anodized according to FMC's specification.
- Parts made of steel material shall be coated according to FMC's specification.
- Parts made of titanium shall have surface treatment according to FMC's specification.
- Parts made of elastomeric materials shall not be coated.

7.4 SPECIFICATIONS AND STANDARDS

FMC material specifications (M-specs) shall be used.

For materials not covered by FMC specifications or when material availability or other reasons dictates alternative solutions, the material shall conform to regional industry standards, such as NORSOK or ASTM or other (preferably international) specifications as applicable. Less detailed specifications may be applied for items of low criticality.

When material standards cover alternative grades or types the selected grade/type shall be stated.

For assemblies and units designed by sub suppliers, the sub-suppliers specifications may be used. The complete bill of material and coatings shall be submitted and formally accepted by FMC.

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8.0 STANDARD ROV TOOLS AND EQUIPMENT

8.1 ROV TOOLS

Subsea Tools operated by the Remotely Operated Vehicle (ROV) are used in all stages in development of a subsea Oil field.

These ROV tools may be mounted directly to the frame of the ROV, or be handled by the ROV manipulator. ROV tools may be used for planned subsea intervention operations such as valve operations by ROV Torque Tool and operating hydraulic functions by the use of a Hydraulic Stab (Hot Stab). ROV tools may also be used for unplanned IMR (Inspection, Maintenance & Repair) operations such as overriding functions by a ROV Override Jack.

FMC delivers a variety of ROV Tools for both planned and unplanned Subsea Intervention activities. These tools may be divided in the following groups:

- ROV Hydraulic Hot Stabs (see section 8.2)
- ROV Torque Tools and Torque/Latch units (see section 8.3)
- ROV Override Tools (see section 8.4)

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8.2 ROV HYDRAULIC HOT STABS

Hydraulic Hot Stabs are used to supply hydraulic fluid to any type of subsea equipment requiring pressurized fluid for operation. Supply of fluid may come from the ROV's reservoir; a separate "clean" reservoir mounted in a skid underneath the ROV, or from a surface supplied hydraulic hose or umbilical.

Hydraulic Hot Stabs may be used to operate any primary function on the Subsea production system, such as hydraulic valve actuators, hydraulic connectors, as well as back-up override of the same functions. Hot Stabs are also used to operate ROV tools launched in a separate basket. Hydraulic Hot stabs may also be used to perform pressure testing of connections and take fluid samples.

FMC delivers a 1-6 line Hydraulic HOT Stab design capable of delivering fluid from low pressure up to High Pressure (690 bar).

Table 3: Hydraulic Hot Stabs

Number of lines	**Bore size**	**Pressure (Bar)**			
1 line	2"	10			
2 line	1/4"		207	345	690
4 line	1/4"			345	690
6 line	1/4"		207	345	690
Pressure Plug (metal)	1/4"		207	345	690
Pressure Plug (plastic)	1/4"				

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8.3 ROV TORQUE TOOLS AND TORQUE/LATCH UNITS

Torque tools range from ISO (API) Class 1 - 7, FMC build torque tools to meet ISO 1632-8 (API 17 H) specifications. The ROV tools may operate rotary spindles including Ball Valves, Gale Valve Actuators, Subsea Control Module (SCM) locking mechanisms, and Multiple-Quick-Connect (MQC) plates on hydraulic umbilical terminations. Torque Tools may also operate any linear rotating spindles on a subsea manifold or template.

Table 4: ROV Torque Tools according to Interface receptacle ISO/ D, Class

ISO Torque Class Nm (lb ft)	**Square Interface Socket dim., mm**	**ROV Torque Tool Interface Receptacle ISO/API Class**		
		1 - 4	**5**	**6 - 7**
4 2 711 (2 000)	38,1	2 700 Nm Torque Tool	N/A	N/A
5 6 779 (5000)	50,8	N/A	6 800 Nm Torque Tool	N/A

NOTE: Subsea intervention fixtures shall be in accordance with ISO 13628-8 (API 17D, H).

N/A: Not available as standard tool

Table 5: ROV Torque Tools according to Interface receptacle ISO/WD Class

ISO Torque Class N m (lb ft)	**Square Interface Socket Dim, mm**	**ROV Torque Tool Interface according to ISO/WD 13628-8 Receptacle size Class**		
		1-4	**5**	**6-7**
4 2 711 (2 000)	38,1	2 700 Nm (4)	N/A	N/A
5 6 779 (5 000)	50,8	N/A	6 800 Nm 10 000 Nm	N/A
13 558 (10 000)	66,7	N/A	N/A	10 000 Nm (6)
33 895 (25 000)	88,9	N/A	N/A	35 000 Nm (7)

NOTE: Subsea intervention fixtures shall be in accordance with ISO 13628-8 (API 17 D, H).

N/A: Not available as standard tool

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8.4 ROV OVERRIDE TOOLS

ROV Override Tools are used to override functions in case of malfunction in the primary operational system. These tools are primarily designed to use physical force to operate function. FMC has standardized on some interfaces for Override tools (Mushroom), but other override tools are tailor made for one specific override operation.

Table 6: Override Tools

Description	Interface / Equipment	Operating Pressure (bar)	Max Pulling Force (kN)	Stroke length (mm)
Universal Override Jack	Mushroom Interface	210 bar	20 kN	200 mm
MFM Override Jack	MFM Connector	200 bar	177 kN	350 mm
Single Override Jack	KC4, PLM	150 bar	250 kN	190 mm
Dual Override Jack	KC4, PLM	150 bar	250 kN	190 mm
Type 3 Override Jack	KC4-3	200 bar	77 kN	100 mm
Tubing Hanger O-pin Override Jack	TH Orientation Pin	80 bar	90 kN	102 mm
Linear Actuator Override Tool	LAOT (STD. 5" 10 K)	172 bar	745 kN	172,8 mm
HD linear Actuator Override Tool	Heavy Duty LAOT 7"	172 bar	1112 kN	277 mm
MQC Override Jack, MK2, with 4L Stab receptacle	MQC	207 bar	136,7 kN	160 mm
Mechanical Override Tool	KC4-10, EH XT	220 bar	530 kN	500 mm

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