University of Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Master in Offshore technology/ Marine and Subsea technology	Autumn semester, 2012 Open / Restricted access
Writer: Katrine Sandvik	Katrine Sandvik (Writer's signature)

Faculty supervisor: Arnfinn Nergaard

External supervisor(s): Kjell Edvard Apeland

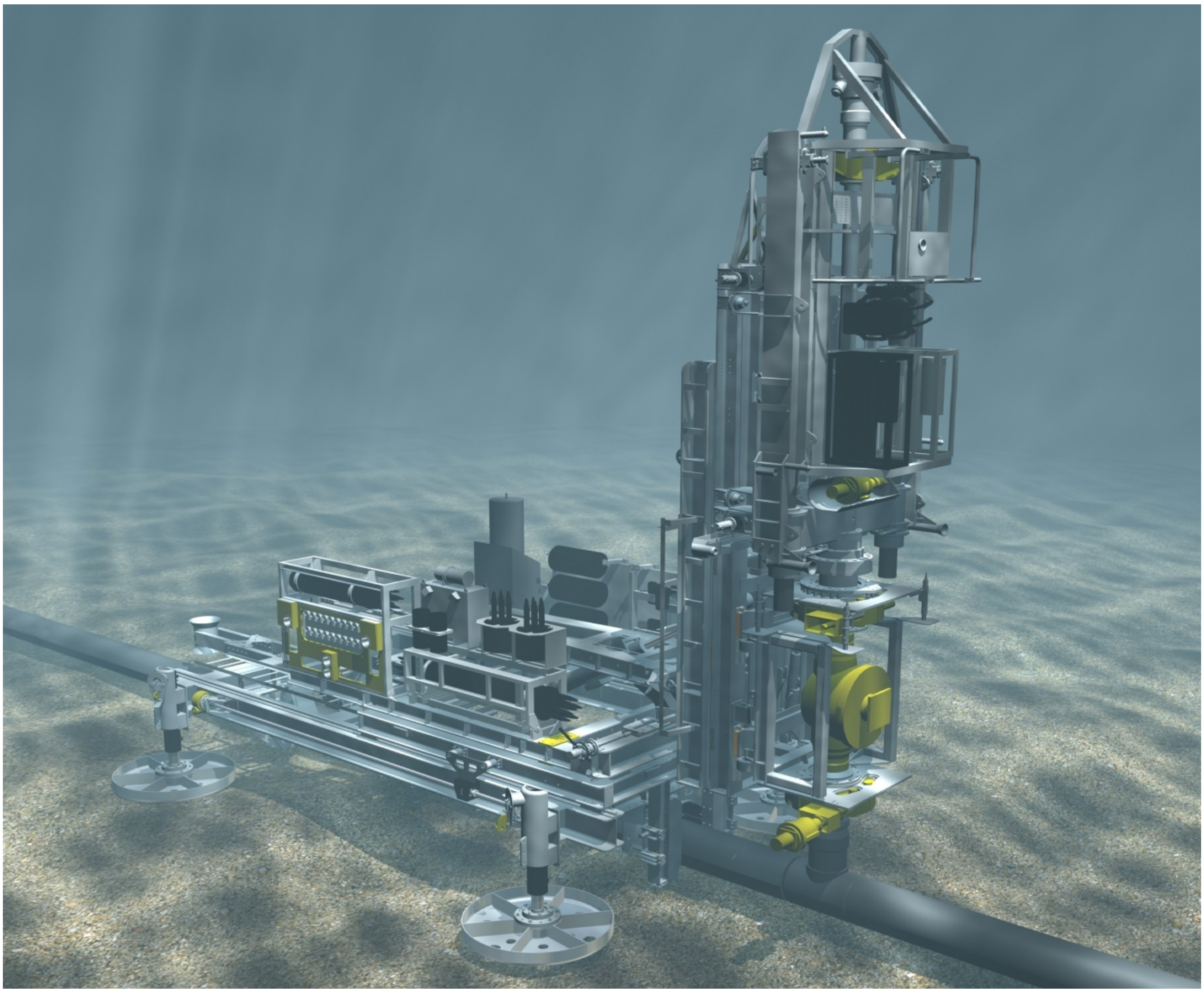
Title of thesis:

Remote hot tapping in ultra-deep water

Credits (ECTS): Thirty (30 ECTS)

Key words: Remote hot tap, Ultra-deep water	Pages: 170 pages + enclosure: - Stavanger, 13.12.2012 Date/year

Remote hot tapping in ultra-deep water



Katrine Sandvik
Student nr. 958679

UiS

2012

1.0 ABSTRACT

Statoil has developed a Pipeline Repair System (PRS) hot tap system at Killingøy Haugesund, which comprises five different tools. This master thesis has focused on one tool, the Hot Tap Cutting Unit (HTCU).

Earlier the depth range of the PRS equipment was to 540 MSW, to cover emergency preparedness for pipelines routed through Fensfjorden. The PRS equipment was upgraded to max. 600 MSW in 1994-95 and due to the Ormen Lange field at 860 MSW, Statoil upgraded the PIF (Pipeline Intervention Frame)/HTCU range to 1000 MSW in 2008-09.

The main objective for this master thesis was to evaluate the HTCU system for extending water depth capability to 3000 MSW.

The main purpose of the report was to describe current design as used during the Åsgard Subsea Compression Project (ÅSCP) in 2012 at 265 MSW, discuss general improvement issues, establish the 3000 MSW design basis and identify necessary upgrades for 3000 MSW operation.

The master thesis included performing a literature study on the topic, conduct interviews with people of different professional backgrounds in the industry, reviewing components, reviewing the ÅSCP, evaluating results, reviewing and evaluating improvements to existing design, as well as assessing 3000 MSW upgrade requirements.

The most critical components extending water depth capability to 3000 MSW are the control cards and the reverse pressure differential challenge on seals and drive shaft.

TABLE OF CONTENTS

TABLE OF FIGURES

2.0 ABBREVIATIONS

Abbreviation	Description
ARIS	Architecture of Integrated Information Systems
CC	Center - Center
CRU	Coating Removal Unit
DNV	Det Norske Veritas
DP	Dynamic Positioning
DSU	Drop in Stab Unit
DWP	Dirty Work Pack
EDRS	Emergency Disconnect and Recovery System
FBE	Fusion Bonded Epoxy
FPSO	Floating Production, Storage and Offloading
GA	General Arrangement
GMA	Gas Metal Arc
GoM	Gulf of Mexico
GPS	Global Positioning System
H5	Pipe Handling Frame no. 5
HPR	Hydro acoustic Position Reference
HPU	Hydraulic Power Unit
HSE	Health, Safety and Environment
HTBV	Hot Tap Ball Valve
HTCU	Hot Tap Cutting Unit
HTS	Hot Tap System
HTT	Hot Tap Tee
HTTF	Hot Tap Tooling Frame
HTVM	Hot Tap Valve Module
HV	High Voltage
Hz	Hertz
IMR	Inspection, Maintenance and Repair
INS	Inertial Navigation System
IPCON	Initial Power and Control Container
ISO	International Organization for Standardization
JB	Junction Box
LARS	Launch And Recovery System
LV	Low Voltage
LVDT	Linear Variable Differential Transducer
MHS	Module Handling System
MSW	Meter Sea Water
NSGI	Norwegian Sea Gas Infrastructure
OBS ROV	Observation ROV
P	Pressure
PG	Pressure Gauge
PIF	Pipeline Intervention Frame
PRS	Pipeline Repair System
QA	Quality Assurance

Abbreviation	Description
QC	Quality Control
QMS	Quality Management System
RIS	ROV Interface Skid
ROV	Remotely Operated Vehicle
RT	Retrofit Tee
RTIT	Retrofit Tee Installation Tool
RTWT	Retrofit Tee Welding Tool
SCM	Satellite Control Module
SCMS	Subsea Compressor Manifold Station
SCSt	Subsea Compressor Station
SIT	Site Integration Test
SJA	Safe Job Analysis
SWT	Shallow Water Test
TMS	Tether Management System
TQP	Technology Qualification Programme
TRL	Technology Readiness Level
TSM	Tool Support Module
TTH	Tether Termination Head
WROV	Work Remotely Operated Vehicle
WSRU	Weld Seam Removal Unit
ÅSCP	Åsgard Subsea Compression Project

3.0 ACKNOWLEDGEMENTS

This master thesis is a part of the fulfilment of my Master`s degree in Offshore technology/Marine and Subsea technology at the University of Stavanger. I have been a part-time student at the University of Stavanger from autumn 2007 to 2012 to earn my Master`s degree.

The master thesis topic is "Remote hot tapping in ultra-deep water". The purpose of the master thesis was to gain knowledge on how the ultra-deep water challenge would affect the HTCU.

Most of the available subsea literature is international; hence I found it appropriate to write the report in English. The methods are based on active research and the report has been prepared during the autumn semester of 2012.

Working with this master thesis has given me more knowledge on the type of challenges Statoil and Technip are facing regarding extending to ultra-deep water.

External help offered by my supervisors has been necessary and substantial. I am very grateful and would like to express my thanks to:

Dr. Eng. Arnfinn Nergaard, UiS, and Kjell Edvard Apeland, Statoil

In addition I would like to thank Statoil PRS Killingøy employees and my colleagues at Technip for their help.

Stavanger, December 2012

Katrine Sandvik
....

Katrine Sandvik

4.0 BACKGROUND FOR MASTER THESIS

Hot tapping is the process of drilling into a live pipeline (within which in the product is flowing) without interrupting the product flow, in order to provide pipeline branch access for possible diversion of the flow in either direction. This is normally done by installing 'tees' either during the laying process (pre-installed tee, see Figure 4-1) or by retrofitting branch structures after the pipe is laid (Retrofit tees, see Figure 4-2).

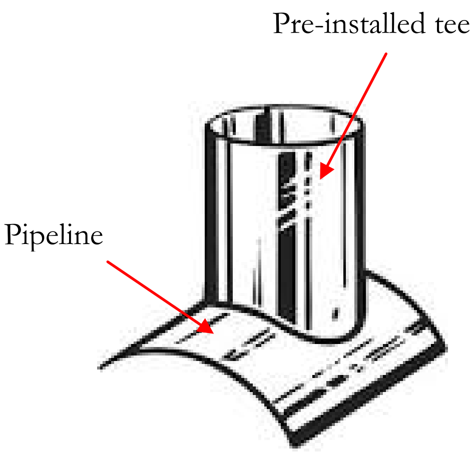


Figure 4-1 Pre-installed tee

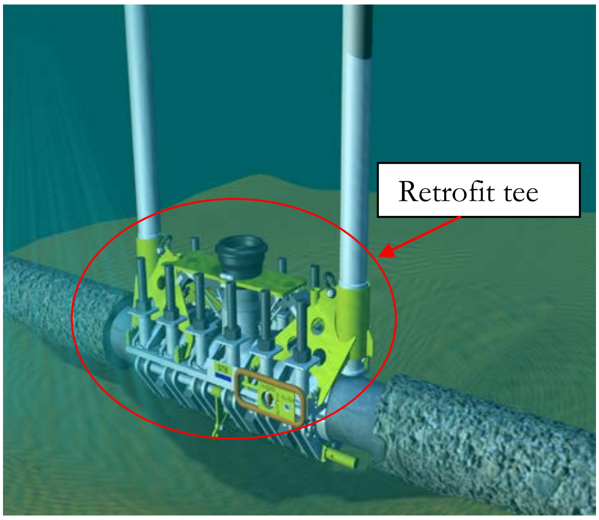


Figure 4-2 Retrofit tee with guideposts

Subsea hot tapping of pipelines is performed for a variety of reasons, including tie-ins, pipeline repair, insertion of instrumentation, providing access for temporary isolation tools or facilitating chemical injection.

The process involves cutting the mother pipe through a valve, extracting the cutter and then closing the valve until an external connection is made to facilitate the diversion.

The Norwegian plumber O.H. Netteberg from Drammen invented the first hot tap tool. He was granted a patent in 1909, see APPENDIX 1. Hot tapping has been performed for several years, both onshore, see Figure 4-3, and subsea employing divers, see Figure 4-4. Currently diver-depth is 180m for Norwegian continental shelf [1].

Figure 4-3 Hot tap onshore [2]

Figure 4-4 Gullfaks in 2000

The world's first remote, subsea without divers, hot tap operation on an unprepared pipeline was performed for the ÅSCP on the Midgard 20" pipeline in August/September 2012. This is a major step for Statoil and opened new opportunities for field development, maintenance and repair. The Hot Tap Cutting Unit has certain depth limitations and needs further development and upgrading.

According to ISO 13628-1[3], International Organization for Standardization, the definition of deep water is water depth generally ranging from 610 m to 1830 m. Ultra-deep water is defined as water depth exceeding 1830 m. In this thesis there will be referred to ultra-deep water due to the 3000 MSW (300 bar) base case.

5.0 OBJECTIVES OF THE MASTER THESIS

The main objective for this master thesis is to evaluate the HTCU - Hot Tap Cutting Unit system for extending its water depth capability to 3000 MSW.

The HTCU is at present limited to operation below 1000 MSW, the control system is designed for 1000 MSW, while the HTCU SeaTap (the drilling element of the HTCU) is designed for 2000 MSW. The SeaTap comprises mechanical parts, seals and hydraulics. The HTCU has been used in actual offshore operations first at 145 MSW (Tampen Link, Statfjord field 2008), then at 860 MSW (Ormen Lange field, 2-off Hot-taps in 2009) and at 265 MSW (Åsgard field, 2012).

The master thesis will describe the five different tools comprising the hot tap system, but the master thesis will focus on one tool, the Hot Tap Cutting Unit. The master thesis will:

- Describe current design
- Describe the Åsgard Subsea Compression Project – hot tap
- Discuss potential general improvement issues
- Establish a 3000 MSW Mardi Gras design basis
- Identify necessary upgrades for 3000 MSW operation

<u>Work method:</u>

To meet the objectives the master thesis will;

- Review literature
- Interview key personnel
- Review the HTCU mechanical, hydraulic and electrical components
- Review the Åsgard Subsea Compression Project, evaluate results and lessons learnt
- Review and evaluate suggested improvements to existing design
- Review and evaluate 3000 MSW upgrade requirements

The master thesis is divided into four main parts to have a natural split;

- State-Of-The-Art for hot tapping
- First ever remote hot tap on an unprepared pipeline – ÅSCP
- General improvements not related to ultra-deep water
- The ultra-deep upgrades

The thesis` main objective is to qualify the system for ultra deep water. Mardi Gras has been selected as a base application case for study work. A design basis is established to qualify for Mardi Gras with a certain margin. The typical water depth at Mardi Gras is 2200 MSW. A water depth of 3000 MSW has been selected as the key parameter in the design basis.

6.0 STATE-OF-THE-ART FOR HOT TAPPING

6.1 Industry set-up

6.1.1 Statoil

According to Statoil [4] the company is an international energy company with business in 36 countries. The company claims to apply technology and innovative business solutions to help meet the world energy demand. Statoil is headquartered in Norway with approximately 21.000 employees worldwide.

6.1.2 Technip

According to Technip [5] the company is the leading subsea engineering contractor on the Norwegian continental shelf. Technip operates a fleet of specialized vessels for pipeline installation and subsea construction [6]. The company is present in 48 countries, with 500 employees in Norway, located in Sandvika, Stavanger, Haugesund and at the spool base in Orkanger [5].

6.1.3 PRS Base – Pipeline Repair System

Statoil is the operator of the PRS (Pipeline Repair System) base at Killingøy, while Technip operates as a contractor to Statoil. The system is used for pipeline repair work, maintenance, modification and subsea installation using manned or remote operated methods.

Killingøy, outside Haugesund, is owned by Karmsund Havnevesen IKS. The contract between Karmsund Havnevesen IKS and Statoil has duration to 2016 with options for further extension [7]. According to the Havnevesen the PRS base has the world`s most operative collection of tools and systems for pipeline repair and connections [7].

A new diving support vessel, Skandi Arctic, see Figure 6-1, with state-of-the-art diving facilities, has been built to support the work offshore. The vessel was nominated for the Åsgard Subsea Compression Project, hot tap in August/September 2012.

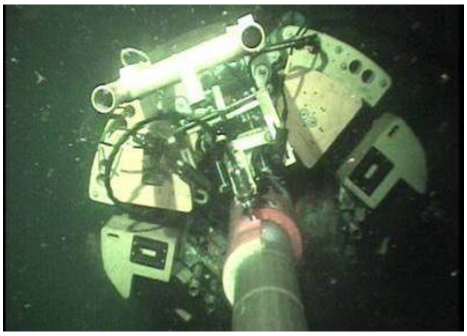
Figure 6-1 Diving support vessel, Skandi Arctic, 160 meter long [8]

6.2 Description of present system

Statoil's remote hot tap system consists of the following tools with their functions:

CRU – Coating Removal Unit

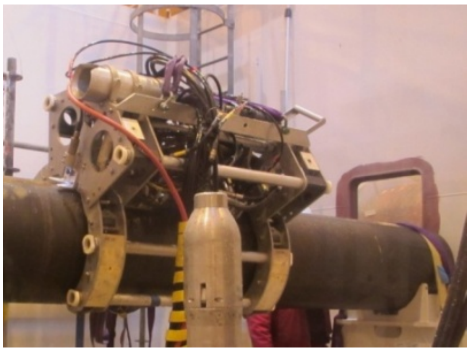
The first operation performed during a hot tap subsea is to remove coating/concrete. Seabed survey including core drilling, foundation design and dredging to provide access is performed prior to using the CRU. For further tool description see section 6.2.1.



WSRU – Welding Seam Removal Unit

The next operation is to remove the longitudinal weld seam on the pipeline.

For further tool description see section 6.2.2.



RTIT/H5 and RT – Retrofit Tee Installation Tool/H-frame nr. 5 and Retrofit Tee

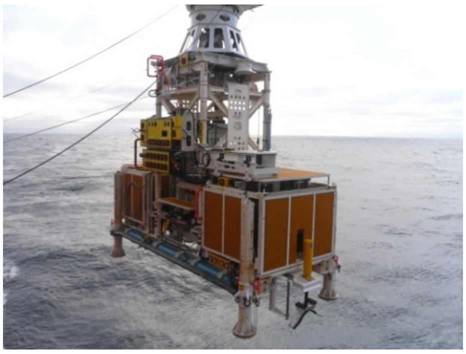
The third operation is to install the Retrofit Tee (RT) on the pipeline.

The Retrofit Tee Installation Tool (RTIT) and RT is deployed and installed onto the pipe.

For further tool description see section 6.2.3.

RTWT – Retrofit Tee Welding Tool

The RTWT is then landed onto the RT. The weld head stabs into the RT branch and is used to blow down using overpressure, followed by flushing with dry argon gas and creation of a suitable dry welding environment. The welding environment is created by a preheat process, two coils heating and drying the branch insert.

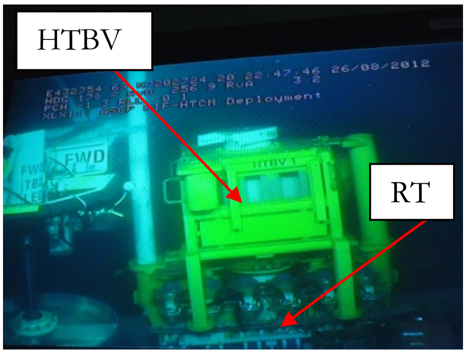


A six pass fillet weld is then performed.

For further tool description see section 6.2.4.

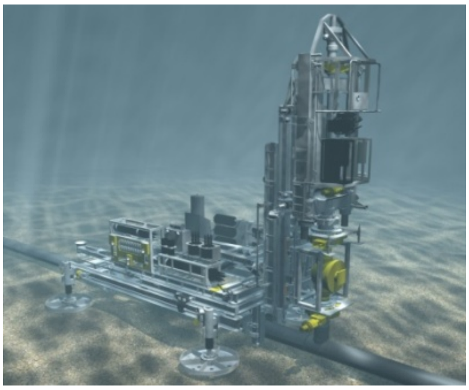
HTBV – Hot Tap Ball Valve

The next operation is to install the Hot Tap Ball Valve onto the RT. The HTBV is closed until an external connector is made to facilitate the diversion. The HTBV was supplied by Apply Nemo AS, Statoil`s contractor.



PIF/HTCU – Pipeline Intervention Frame/ Hot Tap Cutting Unit

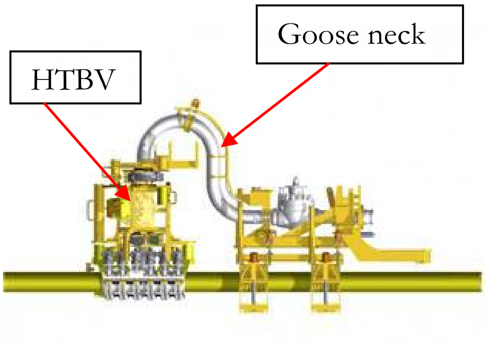
The last operation is the actual hot tap, done through the open HTBV; drill and cut through the pipeline.



For further tool description see section 6.2.5.

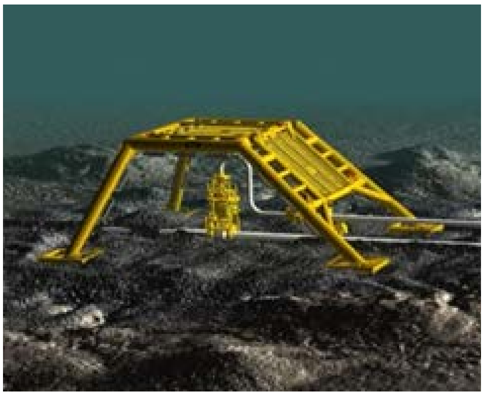
Goose Neck

After the PIF/HTCU has retracted, the HTBV is closed and the Goose Neck installed. The Goose Neck is installed to facilitate the tie-in of a new export/import pipeline in the future. The Goose Neck was supplied by Apply Nemo AS, Statoil`s contractor.



Protection structure – Rosenberg Verft scope

To protect the Goose Neck and HTBV, from fishing equipment, a protection structure is installed. The protection structure was supplied by Rosenberg Verft, Statoil`s contractor.

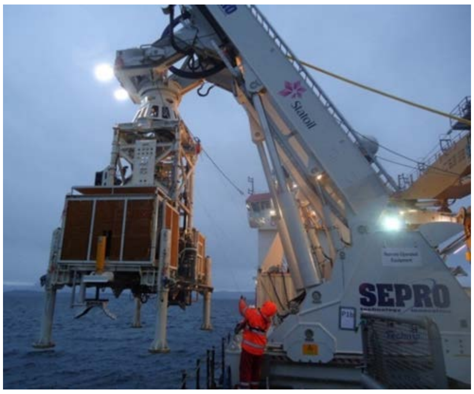


LARS1 – Launch And Recovery System 1

In addition to equipment mentioned above the hot tap system consists of two Launch And Recovery Systems. LARS1 is acquired as primary support and provide main power, back-up power and communication for the PIF/HTCU and RTIT. For further description see section 6.2.6.

LARS02 – Launch And Recovery System 02

The LARS02 is lower and hoisting the RTWT in addition to providing power and control through the umbilical. For further description see section 6.2.4 and



The tools described above are all qualified according to Statoil`s standard FR12 (has replaced the WR1622) and DNV`s (Det Norske Veritas) DNV-RP-A203, see Table 6-1.

	Qualification
CRU	Proven technology used in previous offshore operations, according to WR1622
WSRU	DNV qualified and proven for ÅSCP. SFS*
RTIT/H5 and RT	DNV qualified and proven for ÅSCP. SFS*
RTWT and LARS2	DNV qualified and proven for ÅSCP. SFS*
PIF/HTCU	DNV qualified and proven technology used in previous offshore operations. SFS*
LARS1	Proven technology used in previous offshore operations

Table 6-1 Hot tap system qualification

As indicated in Table 6-1 for the WSRU, RTIT/H5 and RT, RTWT and LARS02 and PIF/HTCU the tools have SFS qualification. This is a `Statement of Fitness for Service` (SFS) issued by DNV, to document that DNV considers the technology documented as fit for service.

The CRU was developed before Statoil used the DNV system. Based on a solid track record the CRU could be considered as proven technology according to FR12 (has replaced the WR1622). The LARS1 is qualified without TQP due to 6-7 years operation at the vessel Viking Poseidon before Statoil purchased it.

For qualification process details see chapter 10.0 Industry qualification/verification system.

6.2.1 CRU – Coating Removal Unit

The Coating Removal Unit is deployed to seabed by means of dedicated Tool Support Module (TSM), see Figure 6-4. The CRU is positioned on the pipe by a WROV (Work Remotely Operated Vehicle), and powered and controlled from the TSM. High pressure water or water-grit mixture is used for coating removal [9], see Figure 6-5.

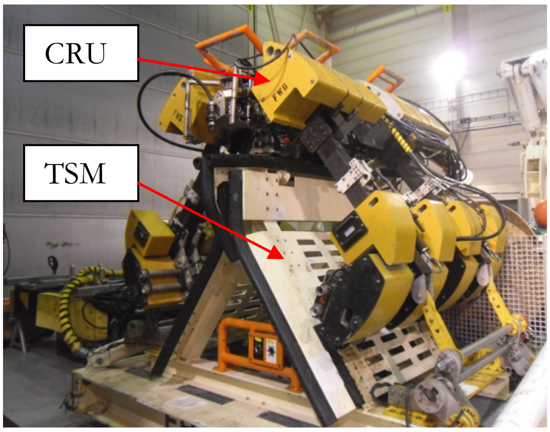


Figure 6-2 CRU on TSM

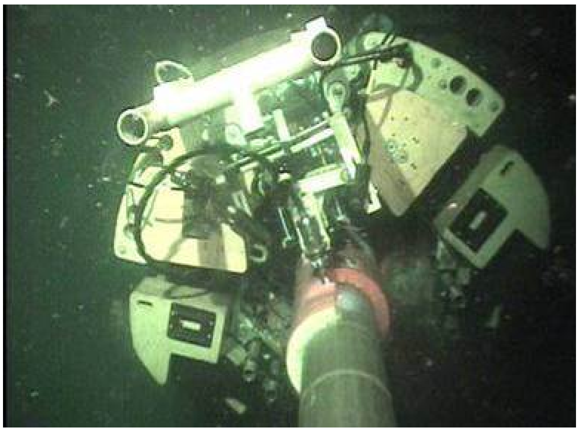


Figure 6-3 CRU subsea

The CRU is rated for 1000 MSW, and has been tested successfully at 940 MSW.

6.2.2 WSRU – Weld Seam Removal Unit

The Welding Seam Removal Unit removes the longitudinal welding seam on a pipe by horizontal milling. The WSRU is fitted in a structural frame (Tool carrier), see Figure 6-6, with pipe-claw arrangement. The tool is handled, operated and controlled by a WROV through the RIS (ROV Interface Skid). The WSRU is rated to 1000 MSW [9]. Figure 6-7 shows the WSRU on a pipe.

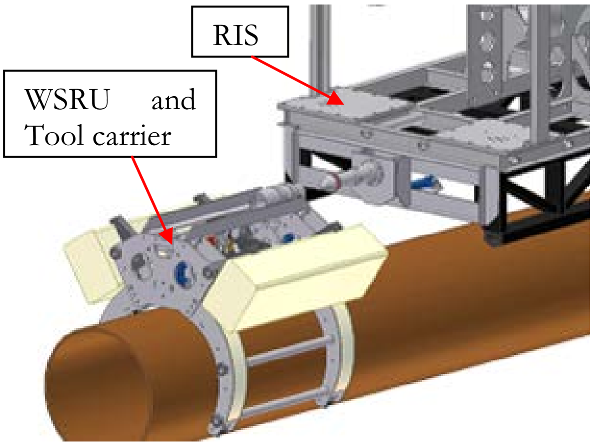


Figure 6-4 WSRU and RIS

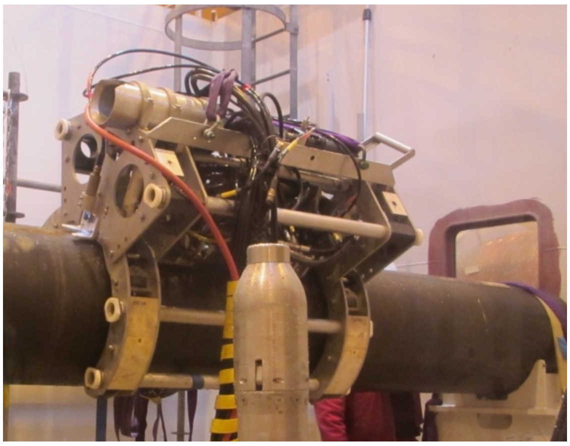


Figure 6-5 WSRU on a pipe

6.2.3 RTIT/H5 and RT – Retrofit Tee Installation Tool and Retrofit Tee

RTIT/H5 – Retrofit Tee Installation Tool

The Retrofit Tee Installation Tool`s purpose is to install the Retrofit Tee, see Figure 6-8. The RTIT is deployed by the ships crane, see Figure 6-9, and positioned over the pipe. The RTIT is fully remotely operated, connected and powered up through LARS1 from surface. The Retrofit Tee is then installed (clamp shell locked, bolt tensioning) onto the pipe, activated, and released from the RTIT subsea.

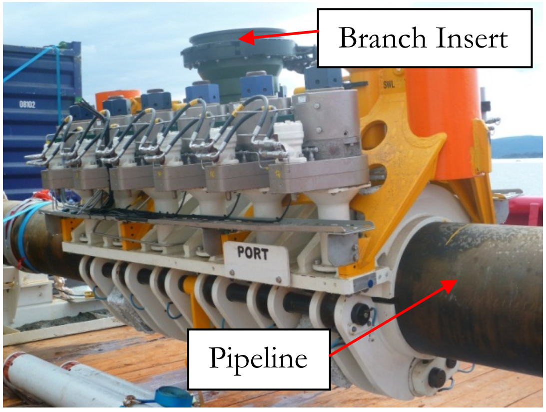


Figure 6-6 Retrofit Tee (RT)

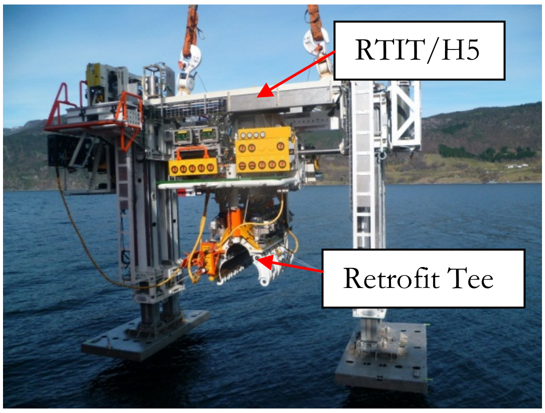


Figure 6-7 Retrofit Tee connected to RTIT/H5

The RTIT is equipped with PRS`s "new generation" control and interconnection systems, and is confirmed rated to 1000 MSW [9].

RT – Retrofit Tee

The RT clamp, see Figure 6-8, contains the branch insert and preliminary elastomeric seals to enable initial sealing for "blow down" and welding, see section 6.2.4.

After RTIT has completed the remote installation the RT is ready for the welding tool, RTWT.

6.2.4 RTWT and LARS02 – Retrofit Tee Welding Tool and Launch and Recovery System

The purpose of the Retrofit Tee Welding Tool is to weld, remotely operated through the power and control umbilical from LARS02, see Figure 6-10. The LARS02 has an umbilical length of 1500 m, with an option to 2300 m.

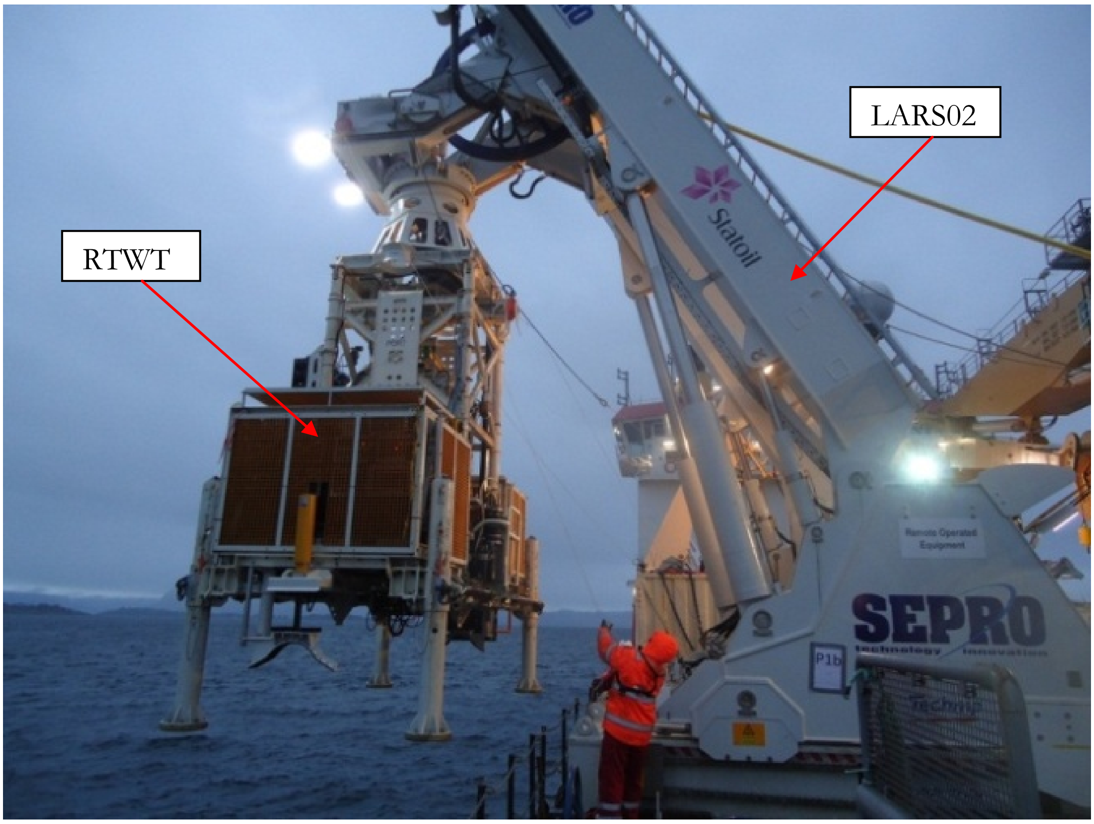


Figure 6-8 LARS02 and RTWT

The RTWT operation sequence is as follows:

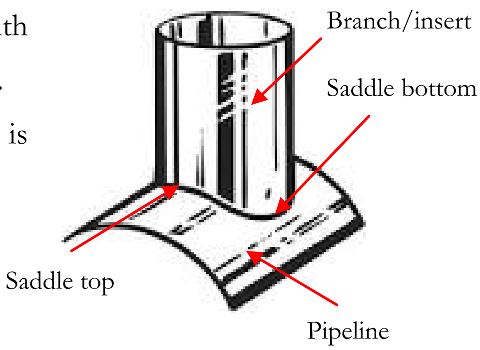
In the hot tap process, after the RT is installed on the pipe, the RTWT is deployed using LARS2.

The RTWT is then landed onto the RT. The weld head stabs into the RT branch and is used to blow down using overpressure, followed by flushing with dry argon gas and creation of a suitable dry welding environment.

The welding environment is created by a preheat process, two coils heating and drying the branch insert. A six pass fillet weld is then performed.

The full saddle weld comprises a six pass fillet weld at the bottom of the branch/insert pipe positioned vertically. Everything is performed remotely.

Each pass is a full circumference weld with start/stop overlaps located at the saddle top. After the welding is completed the RTWT is recovered to deck.



The RTWT has been subject to testing and pre-qualification weld QA (Quality Assurance) QC (Quality Control) for the Åsgard Subsea Compression Retrofit Tee 6-Pass hyperbaric GMA (Gas Metal Arc) seal weld.

The welding process is qualified for 1000 MSW, but welding tests have been performed in simulated conditions at Cranfield University to 2500 MSW. Tests have shown that, within the range 80 to 2500 MSW, the welding is unaltered.

6.2.5 PIF/HTCU – Pipeline Intervention Frame/ Hot-Tap Cutting Unit

The PIF/HTCU has been developed over a number of years:

- 1999 : Strategic development project initiated
- 2005 : Prototype qualification completed
- 2008 : First offshore operation, remote hot tap operation at 145 MSW (Tampen Link, Statfjord field)
- 2009 : World`s deepest remote hot taps performed at 860 MSW (Ormen Lange field, 2 pre-installed Tees)
- 2012 : World`s first remote hot-tap performed at 265 MSW including a subsea remotely welded Retrofit tee (Åsgard field)

The HTCU weighs about 10 Ton, while the combined PIF/HTCU weighs about 40 Ton. The fully remote PIF/HTCU is a self-contained system certified by DNV. The system consist of two main components; the Pipeline Intervention Frame and the Hot Tap Cutting Unit, see Figure 6-11. The PIF holds and positions the HTCU.

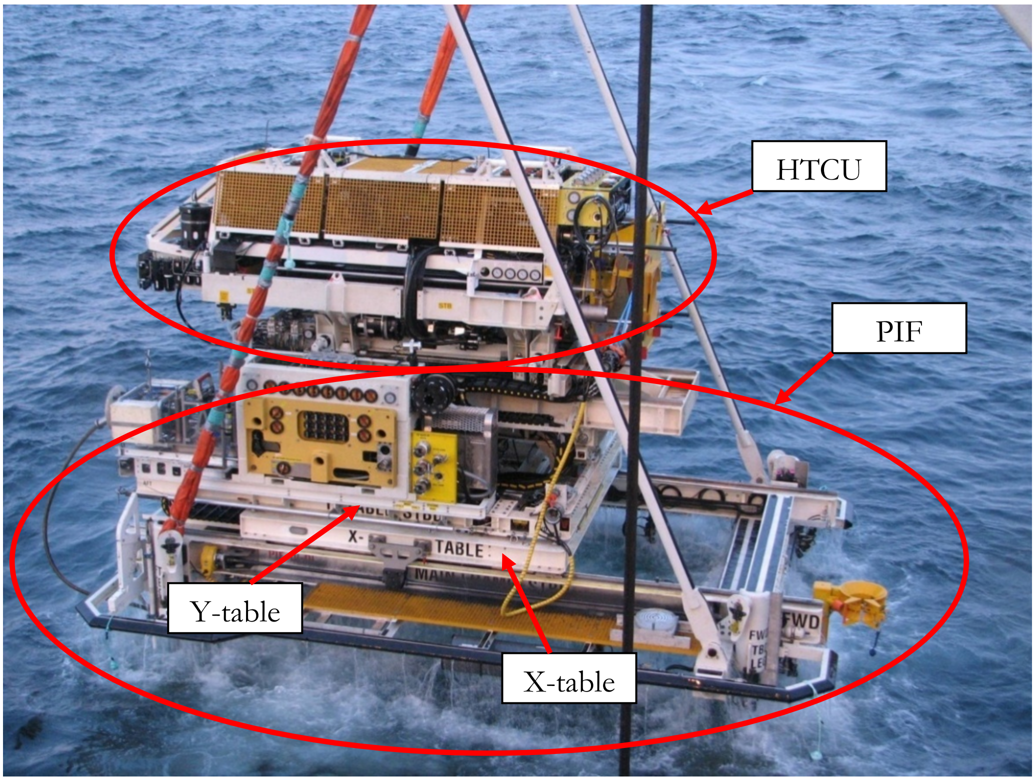
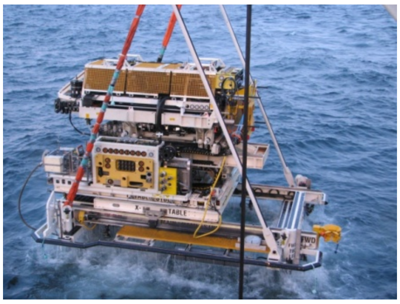


Figure 6-9 PIF/HTCU

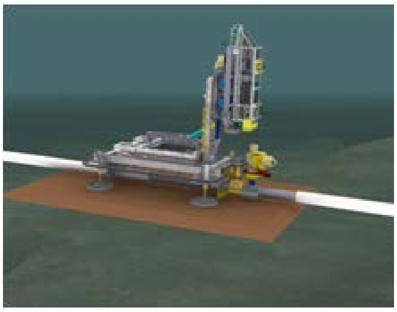
The PIF/HTCU operation sequence is as follows:

When the RTWT has completed the weld, the HTBV is installed into the RT. The PIF/HTCU is then deployed by the ships crane and landed onto the pipe.



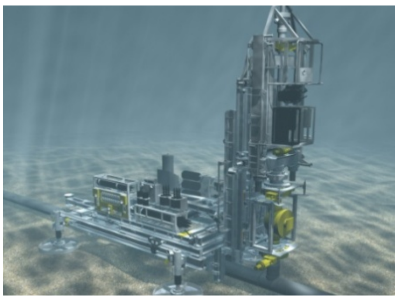
The PIF/HTCU then performs seabed stability, levelling and settling tests.

Then PIF/HTCU performs rough positioning.



The PIF/HTCU performs alignment of the X-table (PIF), see Figure 6-11.

After completion of the pre-operations the HTCU stands vertically above the ball valve in proportion to the seabed (RT installed 12 o`clock), ready to perform the hot tap.



The hot tap is performed through the HTBV; the HTCU drills through the pipe. After the drillings is completed the HTCU retract and the HTBV closes. The PIF/HTCU is then recovered back to deck.

The HTCU is approved [1] for mother pipes in the range of 16-42" and hot-tap holes in the range of 150-400mm. The system has sensors integrated to monitor the pressure barriers, in addition to several other sensors.

6.2.6 LARS1 – Launch and Recovery System 1

The Launch And Recovery System 1, see Figure 6-12, is used for safe lowering and landing of the Tether Termination Head (TTH) by use of tether cable on the TMS (Tether Management System), which is handled by the LARS1 surface umbilical, see Figure 6-13. The TTH is connected by ROV for topside control and power supply.

Figure 6-10 LARS1 with TMS

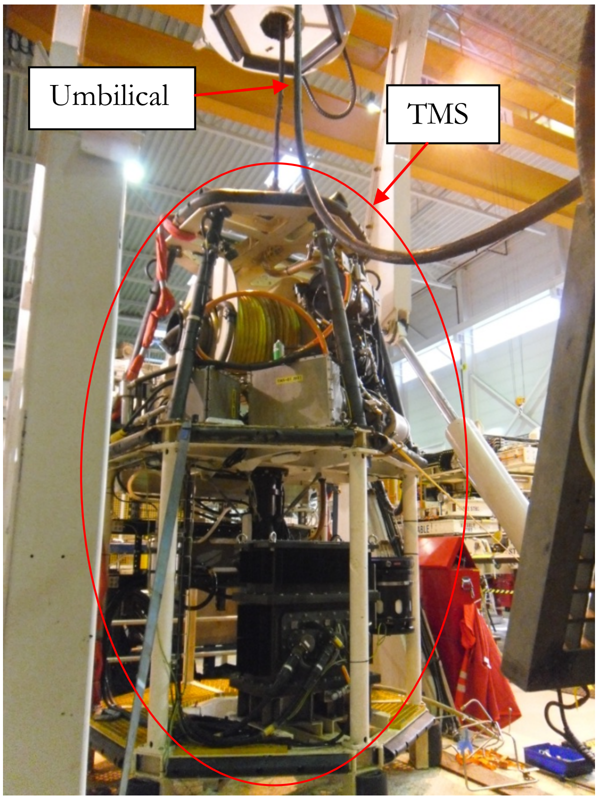


Figure 6-11 TMS

LARS1 is used as primary support for the PIF/HTCU and RTIT, but can also support other PRS equipment controlled from the IPCON (Initial Power and Control Container). The purpose of the LARS1 system is to provide main power, backup power and communication from the deck mounted control container to equipment subsea.

Present steel armoured umbilical is about 1500-1600 m.

6.3 Other remote hot tap cutters developed

Within the latest 20 years several hot tap cutters has been developed:

- Oilstates/ Oceaneering DeepTap™ Remote-tap cutter
- Claxton/ Mirage Diver assisted Hot-tap cutter
- TD Williamson Remote Hot-tap cutter
- Furmanite/ IPSCO
- IK Stavanger AS

These will be briefly presented below

OilStates/ Oceaneering DeepTap™ Remote-tap cutter

Oilstates/Oceaneerings remote-tap cutter comprises the DeepTap™ hot-tap system, see Figure 6-14 and Figure 6-16, and the HydroTap™ clamp, see Figure 6-15. The hot-tap system was developed by Oilstates and Oceaneering in the late 90`s [1]. To Statoil's knowledge, the system was never completed and has never been used.

Figure 6-12 DeepTap™ system [10]

Figure 6-14 DeepTap™ system [10]

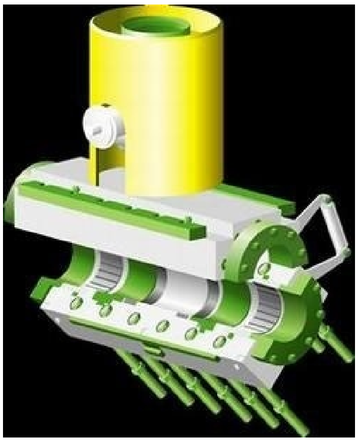


Figure 6-13 HydroTap™ (The clamp) [10]

Claxton/Mirage Diver assisted Hot-tap cutter

The diver-assisted Claxton/Mirage hot-tap system, see Figure 6-17 and Figure 6-18, was attempted used in Tampen Link project in 2007 but failed during offshore operation. The competing PRS HTCU was mobilized and successfully completed the operation in 2008.

In retrospect the Tampen experience caused a major setback for this Claxton/Mirage diver-assisted system [1].

Figure 6-15 Claxton/Mirage Hot-tap cutter [11]

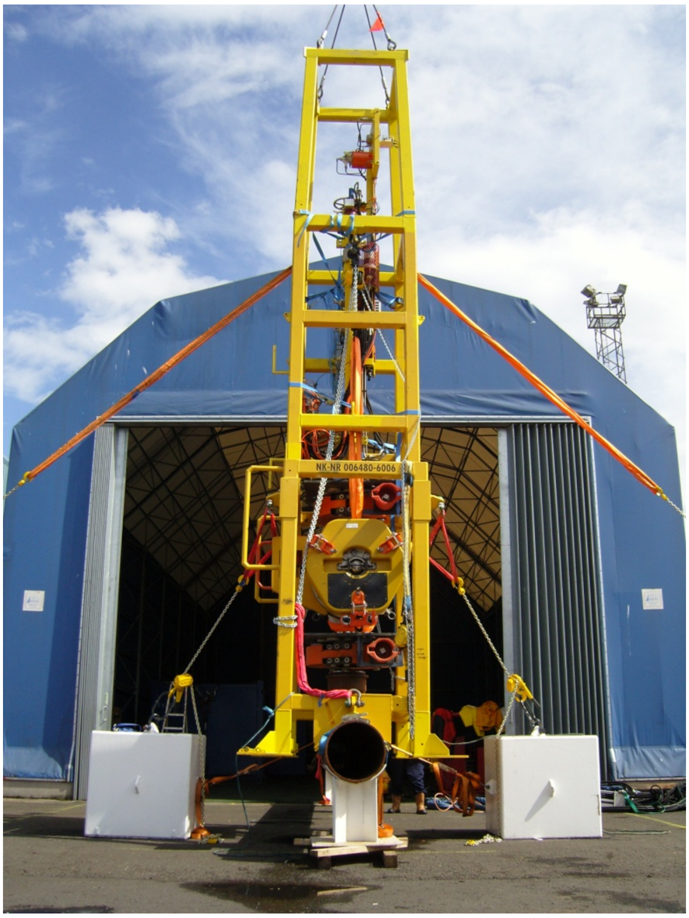


Figure 6-16 Claxton/Mirage Hot-tap cutter [11]

TD Williamson Remote Hot-tap cutter

TD Williamson has been working on a remote hot-tap system for some time. The design is a continuation of the previously developed diver-assisted system adapted to be operated by ROV. The system has performed simulated Hot-tap in the workshop (10" hole in a 12" pipe) in Stavanger during 2011. TD Williamson claims to provide hot tapping anywhere in the world [12], see Figure 6-19. To Statoil's knowledge, the system is neither currently qualified nor commercialized.

Figure 6-17 TD Williamson – Hot tapping Xalapa, MEXICO [13]

Furmanite /IPSCO

Furmanite claims to have over 50-years' experience with land based hot-tapping [14]. Diver-assisted hot-taps have been performed successfully in Statoil projects using the IPSCO tool on Jotun and Gullfaks [1], see Figure 6-20.

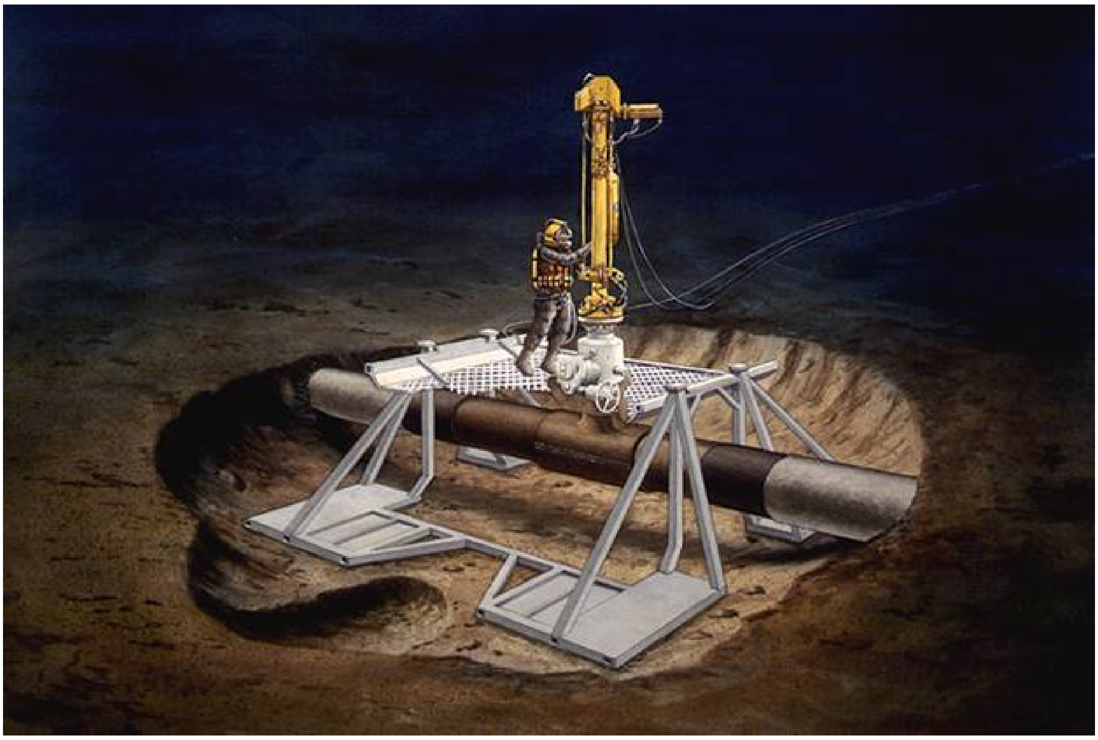


Figure 6-18 The diver-assisted IPSCO tool at Gullfaks in 2000

IK Stavanger as

IK have presented a conceptual hot-tap concept, not field proven. According to IK Stavanger [15] the concept span from small tools to bigger tools capable of large dimension holes on high pressure process systems, see Figure 6-21. IKs hot tap system is driven manually, or by air or hydraulic.

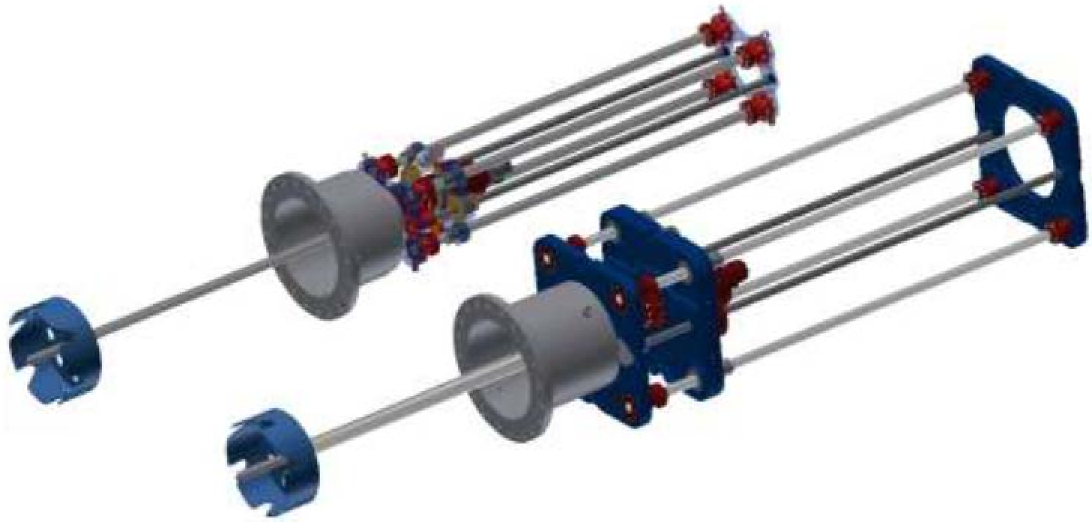


Figure 6-19 IK hot tap tool [15]

7.0 FIRST EVER REMOTE HOT TAP ON AN UNPREPARED PIPELINE – ÅSGARD SUBSEA COMPRESSION PROJECT

7.1 Åsgard field layout

The Åsgard field is located in Haltenbanken in the Norwegian Sea, about 200 kilometres off mid-Norway. It comprises the Midgard, Smørbukk and Smørbukk South fields. Mikkel is located 35 kilometres south of Midgard at the Åsgard field, see Figure 7-1.

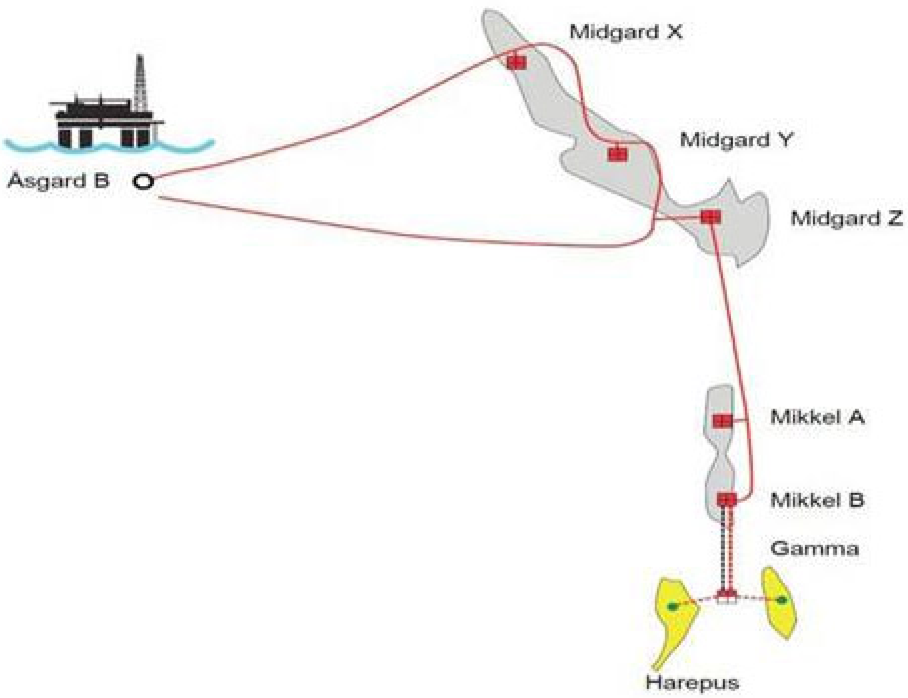


Figure 7-1 Åsgard B illustrated with Midgard (X, Y, Z) and Mikkel, [16]

The Åsgard development consists of an FPSO (Floating Production, Storage and Offloading), Åsgard A which stores and offloads oil, a semi-submersible platform, Åsgard B, which processes gas and condensate, a storage ship, Åsgard C, which stores and offloads condensate, and the necessary associated subsea production installations.

7.2 ÅSCP background

The main objectives for Åsgard Subsea Compression Project are:

- Increase gas recovery from Midgard and Mikkel
- Implement solutions to keep the production above a minimum critical production rate
- Maintain gas in Åsgard Transport within CO_2 specifications
- Enable production volume and rate from Midgard and Mikkel that at all times utilise the available process and transport capacity at the Åsgard facilities.
- Avoid slugging in pipeline system.

The well pressure on the Midgard field is dropping to levels which require boosting to maintain sufficient flow rate without slugging (minimum flow). A subsea compressor station (SCSt) and a valve manifold will be installed to increase line pressure to Åsgard B. Low pressure gas will be imported from X, Y and Mikkel. The outlet from the compressor will be connected to a hot tap tee Y-101 pipeline and a direct pipeline to Åsgard B, see Figure 7-2. The Åsgard subsea gas compressor will increase the production from the Mikkel and Midgard field with approximately 280 million barrels of oil equivalents.

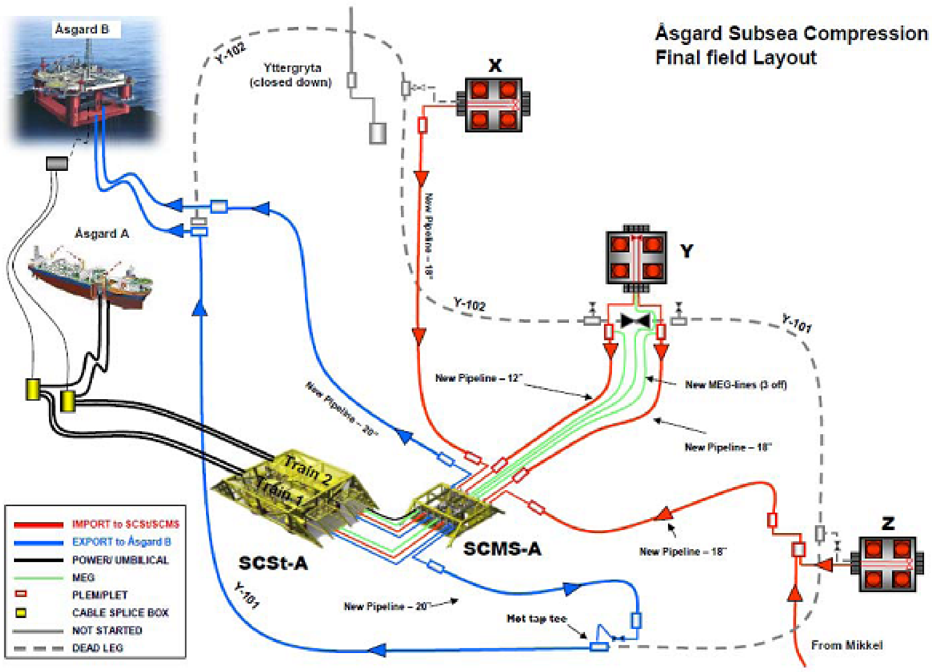


Figure 7-2 Åsgard Subsea Compression illustration final field layout, [17]

7.3 ÅSCP Campaign 3

The scope of work related to the hot tap operation and required preparatory work was organised in several tests and three separate campaigns:

- Shallow Water Tests (SWT) and Site Integration Tests (SIT)
- Deep Water Test I (Sognefjorden Jan/Feb 2011)
- Campaign 1 – Deep Water Test II (Nedstrandsfjorden April 2012)
- Campaign 2 – Hot tap preparatory work (Åsgard field May 2012)
- Campaign 3 – Hot tap operation (Åsgard field Aug/Sept 2012)

The main purpose of Campaign 1 was equipment qualification, verification of procedures and training of personnel for the offshore work in campaign 3.

The purpose of campaign 3 was the actual hot tap operation. Figure 7-3 indicate the ÅSCP hot tap location.

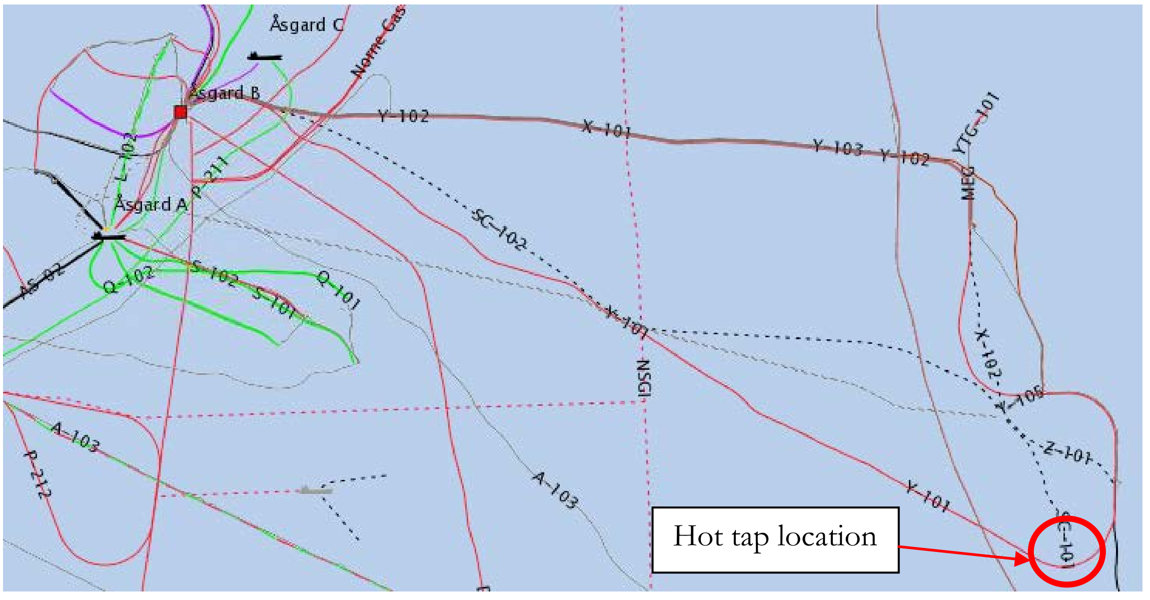


Figure 7-3 Åsgard field layout, indicating the ÅSCP hot tap location [18]

For ÅSCP press coverage see APPENDIX 2, APPENDIX 3, APPENDIX 4, APPENDIX 5, APPENDIX 6, APPENDIX 7 and APPENDIX 8.

7.4 ÅSCP Project Engineer

As the ÅSCP hot tap campaign 3 was performed, my role as project engineer onboard was to:

- Report results/experience from operations offshore. Make a daily status report for each shift.
- Be responsible for assuring that all work was covered with a procedure and that the operation was performed according to the procedures.
- Verify that Technip`s QMS (Quality Management System) and HSE (Health, Safety and Environment) systems were followed.
- Be responsible for required risk assessment (SJA (Safe Job Analysis) and Toolbox Talk) performed before commencing operation.
- Familiarize with the vessels Work Permit system, and regularly verify that planned and ongoing PRS work had valid permits.
- Keep an "Operational Log" (dive log)
- If modification or repair of any tool was required offshore:
  Be responsible for making task plans for fault finding if required, to ensure that this was done safely and effectively.
  Be responsible for preparing procedures, describing required modifications/ repair of tool.
  Be responsible for ensuring that risk assessment for unplanned work was performed.
- Be responsible for preparing test report/End of Job report after completed operation according to Clients requirements.

8.0 GENERAL IMPROVEMENTS BASED ON EXPERIENCE

PIF/HTCU improvements, not specifically related to ultra-deep water upgrade are split into four parts:

- Upgrading the HTCU to operate independent of the PIF
- HTCU handling without PIF – vessel cost
- Evaluating the HTCU for extending water depth capability. Previously offshore operations indicate a system handling evaluation as important
- Optimization of lowering and hoisting speeds

8.1 Upgrading the HTCU to operate independent of the PIF

The PIF function as a frame to hold and position the HTCU. Figure 8-1 presents an overview of the PIF and HTCU. For more detailed PIF/HTCU operation, see section 6.2.5.

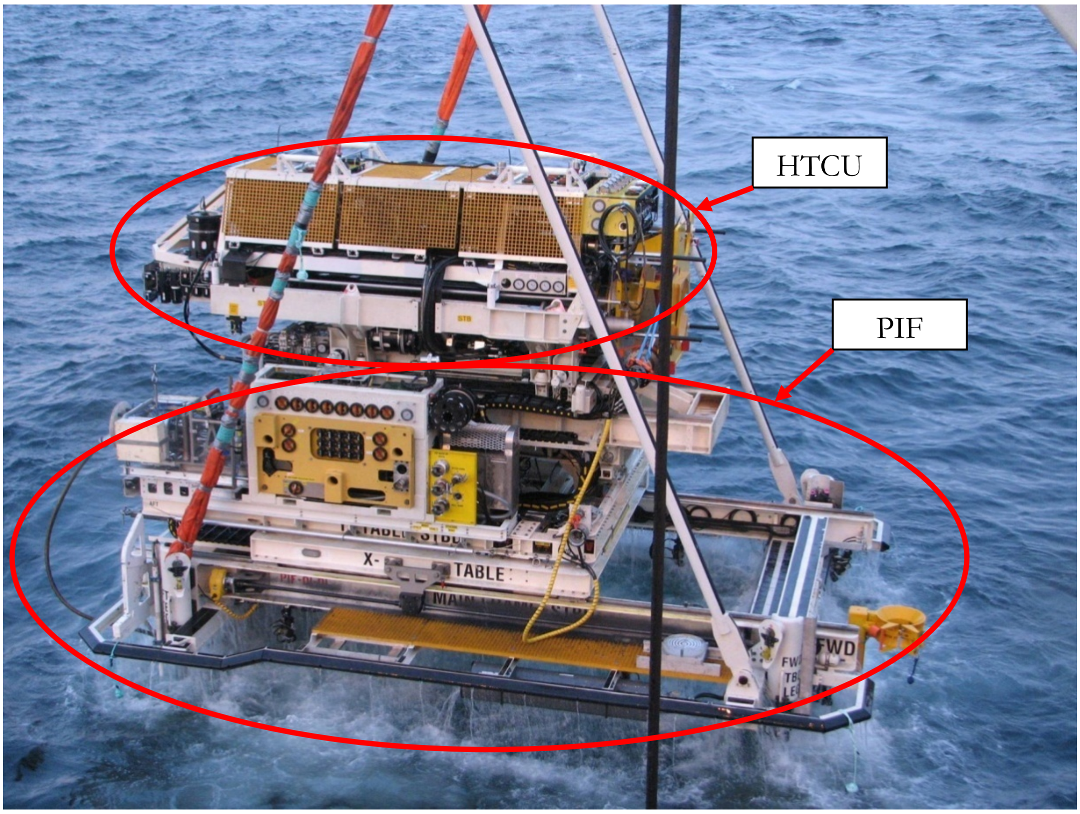


Figure 8-1 PIF/HTCU system

From previous operations the critical areas subsea were mostly PIF related [19]:

- Seabed levelness for PIF/HTCU land out (...)
- Lifting/landing of PIF/HTCU (...)
- Malfunction of PIF/HTCU during cutting operation (...)

In addition to the critical areas mentioned above, there is also the "dropped object" risk (the risk of dropping heavy load on the pipeline).

PIF`s function is to position the HTCU for connection to the HTBV. Installing a Retrofit tee 12 o`clock vertical on the pipeline, do not say anything about the pipeline horizontal axis position. In addition there are tolerances on the RT-installation (clock positions), measuring the pipelines' incline, etc. These tolerances are compared to the capture angle for connection between the HTCU and HTBV.

Extending water depth to 3000 MSW, it is recommended to only upgrade the HTCU tool, not the self-contained system PIF/HTCU. HTCU operation independent of PIF would make the operation safer and the HTCU could operate vertically. For evaluation of vertical handling of HTCU, see chapter 8.3.

8.2 HTCU handling without PIF – vessel cost

Handling the HTCU without PIF will decrease the operation cost. Åsgard Subsea Compression Project hot tap PIF pre- and post operational time was approximately 10 hours (without mobilization/demobilization and IMR), which result in a vessel cost of 1 100 000 NOK. Pre-operation checks such as seabed stability, levelling, settling, rough positioning and alignment of the X-table, and post operation (revert to recovery position), in addition to dredging would be unnecessary. PIF is presently installed together with HTCU to handle pre-installed tees. Upgrading the HTCU handling without PIF assume operation on Retrofit tees (always installed vertically).

Making the HTCU operate without PIF will make the operation more efficient, decreasing pre- and post operation time. The operation time could be decreased with 10 hours (PIF operations) and additional cost reduction on mobilization/ demobilization expenses, IMR expenditure, operator training, spare parts and maintenance.

According to Statoil designing and building a new vertical HTCU structure frame will have a project expense of approximately 5 MNOK, while at least 20 MNOK upgrading the PIF. It is concluded that designing a new vertical HTCU structure frame will be the best alternative. However, this implies that the HTCU is limited to operation on Retrofit tees only.

8.3 System handling evaluation

Experiences from previous offshore operations recommend handling the HTCU vertically for Retrofit tees. The present HTCU structural design contains some superfluous steel. The only beams necessary are the two beams (yellow) on the side, see Figure 8-2.

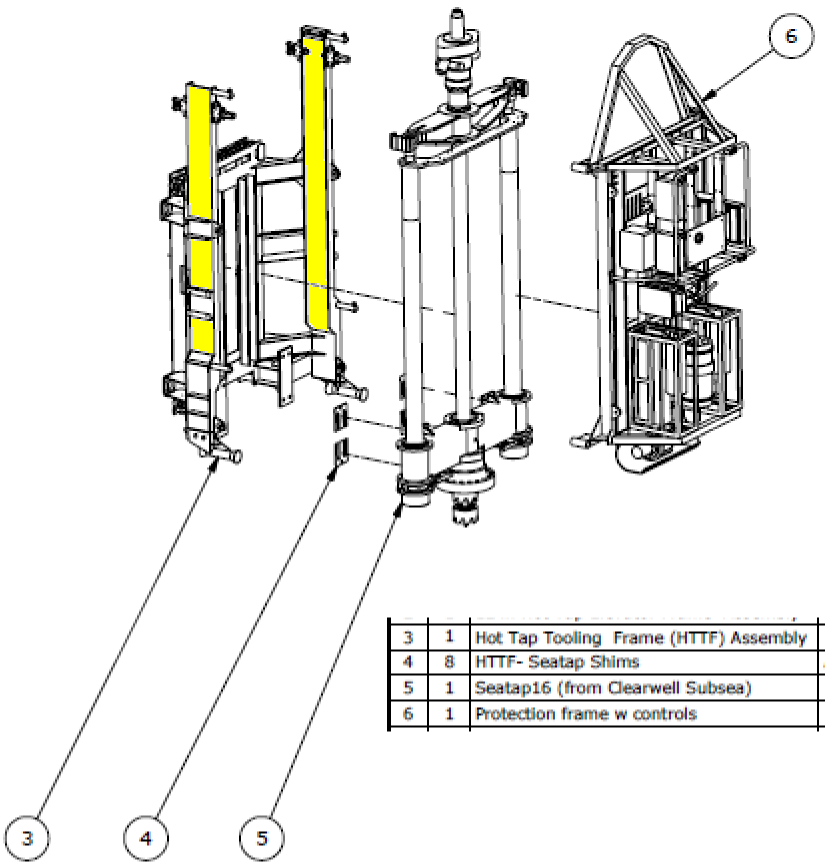
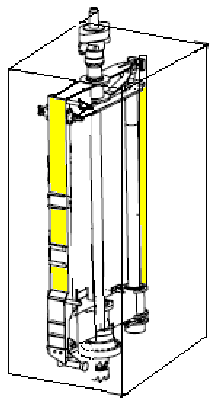


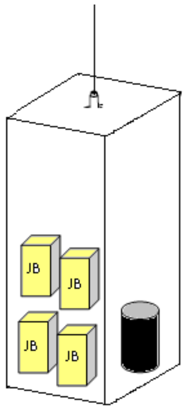
Figure 8-2 Present HTCU structure [20]

A new designed vertical structure for the HTCU is recommended.

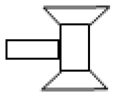
A new structure will be designed, see figure, in such a way that the frame do not contain any enclosed volumes in the steel, which could collapse. In addition a new soft landing and guiding system is required – which substitute the requirement for PIF on vertically Retrofit tees.



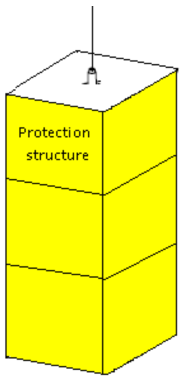
A new structure will be designed to relocate all the Junction boxes (JB) as low as possible. This is done to ease the access so climbing can be avoided, see figure. The structure will be designed with a single lifting point making the vertical handling secure and reliable.



A new structure will include guiding and soft landing to assure a successful HTCU installation on the Hot Tap Ball Valve. Guidelines are not recommended and inappropriate at ultra-deep water depths, due to twisting entanglement and that the guidelines become heavy (3000 m with wire) in proportion to the benefit. Guide funnels, see figure, will therefore be evaluated. To have a more stable lowering the upper guide funnels is to be designed to handle long prongs (part of the MHS (Module Handling System) upper cursor frame).
CC (center-center) between the funnels should be 2586 mm, max 2900 mm, which is standard for IMR vessels.



A new structure will be designed with protection structure, see figure.



Handling the HTCU vertically facilitates deployment by the ships crane or MHS/Tower through the vessel`s moon pool. A moon pool is an opening through the hull, providing access to the water below, allowing protected lowering of tools and instruments into the sea. In addition use of the vessel`s moon pool will increase the weather window, from H_S (Significant Wave Height) 2.0 - 2.5 m to 5.0 - 6.0 m. Increased weather window implies lower risk of waiting on operable weather, which will facilitate higher up-time.

The MHS comprises a skidding system and pallets on deck. If the HTCU is to be handled vertically the tool will be welded/strapped on to the skidding pallet. The pallet is then positioned over the moon pool hatch by push/pull units and the crane is fastened to a single lifting point at the HTCU. The MHS upper cursor frame is lowered until the prongs are stabbed into the upper HTCU guide funnels and locked. The cursor frame is then lifted, the “skidding pallet” removed and the moon pool opened. Running the wire and cursor frame synchronous through the moon pool, leaving no slack during lowering.

8.4 Optimization of lowering and hoisting speeds

Given from previous offshore campaigns and projects, the vessel time is an important cost factor. Optimization of lowering and hoisting speeds (especially at deep waters) will reduce vessel time and thus project cost. Some components in the involved tools do however have limitations with respect to lowering speed.

The vessel, Scandi Arctic, has an operational cost per hour of 110 000 NOK. This includes only the vessel and its crew, not hot tap operators/team. To illustrate the operational lowering and hoisting cost when it comes to vessel, it is divided into:

1. Present vessel cost
2. Vessel cost extending to 3000 MSW

1. Present vessel cost

   During Åsgard Subsea Compression Project, for PIF/HTCU, the vessel cost was:

   Crane speed: 10 m/min
   Target depth: 266 MSW
   Which resulted in a vessel cost of: 26.6 min * 2 (lowering and hoisting) ~ 110 000 NOK

   For ÅSCP, total cost of vessel HTCU/PIF: 330 000 NOK

2. Vessel cost extending to 3000 MSW

   Ultra-deep water scenario: Submerging the HTCU with the ship crane, on present speed of 10m/min to 3000 MSW:

   Crane speed: 10 m/min
   Target depth: 3000 MSW
   This will result in a vessel time of:
   300 min * 2 (lowering and hoisting) = 10 hours ~ 1 100 000 NOK
   For HTCU extending to ultra-deep water, total cost of vessel will be ~ 1 100 000 NOK.

8.4.1 Lowering and hoisting speed

Lowering and hoisting speed represents a substantial cost factor in this operation. Experience shows that advanced tools often needs to be recovered several times to deck for repairs and maintenance during an operation. This will make the lowering and hoisting associated vessel cost even higher. Increasing lowering and hoisting speed will reduce vessel time, but will also be limited by certain characteristics.

Lowering and hoisting speed can be significantly increased extending to ultra-deep water without overstraining sensitive components

In subsea equipment oil-filled systems are fitted with oil compensators whose task is to keep the internal pressure as equal as or higher than the ambient pressure as possible. Having equal pressures in all cavities of the system prevents pressure induced forces and keeps the system intact. If the compensators for some reason are blocked or runs out of oil the differential pressure (internal compared to ambient) can build up, leading to pressure induced forces and tension which at some stage might lead to cracks, burst or failure of components.

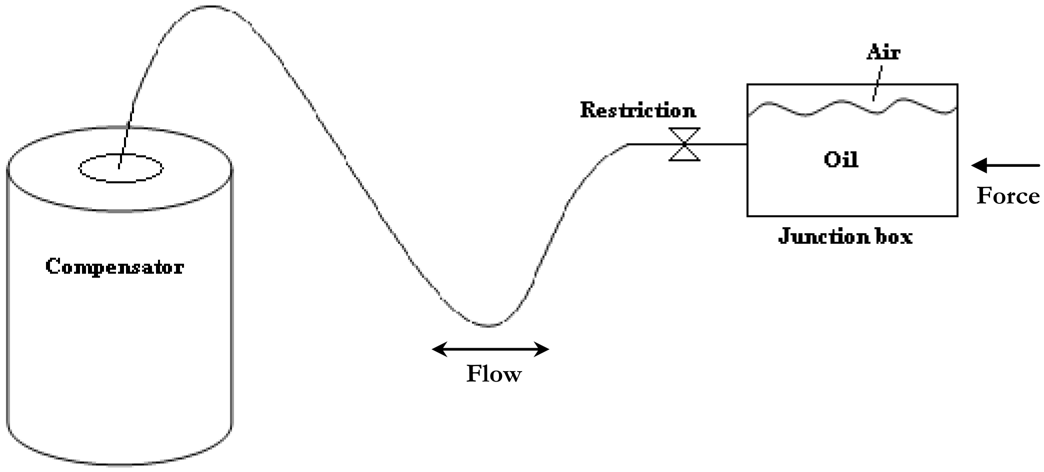


Figure 8-3 Compensator connected to a Junction box

A subsea system designed for ambient pressure needs to be connected to a closed loop compensator which has a set pressure slightly above ambient, see Figure 8-3. Higher flow and narrow channels will give a higher pressure difference. Thus it is important with compensators and hoses to handle the capacity required. Insufficient compensation will lead to slower lowering speeds and potential destruction of components. The lowering and hoisting speed needs to be sufficiently low to prevent build-up of differential pressure.

The internal cavities consist of hydraulic oil and trapped air. The hydraulic oil itself is incompressible in practical terms (APPENDIX 9).

Due to the near incompressibility of water and hydraulic oil, the major contributor for requiring compensation is the trapped air. The more air the more oil is required to move to compensate for the reduced volume as the air gets compressed at increasing depths.

Assuming incompressibility of water and hydraulic oil, the relative compensator volume will be approximately inversely proportional to depth.

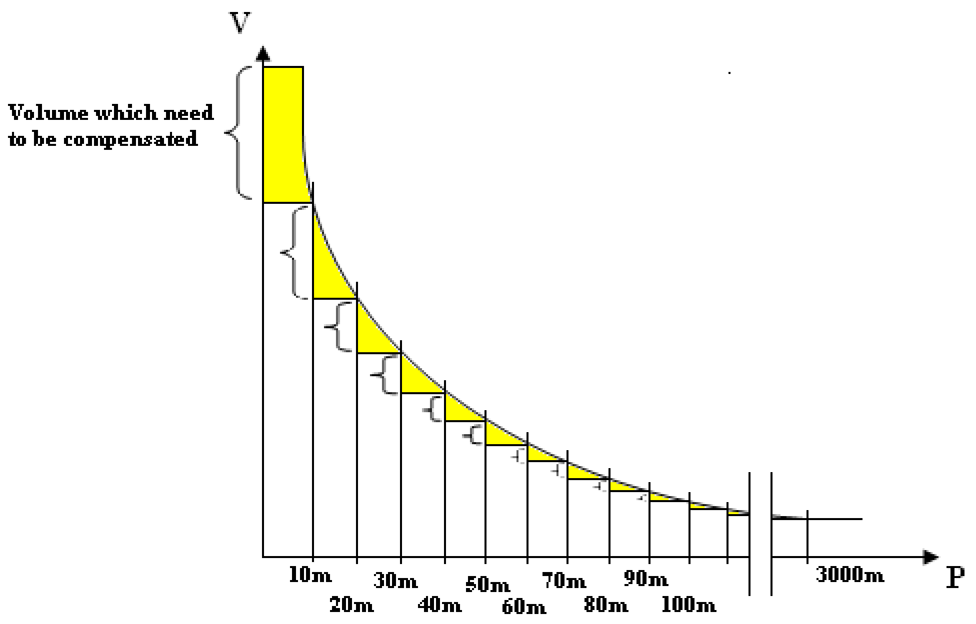


Figure 8-4 Volume decrease and pressure increase during lowering

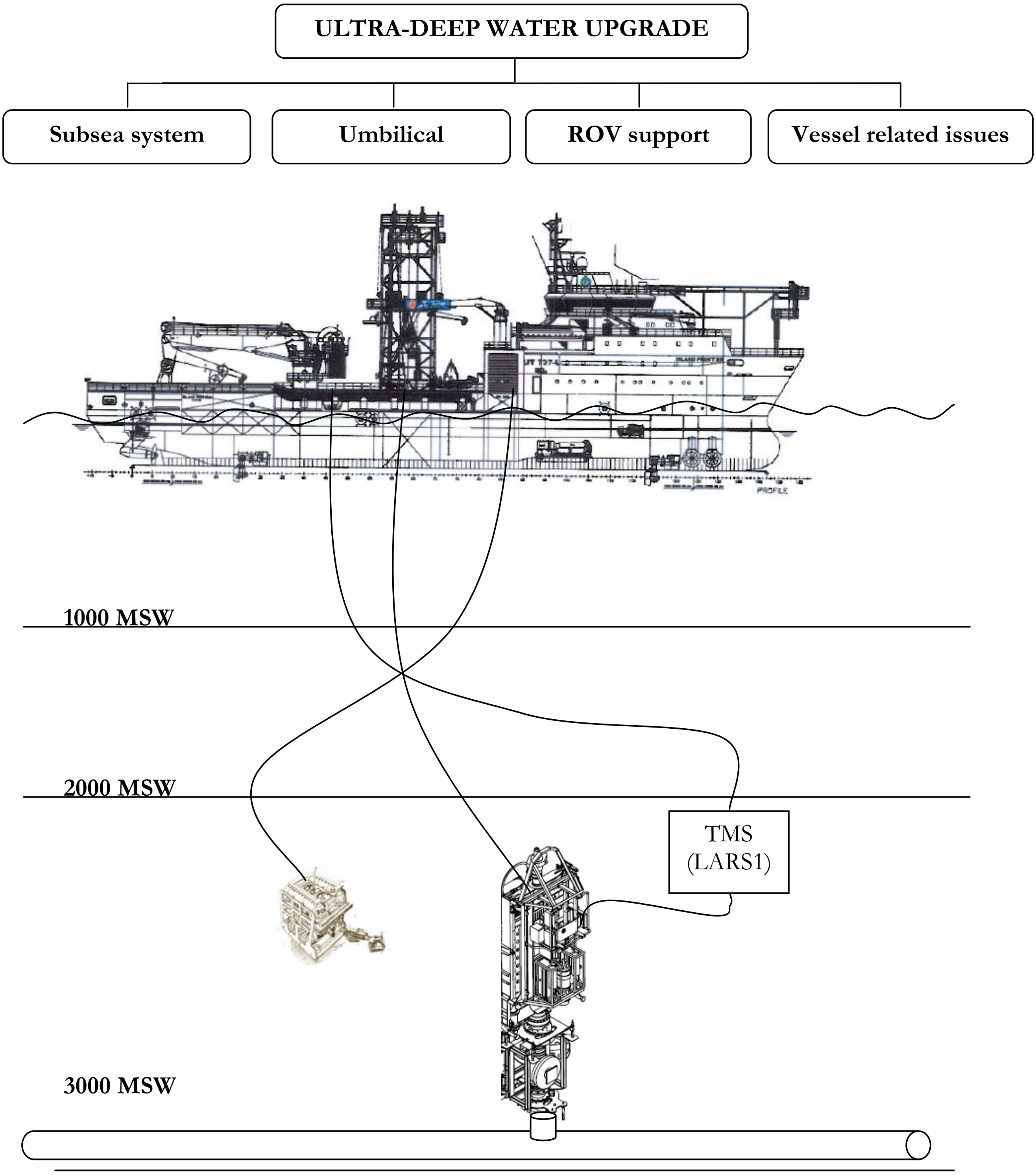
Figure 8-4 shows that the incremental compensator volume ΔV (yellow) is decreased at higher pressure in deeper water. This implies that the required flow per depth interval between the compensator and the compensated unit (i.e. junction box, as show in Figure 8-3) also decreases correspondingly.

The lowering and hoisting speeds can thus be increased with water depth. Consequently, dimensioning a compensator is more critical in shallow water, but needs to take into consideration whatever added compression takes place in deeper water.

In any case it is important to dimension the compensator and the connection lines to the units to be compensated properly. Additionally it is important to reduce risk of trapped air in the system.

9.0 ULTRA-DEEP UPGRADES

The ultra-deep water upgrade is broadly applicable to four subsystems; Subsea system, Umbilical, ROV support and Vessel related issues. Each subsystem contributes as an important part of the upgrade.

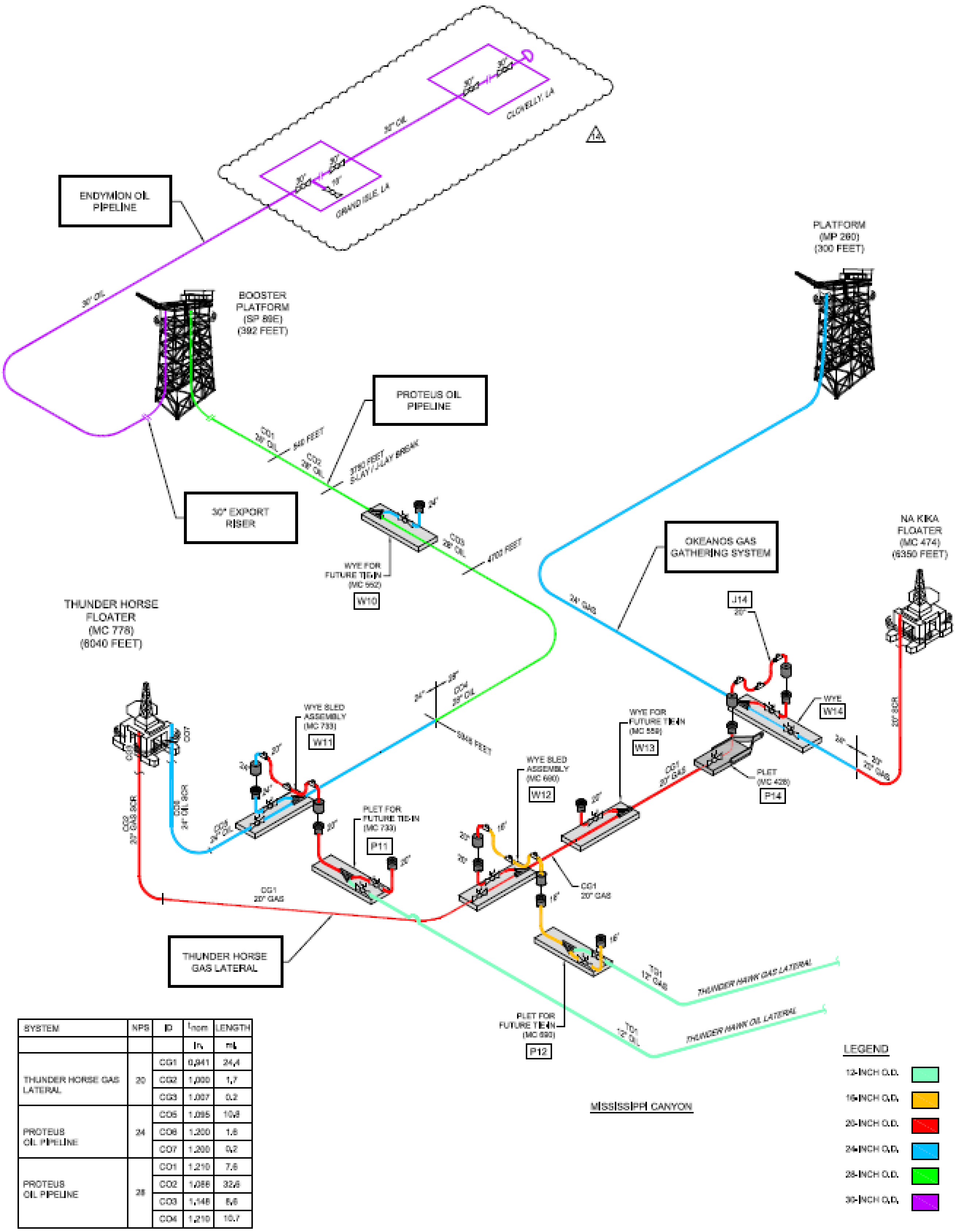


9.1 Design basis – Mardi Gras deepwater pipeline

As a base application case for the master thesis the ultra-deep water BP Mardi Gras Transportation system in the Gulf of Mexico (GoM) has been selected. According to BP the transportation system consists of five main lines, totalling some 790 km (490 miles), the highest capacity deep water pipeline system ever built [23]. The transportation system consists of a number of lines and sections with different dimensions, see Figure 9-1.

Design basis according to BP, see APPENDIX 10:

Depth	: 2200 MSW, master thesis case 3000 MSW
Dimension, OD	: 24”
Wall thickness	: 24.6-31.2 mm (0.971” – 1.227”)
Material Class & Strength	: API 5L X-65 (Carbon steel grade X-65)
Coating Type & Thickness	: FBE 18-22 mm (Fusion Bonded Epoxy coating 18-22 mm)
Pressure rating	: 215-251 bar (3115-3630 PSIG)
Temperature	: 160 F (71.1 deg C)
Seawater temperature	: 40 F (4.4 deg C)
Soil	: Generally soft clays with pipe embedment of 30-50%
Visibility	: Good visibility beyond 800 MSW except after hurricanes
Seawater current	: 0.3 m/s



SYSTEM	NPS	ID	t_{nom}	LENGTH
			In.	mi.
THUNDER HORSE GAS LATERAL	20	CG1	0,941	24,4
		CG2	1,000	1,7
		CG3	1.007	0.2
PROTEUS OIL PIPELINE	24	CO5	1.095	10.8
		CO6	1.200	1.6
		CO7	1.200	0.2
PROTEUS OIL PIPELINE	28	CO1	1.210	7.6
		CO2	1.086	32.6
		CO3	1.148	8.6
		CO4	1.210	10.7

Figure 9-1 Mardi Gras pipeline schematic, see APPENDIX 10

9.2 Systems upgrades

9.2.1 Subsea system

The subsea system upgrades focuses on what is required on the vertical HTCU. System/component upgrades are related to differences in hydrostatic pressure, temperature, seabed conditions and visibility.

As mentioned in the design basis the Mardi Gras pipeline is installed at ultra-deep water depths. Statoil needs to keep up exploring increasing water depths and is therefore looking into the possibility to upgrade the HTCU. At 3000 MSW the hydrostatic pressure will be 300 bar. ϱ

As mentioned earlier, the HTCU is rated to 1000m. Extending water depth from 1000 MSW, to 2000 MSW and then 3000 MSW the differences is mainly the ambient hydrostatic pressure *P*, [24]:

$$P = \varrho\, g\, h$$

where ϱ is water density *(kg/m³)*, g gravitational acceleration *(m/s²)* and h is water depth *(m)*. In addition there will be differences in temperature, seabed conditions and visibility. HTCU affected subsystems are mechanical, hydraulic and electrical systems.

As for the ÅSCP, at 265 MSW, the internal Midgard pipeline pressure was 91 bar, while the hydrostatic ambient pressure on the location was 26.5 bar implying a positive pressure differential from inside to outside, see Figure 9-2, overpressure.
In this ultra-deep water depth (3000 MSW) base case the hydrostatic ambient pressure is higher than inside the pipeline. As this base case indicates the pressure rating inside the pipeline is 215-251 bar giving a negative-pressure differential see Figure 9-3, negative pressure.

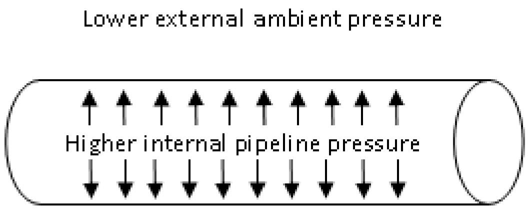


Figure 9-2 Higher internal pipeline pressure than external ambient pressure

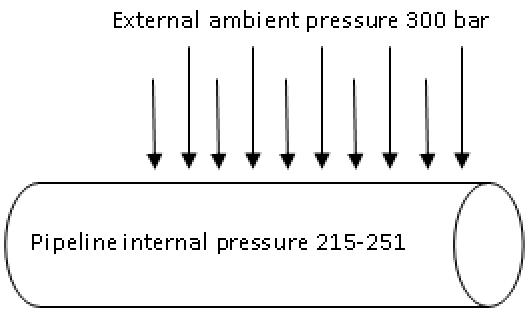


Figure 9-3 Higher external ambient pressure than internal pipeline pressure

Higher hydrostatic ambient pressure than internal pipeline pressure, reversed pressure differential, creates challenges such as:

1) Direction of action due to reversed pressure differential
   - EDRS system
   - Cutting function
2) Sealing
   - Seals – Volume compression due to absolute pressure
   - Seals – Direction of action due to reversed pressure differential

1) Direction of action due to reversed pressure differential

EDRS system

EDRS is used to recover the HTCU from the pipeline and the valve such that the valve could be closed and the HTCU recovered back to deck.

If an emergency occurs ROV will stab the 4 port Ifokus stab (Hot stab used by ROV to connect hydraulic oil) into the EDRS panel, see Figure 9-4.

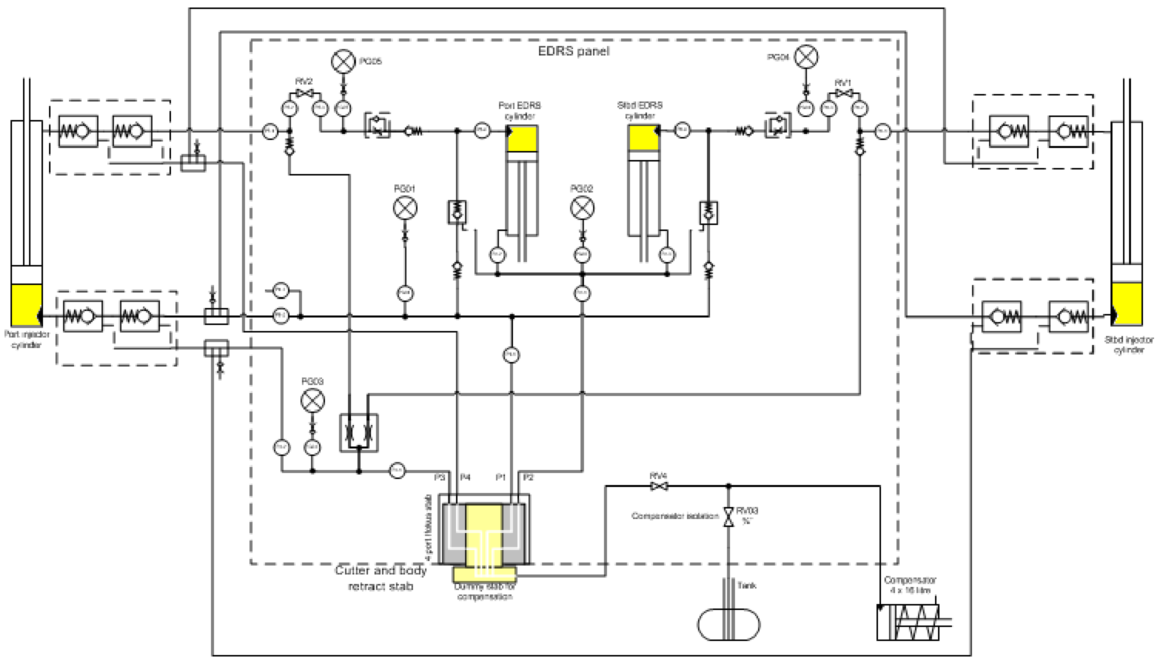


Figure 9-4 HTCU EDRS Panel – Hydraulic Circuit, [25]

When the Ifokus is stabbed the operator can operate necessary valves and retract the port and starboard injector cylinder, see Figure 9-5. The EDRS and the pipeline pressure (overpressure) will work together to retract the tool shaft. The EDRS is run on hydraulic supplied by ROV.

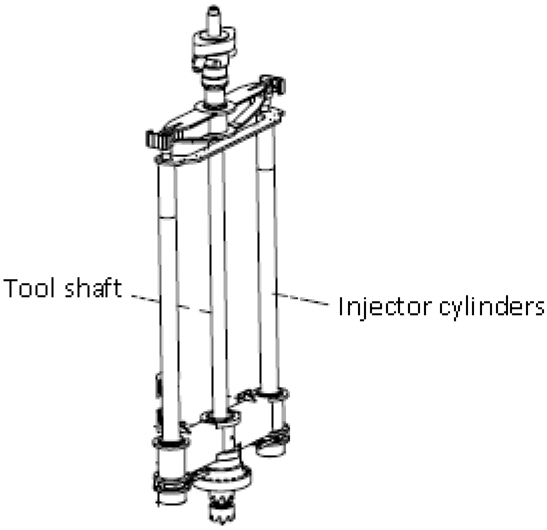


Figure 9-5 SeaTap

Due to the reversed pressure differential effect the EDRS will act opposite of its design. The HTCU present design covers this to 2000 MSW. The port and starboard injector cylinders must retract against the reversed pressure differential.

Most of the EDRS functions are mechanical or hydraulic, and the pressure effects should be minimal. The EDRS need to be evaluated and tested extending to ultra-deep water.

<u>Cutting function</u>

The HTCU present cutting design function: the cylinders must pull the SeaTap (the drilling element of the HTCU) towards the pipeline.

The HTCU seal design (to seal against water intrusion due to negative pressure) is similar to the seal used for overpressure during cutting and is designed for 250 bar (delta pressure), see Figure 9-6 and Figure 9-7. Thus there is a margin of 50 bar (from a negative pressure at 200 bar) to avoid water intrusion.

Present HTCU, structural and hydraulic, is designed to 2000 MSW:

- Negative pressure: assuming 1 bar (atmospheric pressure) in the pipeline, ergo a negative pressure of 200 bar, see Figure 9-6.
- Overpressure: In addition a delta pressure design of 250 bar, indicate that at 2000 MSW the pipeline could have a overpressure of 450 bar (200 bar at 2000 MSW + 250 bar), since the HTCU is pressure balanced with the hydrostatic pressure, see Figure 9-7.

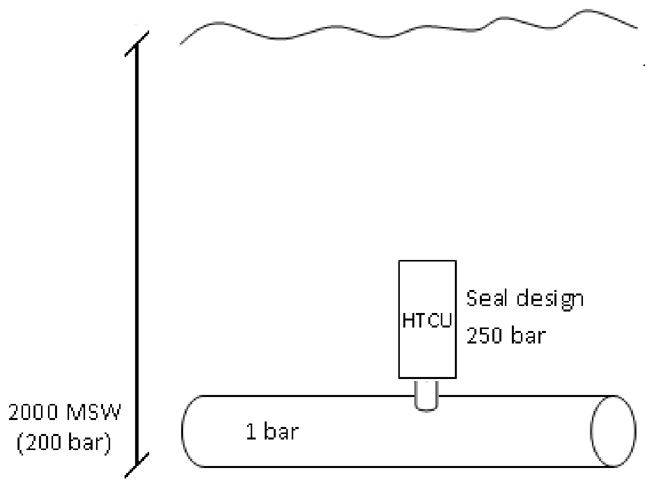


Figure 9-6 200 bar negative pressure

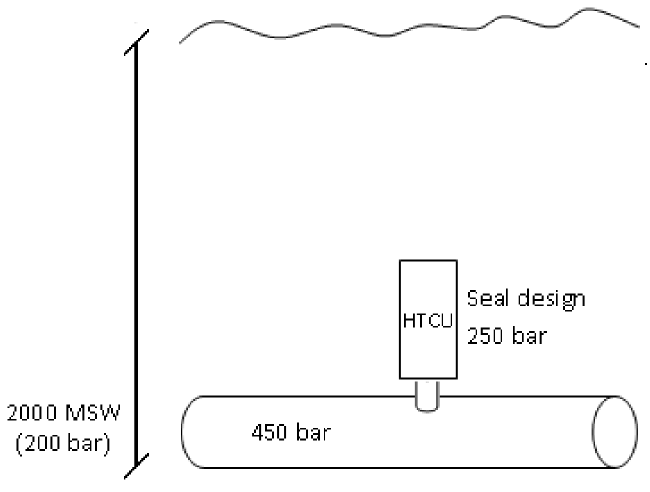


Figure 9-7 250 bar overpressure

Figure 9-8 indicates the Mardi Gras reversed pressure differential, the hydrostatic ambient pressure is 49-85 bar higher than the internal pipeline pressure.

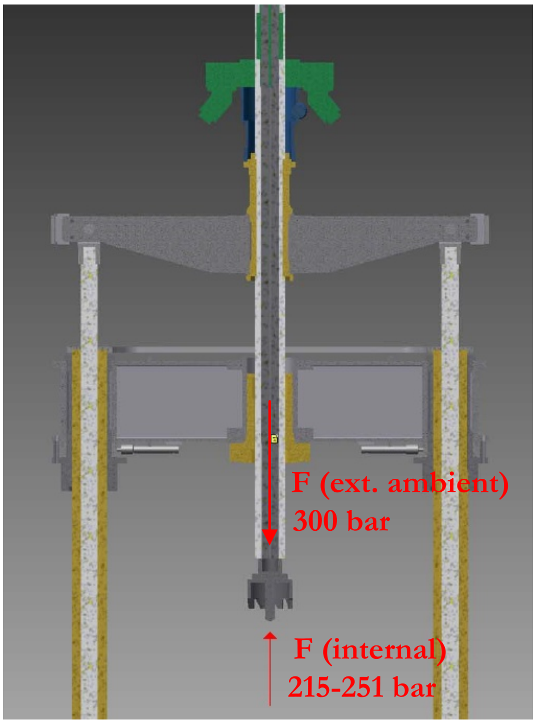


Figure 9-8 Tool shaft forces

The HTCU will together with the ambient pressure push the drive shaft into the pipeline. At 3000 MSW the challenge will be to prevent HTCU from going to and through the bottom of the pipeline.

It is required to extend seal design pressure from 250 to 350 bar, with a margin of 50 bar, to cope with the reversed pressure differential effect.
The seal design requires reinforcement and some hydraulic modifications in addition to higher range to withstand the hydrostatic ambient pressure at ultra-deep water.

2) Sealing

Seals – Volume compression due to absolute pressure

Present general seal function is to assure proper function and to prevent hydraulic oil spillage to sea.

At 3000 MSW the seals are exposed to 300 bar absolute pressure. The issue is whether the seal rings will maintain sufficient volume to seal properly, in addition to the local effects of collapse of the seal rings. Resilient seals exposed to higher absolute pressure are at the risk of shrinking and could represent risk of leaks or completely loss of function. These concerns depend on the volume compression issue due to absolute pressure. Components affected by this compression effect are for instance cylinders. The cylinders seals are dependent on working pressure, wear resistance, low friction, mounting conditions, etc. Extending water depth capability it is recommended to replace present cylinders with new ones rated to 300 bar external pressure.

In addition Clear Well Subsea Ltd require some modification of the Injector cylinders (SeaTap) to compensate the cylinder bodies during lowering and ensure that trapped pressure does not overpressure the cylinders during hoisting.

Except for the cylinder seals, all PRS equipment uses Nitrile Rubber (NBR) o-rings. Nitrile is compatible with most environments, has good mechanical properties and high wear resistance [26]. The Nitrile rubber is not a concern extending to ultra-deep water due to the hydraulic system compensation and Nitrile`s properties (Nitrile is incompressible, deflect by changing shape rather than changing volume [27]).

Water in Tellus S 22 mineral oil can be discovered with a visual check, the oil becomes white already just containing 0.05-0.1 % water [28].

Seals – Direction of action due to reversed pressure differential

As mentioned the HTCU SeaTap is designed for 2000 MSW, see Figure 9-9.

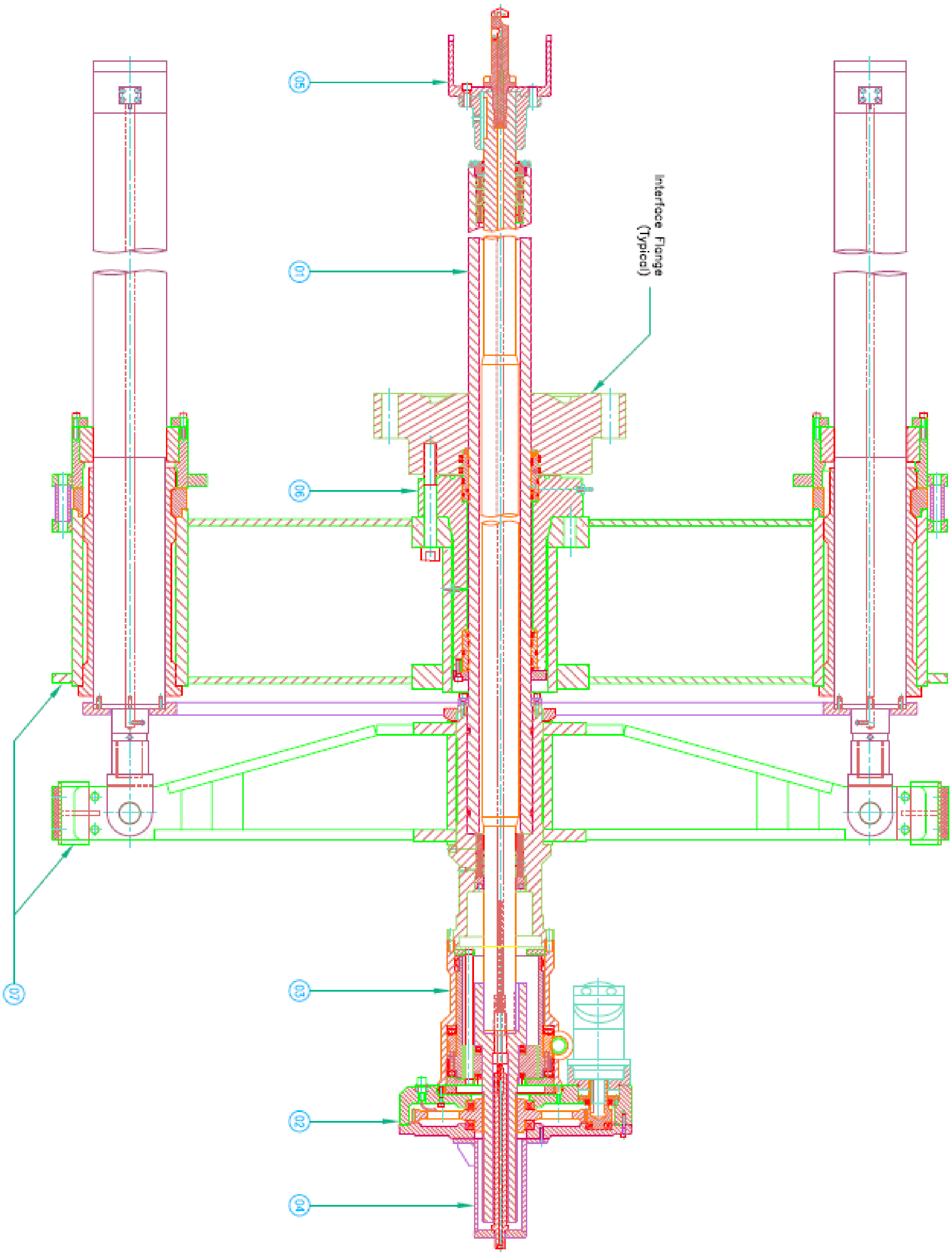


Figure 9-9 Hot Tap Cutting Unit – SeaTap (Clear Well Subsea Ltd.) see APPENDIX 11

To minimise water intrusion, the SeaTap is designed with seals with the right shape and materials, in addition the hydraulic system holds a back-pressure. In a hydraulic system surrounded by sea water seals against the surroundings are even more important than usual. Water intrusion on the system has several negative effects:

- Increased corrosion with following function failure or reduced efficiency.
- Reduced lubricating quality with following component breakdown
- Possible growth of organisms in the system, with following blocking of valves etc.

According to Clear Well Subsea Ltd., APPENDIX 12, extending water depth capability will affect the SeaTap sub systems in different ways:

Tool Shaft Assembly – Item 1 – see Figure 9-9

The cavities within the Tool Shaft see hydrostatic ambient pressure and are pressure compensated. The cavities are therefore relatively immune from this pressure effect, provided that the internal pipeline pressure is higher than hydrostatic ambient pressure.

In the Mardi Gras case the seals will see reversed pressure differential. This will not be a problem for the upper seals cartridges, but it will be a problem for the lower seals due to problems of type (single acting lip seals) and configuration of seals.
In addition the reversed pressure differential will impose loading on the Tool Shaft Drive Shaft which would require modifications.

It is required to modify the compensation system and the seals. Additionally the new systems need qualification through testing.

Drive Unit Assembly – Item 2 – see Figure 9-9

The cavities within the Drive Unit, as the cavities within the Tool Shaft, that see external ambient pressure are pressure compensated. The Drive Unit cavities will therefore be completely immune from this pressure effect.
Possible modification of the Feed Unit Drive Shaft could affect the Drive Unit.

Feed Unit Assembly – Item 3 – see Figure 9-9

The cavities within the Feed Unit, as for the two previous, see hydrostatic ambient pressure and are pressure compensated, and will be immune from this pressure effect.

The reversed pressure differential requires modification of the Drive Shafts both in the Tool Shaft and Feed Units.

Pilot Probe Assembly – Item 4 – see Figure 9-9

A re-qualification of the dynamic seals is required. If the seals are out with their "Pressure Vessel" (PV) values redesign will be required.

Cutter and Pilot Drill Assembly – Item 5 – see Figure 9-9

The cavities within the Feed Unit, as previous, will be compensated by the pilot drill circuit after actuation, and will be immune from the reversed pressure differential effect. It is required screening for reversed pressure differential on the piston in a pressure locked position.

Seal Box Assembly – Item 6 – see Figure 9-9

Subject to a detailed review there should be no issues within the seal box.

Injector Assembly – Item 7 – see Figure 9-9

As mentioned it is required some modifications of the Injector cylinders to compensate the cylinder bodies during lowering. In addition to ensure that trapped pressure do not overpressure the cylinders during hoisting.

Present Clear Well Subsea Ltd. equipment requires testing and a detailed review of all the items extending to ultra-deep water.

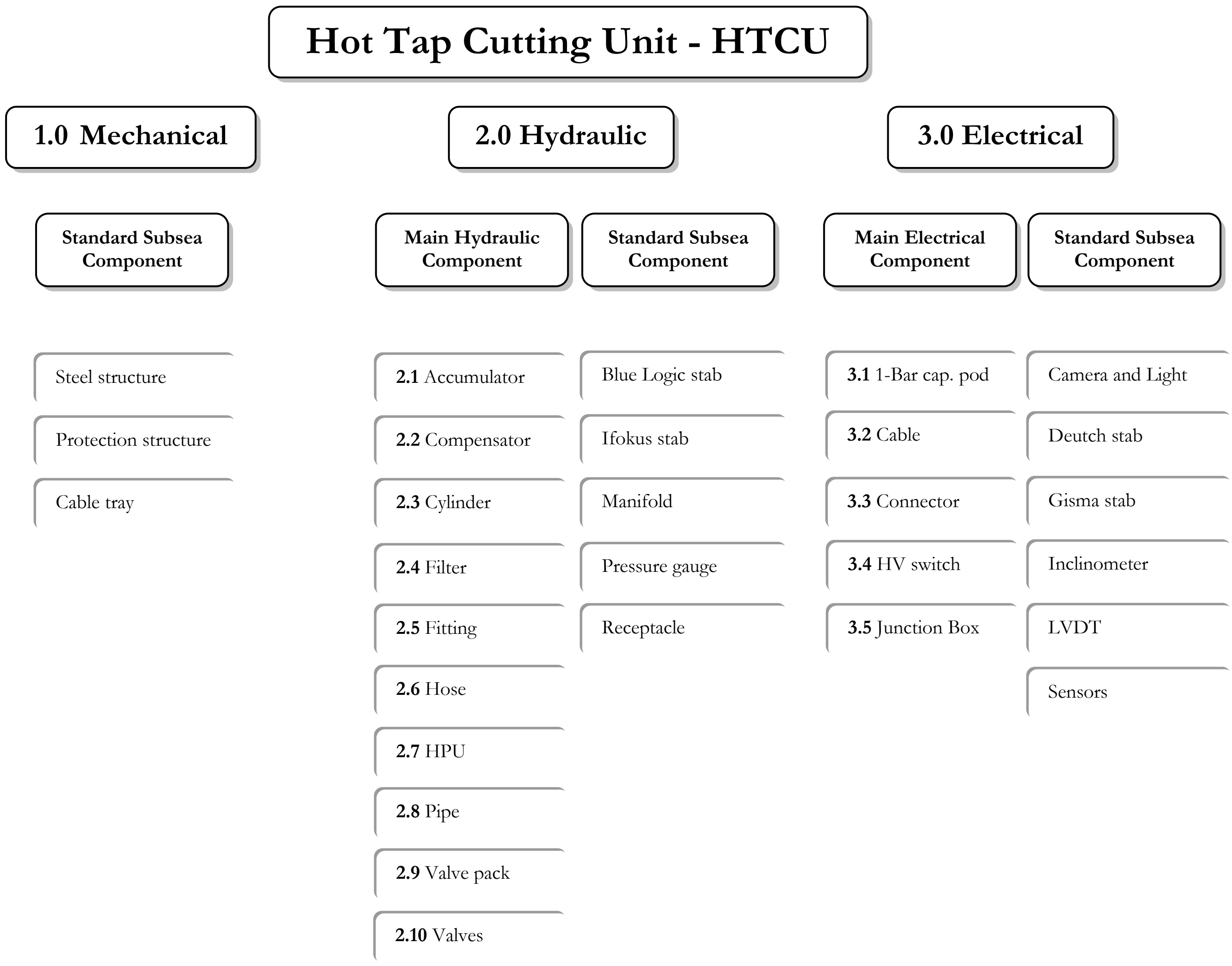


Figure 9-10 HTCU components, split into main- and standard subsea components

Figure 9-10 indicate main components, designed for 1000 MSW, that need to be evaluated for the ultra-deep water upgrade in addition to standard subsea components. Standard subsea components will not be considered in this master thesis. Standard subsea components is referred to components which only require re-qualification/certification, new to be purchased or components already operating at ultra-deep water.

9.2.1.1 MECHANICAL

A hydraulic cylinder is a mechanical element, designed to convert hydraulic pressure to mechanical force. The hydraulics is about the fluid and its functions in the system. The cylinder converts hydraulic capacity to mechanical capacity/work.

The HTCU consist, of among other, the following mechanical components:

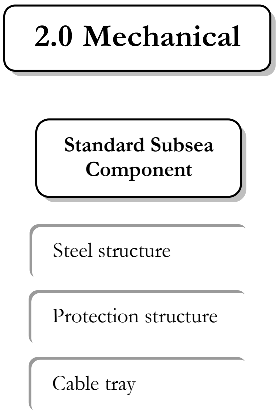
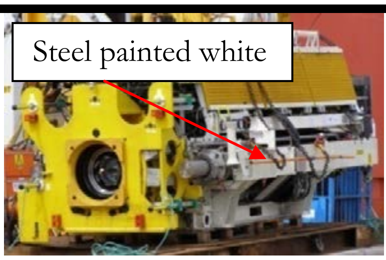
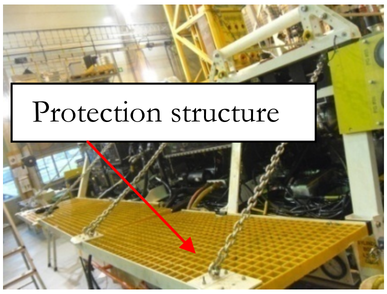


Figure 9-11 Mechanical components

Figure 9-11 is an abstract from Figure 9-10.

Mechanical components mentioned in this master thesis are the HTCU steel structure, protection structure and cable trays:

Component	Picture	Function
Steel Structure		In addition to components and equipment the HTCU steel structure is also an important part. Steel is the strongest and best suited material at this depth and ambient pressure.
Protection structure		The protection structure protects the HTCU subsea and while doing fault finding the protection structures being used as working platforms.
Cable tray		Cable trays for electrical cables.

All mechanical are standard subsea components and is a concern extending to ultra-deep water.

9.2.1.2 HYDRAULIC

From a professional point of view the hydraulic comprises fluids at rest and in motion, respectively hydrostatics and hydrodynamics.

Operating a subsea hydraulic system includes generating, transmission and control of energy. By means of the hydraulic components, systematically organized, with pre-set settings completes the desired function. Figure 9-12 is representative to the HTCU hydraulic system, indicating a basic hydraulic system with its components. The sectional drawing to the left indicates the components function, and the drawing to the right indicate corresponding standard symbol for each component. One simple solid-drawn line indicates the pipe/hose which connects the components. Figure 9-12 indicates main hydraulic components such as: tank, filter, pump, pressure relief valve, directional control valve, check valve (non return valve), flow control valve, cylinder and hydraulic motor. Other important HTCU hydraulic components not shown are accumulator, compensator and HPU (Hydraulic Power Unit, including electrical motor, hydraulic pump, filter and pressure relief valve). For a hydraulic component overview see Figure 9-13.

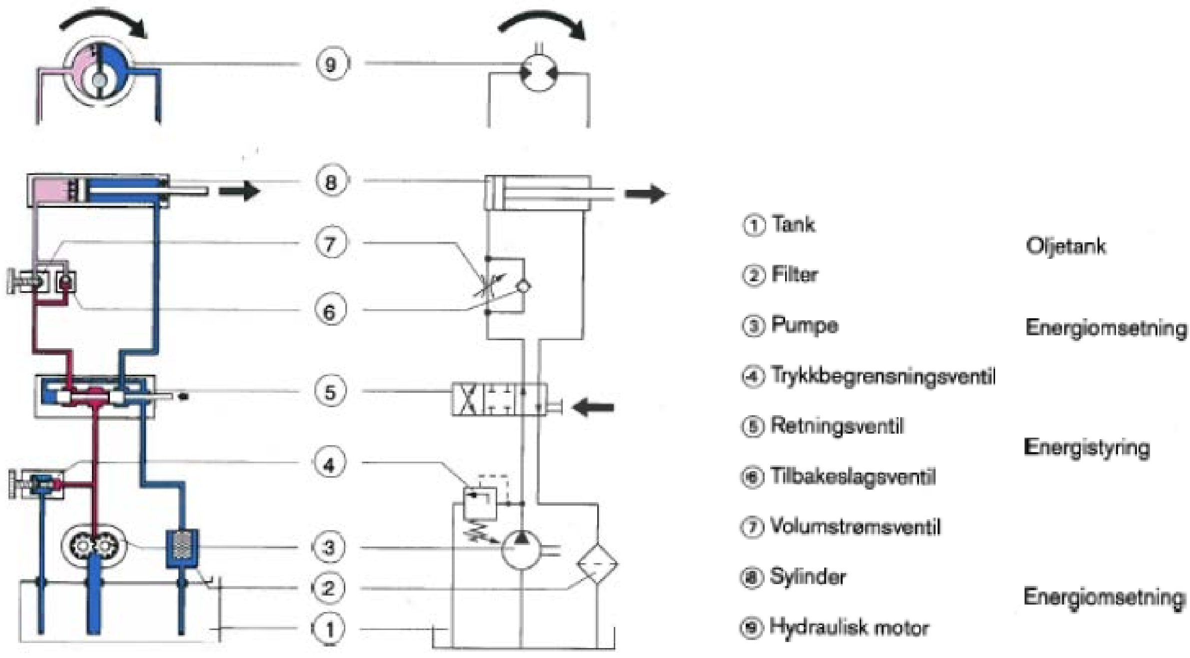


Figure 9-12 Hydraulic system [29]

The subsea hydraulic system has a return side (cold side, blue colour), and a high pressure side (hot side, red colour), see Figure 9-12. First in this system there is a tank (1) containing the hydraulic oil. The pump (3) produces flow and pressure (energy conversion). The pressure relief valve (4) controls the hydraulic pressure and relief if the pressure gets too high according to pre-settings. Then the hydraulic fluid reaches the directional valve (5), which has 3 operation modes and controls the flow. The right hand position makes the fluid extend the cylinder. The central position stops the fluid in both directions. The left hand position retracts the cylinder. In this case the cylinder is in the right mode. Next step in the system is the check valve (non return valve) (6) and the flow control valve (7), controlling fluid flow. Then there is the cylinder (8) extending or retracting depending on function. The last component is the hydraulic motor. The hydraulic energy, created by the pump, is being transformed into mechanical energy in the form of rotary motion and a torque. On the low pressure side back to tank there is installed a filter (2) removing particles and water before the fluid return back to tank.

Two of the main components not shown in Figure 9-12 are the compensator and the accumulator. In a hydraulic schematic the compensators are always located on the low pressure side and the accumulators on the high pressure side.

Extending water depths from 1000 MSW to 3000 MSW and the following increase in ambient pressure from 100 bar to 300 bar will still make the HTCU operate at the same operating ΔP Pressure = ΔP Return (+ 300 bar). The absolute pressure in the system increases in proportion with ambient pressure, in such a way that all systems sense higher absolute pressure.
The most important factor for hydraulics subsea is the compensation, see section 8.4 Optimization of lowering and hoisting speeds.

Present operating pressure is 210 bar at 1000 MSW (100 bar), which means that the absolute pressure is 210 bar (operating) + 100 bar (ambient).
At 3000 MSW (300 bar) the operating pressure, the pump`s ΔP, will be the same as at 1000 MSW. Due to the hydrostatical pressure both outside and inside the system (the hydrostatical pressure increase in proportion both on the housing etc.) high pressure side and return side + external pressure on cylinders, motor) it is possible to keep the

operating pressure unaltered, 210 bar. An unaltered operating pressure requires that the hydraulic system is generally evaluated and checked for enclosed volumes. Enclosed volumes will not have any fluid flow, because the fluid is trapped for instance between an actuator and a valve, which could result in burst valves, hoses or fittings. The enclosed volumes could be a problem if the tank is closed. A solution will be to install a ROV operated valve, connected to a compensator, to empty the enclosed volume (equalize pressure differentials).

The HTCU uses Shell Tellus Oil S 22 for the hydraulic system. Tellus is a mix of among other high refined mineral oils and is not classified as hazardous [30]. The Midel 7131 dielectric oil is used for electronics in oil, for instance the Junction boxes.

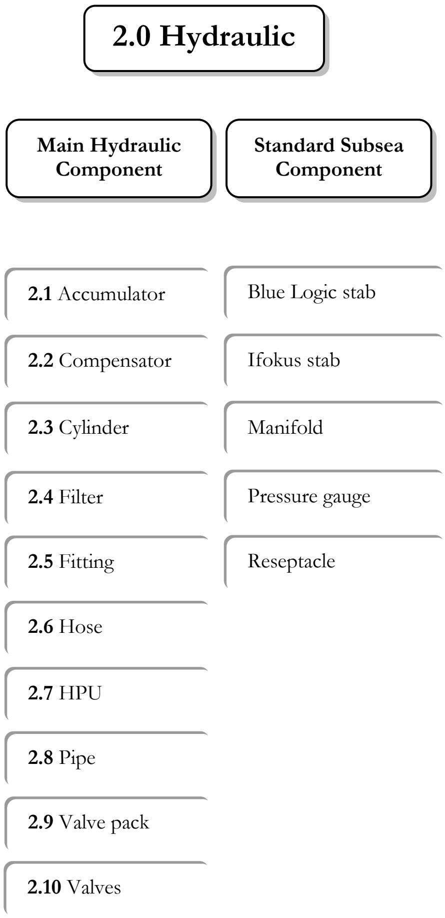


Figure 9-13 Hydraulic components, abstract from Figure 9-10 HTCU components, split into main- and standard subsea components

Figure 9-13 indicates HTCU hydraulic components. As previously mentioned only the main components will be evaluated in this master thesis.

2.1 Accumulator

Accumulator function:

The accumulators operate as energy storage, power reserve, see Figure 9-14. When required the energy will be sent back to the system. For accumulator hydraulic symbol see Figure 9-15.

Figure 9-14 Tool shaft accumulators

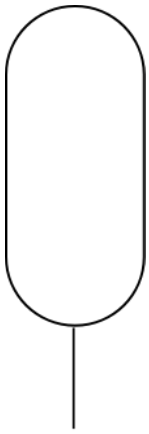


Figure 9-15 Accumulator hydraulic symbol [31]

Technip uses bladder accumulators, see Figure 9-16. The bladder (3) forms a flexible boundary between the hydraulic oil and compressible medium (Nitrogen, N_2). The bladder is attached inside the steel tank (1) by means of a vulcanized gas valve (4). This could be replaced through the steel tank opening by the oil-valve (2). The oil-valve function is to close the feed opening when the bladder is expanded. Having the bladder expanded, the bladder is obstructed from being pushed into the opening.

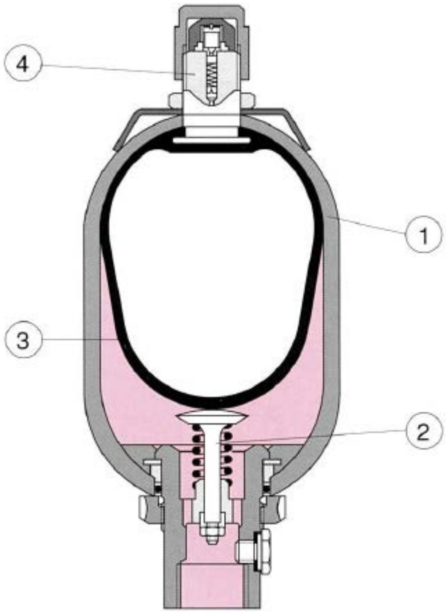


Figure 9-16 Bladder accumulator [29]

Component upgrade?

The accumulator is pre-charged with the Nitrogen gas to 12 bar + depth pressure. The accumulator capacity will decrease with the absolute pressure. To solve this it is required to install additional accumulators. To achieve 210 bar effective operating pressure it is recommended to choose 510 bar (210 bar operating pressure + 300 bar ambient pressure) rated accumulators versus present 300 bar rating.

2.2 Compensator

Compensator function:

The compensator is a hydraulic fluid reservoir, which replaces the tank used onshore, see Figure 9-17. The compensator balances the pressure according to surrounding pressure with a spring that creates overpressure in the system. The overpressure makes sure that the system does not have any water intrusion and regulates in proportion to the surroundings (the deeper water the higher pressure). If a leakage occurs, the hydraulic fluid will leak into the sea water, not opposite (water intrusion). Using hydraulic equipment, creating a volume change in hydraulic fluid, the compensator will compensate for this as well (for instance cylinders). For compensator hydraulic symbol see Figure 9-18. The HTCU is filled with approximately 75 l Tellus hydraulic oil.

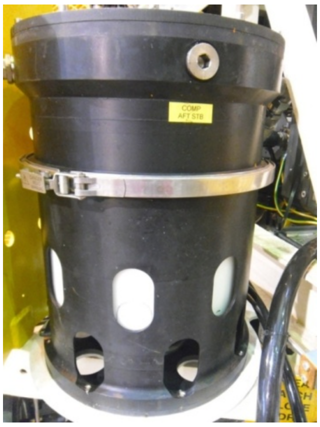


Figure 9-17 Compensator 16 l

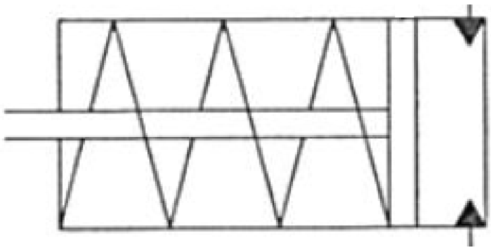


Figure 9-18 Oil compensator – Hydraulic symbol [32]

Component upgrade?

Extending to ultra-deep water it will be necessary to evaluate to increase the compensators capacity. This is very important due to that the hydraulic system is dependent on the compensation. Present design has restrictions on deployment speed in splash zone and the following 10 meters, which also could be improved. Due to the hoses from the compensators (length and diameter), it require time to fill volumes, which need to be compensated. If the hoses and compensators were larger the deployment speed would not be an issue. Refer section 8.4.1 Lowering and hoisting speed.

2.3 Cylinder

Cylinder function:

All cylinders are double-acting, as Figure 9-19 indicates, getting a positive movement extending the cylinder and a negative movement retracting. The hydraulic cylinders function is oil supplied on the reverse side of the piston rod to extend. To retract the oil gets supplied in the front of the piston rod. Leakage past the piston is negligible. The piston rod is made of stainless steel and the cylinders are painted with subsea specified paint. The HTCU has cylinders located in front (body latches), sides (injectors), see Figure 9-20, and aft end (cross head latch) on the HTCU. For cylinder hydraulic symbol see Figure 9-12.

Figure 9-19 Hydraulic cylinder illustration [33]

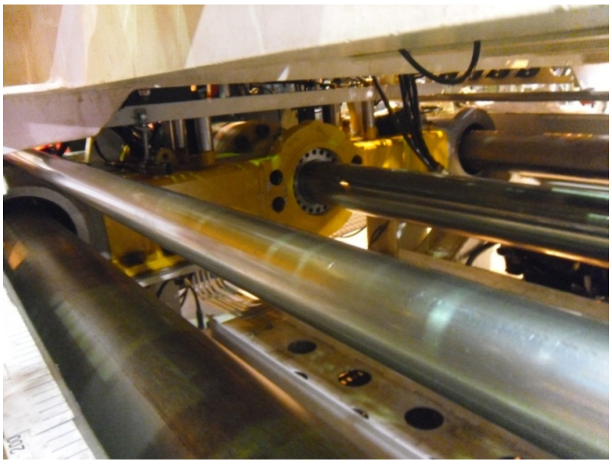


Figure 9-20 The injector cylinder bodies

Component upgrade?

The cylinder concern is whether the seal rings will maintain sufficient volume to seal properly. Extending water depth capability to 3000 MSW it is therefore recommended to replace cylinders with ones rated to 300 bar, due to the local effects of collapse of the seal rings, see section 9.2.1 Subsea system.

2.4 Filter

Filter function:

The filter function is to reduce the pollution contamination in the hydraulic oil and protect against wear and tear of the components, see Figure 9-21. Pollution is dust, fibre, sand, flake of paint or weld. Pollution in the hydraulic fluid is one of the usual reasons for failure in the hydraulic circuit. The HTCU has two types of filter; pressure filter and return filter. The HTCU has pressure filter housing for the HPU and for the oil dirty pack. For filter hydraulic symbol see Figure 9-12.

Figure 9-21 HPU Filter housing

To quantify the pollution in a hydraulic system Technip uses NAS 1638, see Figure 9-22. The diagram indicates the relative occurrence of each particle. Technip uses code 5 > as acceptance level.

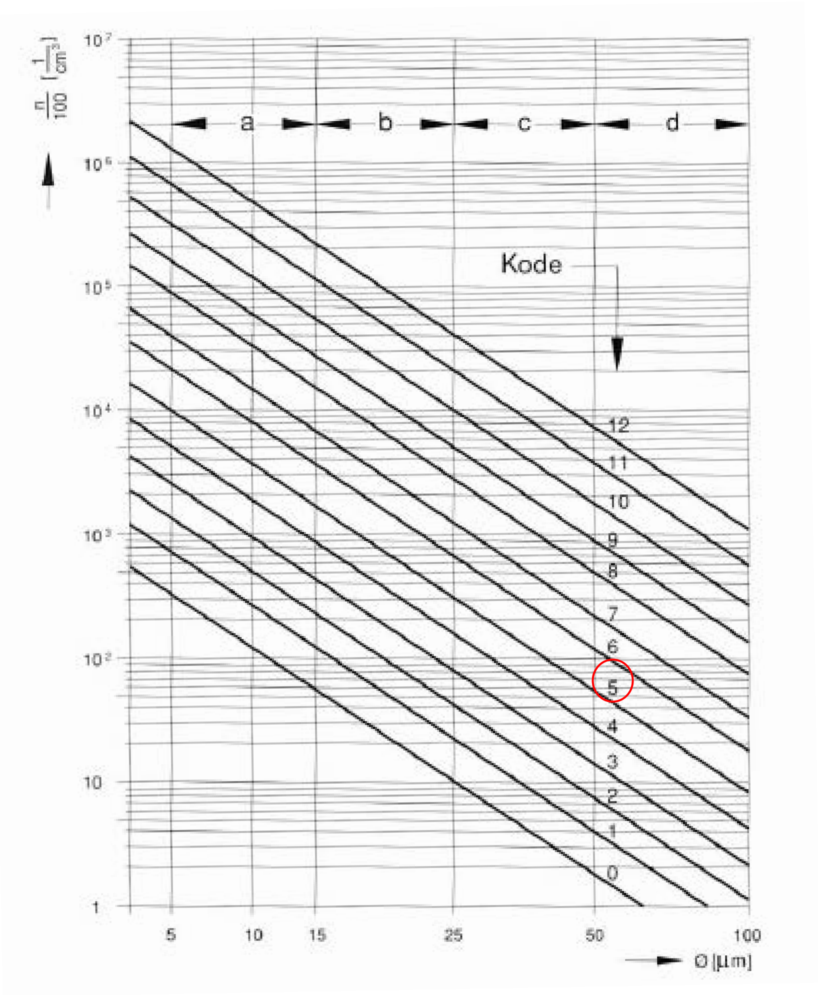


Figure 9-22 NAS 1638, code 5 > [29]

Component upgrade?

The filters will not be a concern extending to ultra-deep water due to the compensation in the hydraulic system.

2.5 Fitting | 2.6 Hose | 2.8 Pipe

Fittings, Pipes and Hoses function:

The function of fittings, hoses and pipes is to transport the flow through the HTCU hydraulic system in a safe and efficient way, see Figure 9-23. There is no special requirement to the hoses and pipes subsea, but the fittings are made out of stainless steel (grade 3-16). If one has larger spills of hydraulic fluid, this is most likely due to sudden physical damage to the hydraulic circuit, including fittings, hoses, pipes etc. Hoses and pipes are indicated on a hydraulic drawing with a straight line.

Figure 9-23 Illustration photo Parflex hose

Component upgrade?

The fittings and pipes will not be a concern extending to ultra-deep water due to the compensation in the hydraulic system. All hydraulic circuits are pressure compensated, but needs to be designed for the pressure difference. To be sure of the hose compensation, extending to ultra-deep water, it is important to check that the compensator volume is well dimensioned, as mentioned in the compensator section 2.2 and section 8.4 Optimization of lowering and hoisting speeds. In addition it's recommended to evaluate the hose wall (material), due to risk of collapse.

2.7 HPU

The HTCU has two different HPUs (Hydraulic Power Unit) one primary and one secondary.

Primary HPU

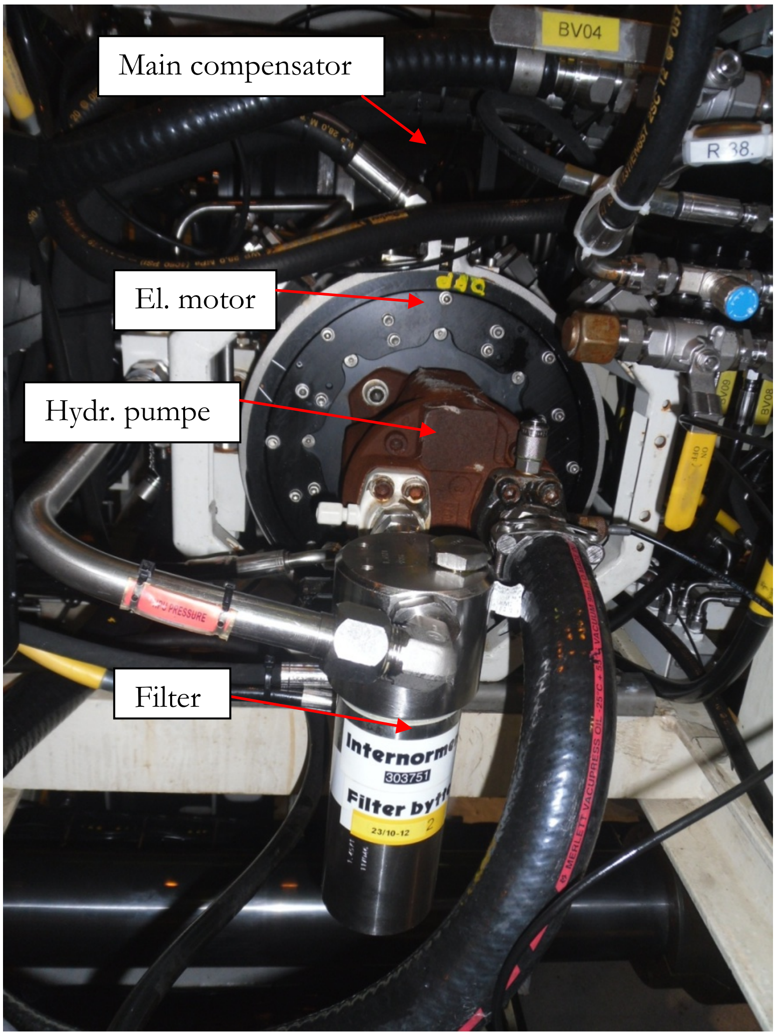


Figure 9-24 HPU

Primary HPU function:

The primary HPU, see Figure 9-24, function is to generate hydraulic power in terms of flow and pressure to the system. The HPU as indicated in Figure 9-25 consists of an electric motor with a shaft driving a hydraulic pump, a filter and a relief valve. The HPU cable, see Figure 9-26 provides three phase power through: brown (L2), white (L1) and green (L3) coloured cables. The yellow cable is ground while the rest is filling compound.

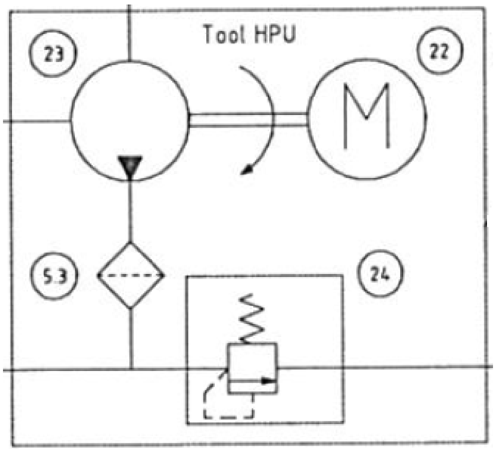


Figure 9-25 HPU – Hydraulic schematic [32]

Figure 9-26 HPU cable

The hydraulic pump function is to produce flow and pressure. The pump brings oil from the compensator (inlet- or suction side) and pumps to the pumps outlet (discharge side). Figure 9-27 and Figure 9-28 indicates the pump and its operating principle.

Figure 9-27 A10VO Variable displacement piston pump [34]

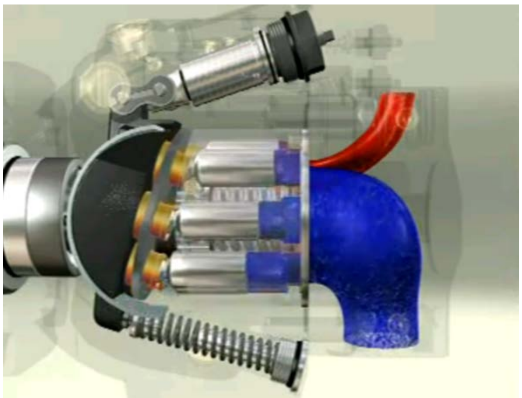


Figure 9-28 Pump construction [35]

The electro motor drives the hydraulic pump (supply power). The IKM electro motor has a maximum power (effect) of 15 kW and a voltage of 1000V. The electro motor is also compensated with Tellus S22 hydraulic oil.

<u>**Secondary HPU (ROV Supplied Back-up Power)**</u>

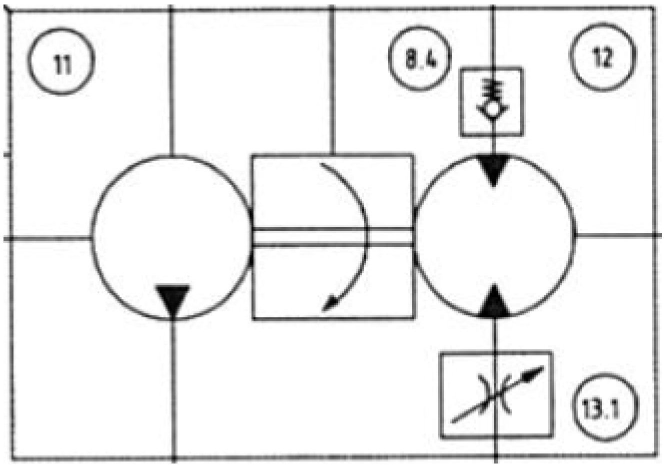


Figure 9-29 Secondary HPU – Hydraulic schematic [32]

Secondary HPU (ROV Supplied Back-up Power) function:

The secondary HPU (Dirty Work Pack) is used as back-up power for the main hydraulic system, see Figure 9-29. All the HTCU functions can be activated in this mode.

The secondary HPU is a hydraulic system, driven by a hydraulic motor which gets its hydraulic power through ROV. The back-up valve, see Figure 9-30, is controlled and activated by ROV if an unexpected situation occurs. The ROV then connects the blue logic 3 port hydraulic stab (Pressure, Return and Drain) into the PIF override panel (connected to HTCU), supplying 70 lpm and 185-200 bar. ROV then drives the hydraulic motor which again drives the pump (one direction of flow) in the secondary HPU-circuit [28].

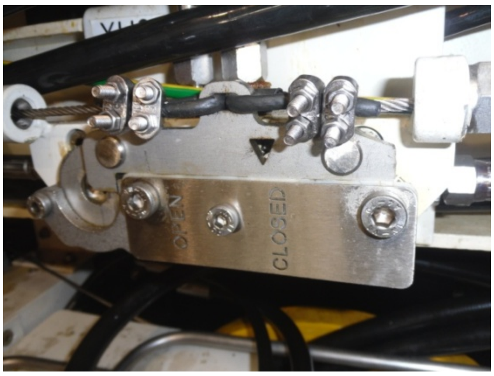


Figure 9-30 Back-up valve

Component upgrade?

The primary HPU mounted onto HTCU today works satisfactorily, but not optimal when it comes to repair and maintenance accessibility. A new HPU is to be installed, the same HPU as mounted on RTIT and RTWT. Since the hydraulic system is compensated, including the electro motor, neither of the HPUs (Primary and ROV supplied back-up power) will be a concern extending to ultra-deep water.

In part 3.4 the HV switch is recommended removed. Removing the HV switch will require an electro motor with increased capacity. The existing primary HPU HTCU electro motor voltage is 1 kV but will be increased to 3 or 3.3 kV.

2.9 Valve pack

Valve pack function:

The valve pack is the module distributing the hydraulic oil to different functions (SCM – Satellite Control Module), see Figure 9-31. The valve packs are electric (Isotek Oil and Gas Limited electronics) controlled by the operator at surface, commands done in the IPCON being transferred through the LARS1 umbilical and to the valve pack. The valve packs are filled with Midel 7132, no air present. The SCM also contains electrical valves controlled by applying 24 V.

Figure 9-31 SCM 01 valve pack

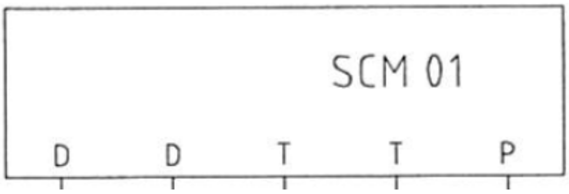


Figure 9-32 SCM 01 valve pack – Hydraulic schematic [32]

Figure 9-32 shows one of the two SCM valve packs (SCM 01 and SCM 02). Both of the valve packs contains 12 valves (on/off – not proportional) in addition to two D lines (drain), two T lines (tank) and one P line (pressure).

Component upgrade?

The valve packs will not be a concern extending to ultra-deep water due to the compensation in the hydraulic system.

Inside the valve packs there are control cards, manufactured by Isotek Oil and Gas Limited, which never have been at ultra-deep water depths. Electronic issues are included in the Electric section, see section 9.2.1.3.

2.10 Valves

Valve function:

The HTCU valves in general include ball valves, pressure relief valves, directional control valves, check valves (non return valves) and flow control valves.

The ball valves are either open or closed, see Figure 9-33. The disadvantage with a ball valve (globe valve) is to achieve precise regulation to intermediate position.

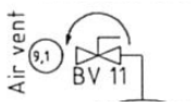


Figure 9-33 Ball valve – Hydraulic symbol [32]

The directional control valve is controlled and used to decide which function to be executed. There is a directional control valve for each hydraulic function. HTCU uses among other 2/2 directional valve (2 ports and 2 positions), see Figure 9-34. Directional control valves are part of the valve packs which is electronically controlled (solenoids), see previous section describing valve packs. For directional control valve hydraulic symbol see Figure 9-12.

The pressure relief valve function is to set and control the systems operating pressure, also called safety valve. The valve regulates operating pressure and prevents overloading or destruction of the components. If/when the hydraulic system reaches it maximum pressure, the pressure relief valve opens. The flow rate is then returned back to tank. For pressure relief valve hydraulic symbol see Figure 9-12.

The check valve (non return valve), is a one-way directional control valve. The valves function is to close the flow in one direction, and open for flow in opposite direction. For check valve hydraulic symbol see Figure 9-12.

The flow control valve is being used to control the flow with choking. For flow control valve hydraulic symbol see Figure 9-12.

Component upgrade?

The valves in general will not be a concern extending to ultra-deep water due to the compensation in the hydraulic system. Valves must be checked for enclosed volumes, which could collapse.

<u>Standard hydraulic subsea components</u>

Table 9-1 gives an overview of HTCU standard subsea components not considered in this master thesis.

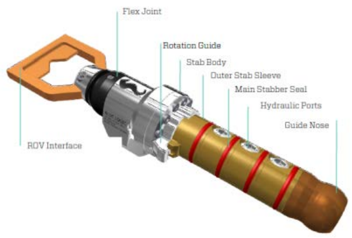
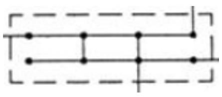
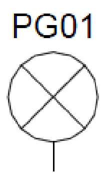
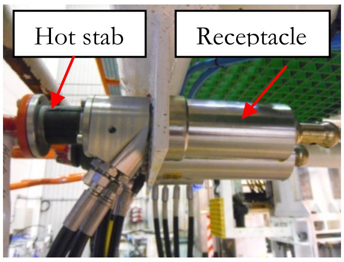
Component	Picture	Function
Blue Logic stab		The Blue Logic hot stab supplies hydraulic oil to dirty pack on the HTCU. Stabs are easy to operate and maintain.
Ifokus stab		The Ifokus hot stab is used by ROV to connect MEG and/or hydraulic oil.
Manifold		A manifold is a component that distributes or collects the fluid flow in the hydraulic system.
Pressure gauge		The pressure gauges (PG) (compensated) measure typically from 0-400 bar. The gauges need to be re-qualified for higher pressure.
Receptacle		The stabs are being stabbed into the receptacle which function is to make the fluid pass onto the tool in a safe and efficient way, prevent oil spillage. The receptacle has an integrated check valve to avoid water intrusion.

Table 9-1 Standard subsea components

9.2.1.3 ELECTRICAL

Figure 9-35 indicates the HTCU simplified electric power system.

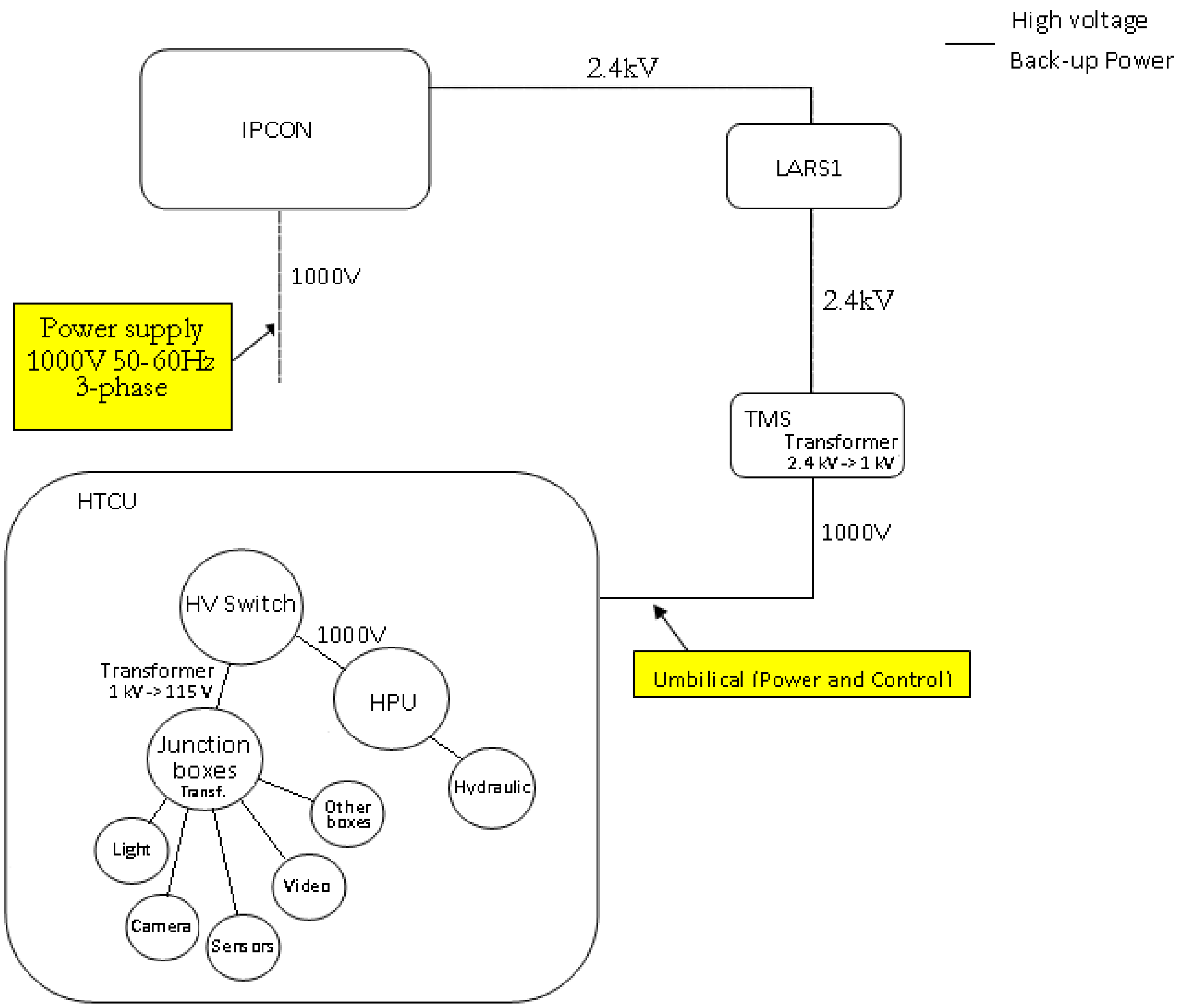


Figure 9-34 HTCU – System simplified power supply

The power supply is 400-440 V, 50-60 Hz and 3 phase into the IPCON at surface. The IPCON transforms the voltage and supplies the LARS1 with 2.4 kV (power supply). The LARS1 supplies the TMS, see Figure 9-36, with 2.4 kV subsea. The TMS has a transformer, which transforms the voltage down to 1000 V. The TMS supplies the TTH, with main power and control power. The TTH is connected to the PIF (cable to HTCU) DSU (Drop in Stab Unit), see Figure 9-37. All PRS subsea equipment are fitted with a stab receiver called the Drop in Stab Unit.

When the TTH is stabbed into the DSU, the HTCU is ready to start-up. The high voltage (1000 V) is supplied into the HV switch. The HV switch again distributes voltage to Junction boxes and HPU. The HPU powers the hydraulic system. The Junction boxes distribute electric power to light, camera, sensors, video and other users.

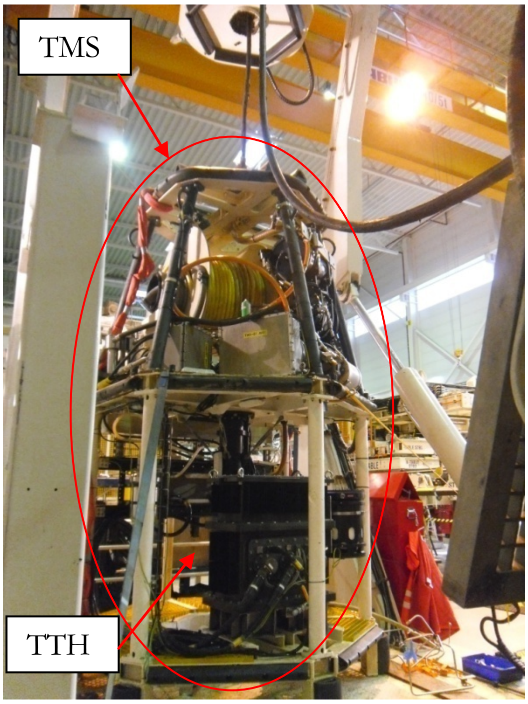


Figure 9-35 TMS (LARS1) with TTH

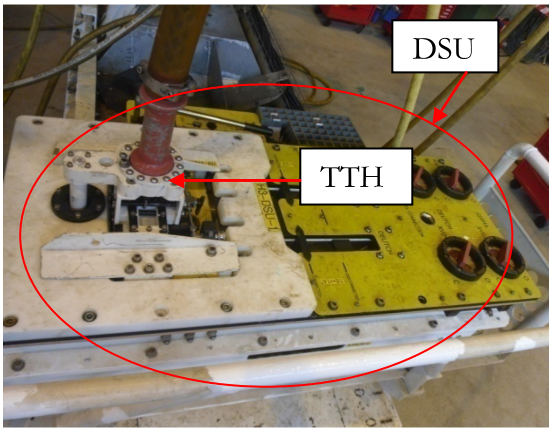


Figure 9-36 TTH connected in DSU

The present LARS1 voltage supply subsea is 2.4 kV, but LARS1 has a 3.3 kV capacity. The question is whether it will be possible to use the same power supply at 3000 MSW, assuming the LARS1 arrangement is similar as current system and a voltage supply of 3.3 kV is used. Current umbilical could be replaced with a new umbilical 3200 m, with similar technical data. The conditions are ideal, so the physical limitation could be neglected (temperature, inductive and capacitive effect, harmonic interference, voltage variation and frequency). Then the Umbilical voltage loss will be 1.49 %, ref APPENDIX 13, while the voltage loss for the tether will be 0.88 %, ref APPENDIX 13. Both for the umbilical and tether the voltage loss are within acceptance criteria of 3%.

Isotek Oil and Gas Limited deliver most of the electronics to PRS. The electronic delivered is for instance 1-bar Capacitor pods, Junction boxes, electronics inside valve packs and HV Switch. All electronics subsea, except 1-bar capacitor pods, are filled with dielectric oil Midel 7131. Isotek Oil and Gas Limited recommends a verification of electronic in oil as appropriate to verify that electronic components function satisfactorily under higher absolute pressure by testing under simulated conditions. For components in oil, for instance Junction boxes have a hydraulic port which is connected to a compensator.

A control card, a card filled with electronic components, function is to receive/process/transmit electronic signals. All electronic devices for instance JB and valve packs, contain one or several control cards, which never have been at ultra-deep water depths (rated for 1000 MSW). Out of own interest Isotek Oil and Gas Limited has tested control cards in oil to 400 bar, which have been largely informal and highlighted issues. The testing revealed that the epoxy currently used is inadequate for higher pressures and a new proper professional grade of epoxy must be selected [36].

3.0 Electrical

Main Electrical Component	Standard Subsea Component
3.1 1-Bar cap. pod	Camera and Light
3.2 Cable	Deutch stab
3.3 Connector	Gisma stab
3.4 HV switch	Inclinometer
3.5 Junction Box	LVDT
	Sensors

Table 9-2 Electrical components, abstract from Figure 9-10 HTCU components, split into main- and standard subsea components

3.1 1-Bar capacitor pod

1-Bar capacitor pod function:

Electronics not suitable for mounting in pressurised environments are housed in 1–bar pods, supplied by Isotek Oil and Gas Limited, see Figure 9-38. The function of the capacitor pod (remove noise from the direct current) is to store energy. The pods are not oil filled, do not have oil compensators, and is therefore vacuumed to 0.8 bar before deployment to verify and activate seal. The pods are certified for 100 bar external hydrostatic pressure with 1 bar internal pressure. In addition to free-standing pods the-HV switch has 1-bar pods integrated into the oil-filled enclosure to protect capacitors. These 1-bar pods are designed for 100 bar external ambient pressure but have been tested to 150 bar [36].

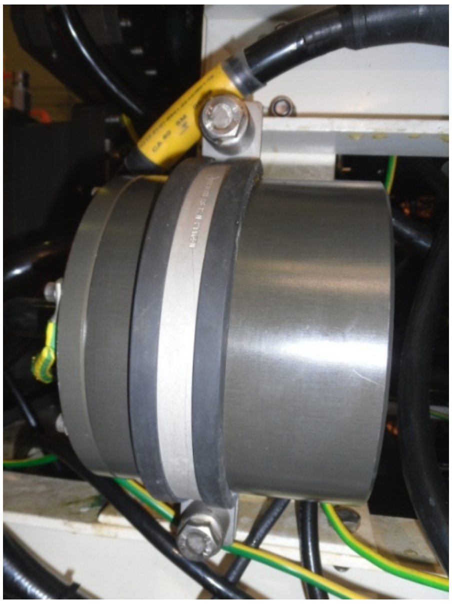


Figure 9-37 1-bar capacitor pod

Component upgrade?

Upgrading the HTCU will require a new casing to be designed for all pods [36]. As a safety margin of 1.5, the new casings will be qualified for 450 bar (300 bar 1.5). Thicker wall or stronger materials can be used (this is also something that ROV uses). Check if there are any other components that need to be placed in a 1-bar capacitor pod.

3.2 Cable | 3.3 Connector

Connectors and cables function:

The cables and connectors functions are to transmit power and signals to different components. Present connector, see Figure 9-39, has a limitation at 1000 MSW, and even less if the connector is unmated [37] (the caps are filled with air). Figure 9-40 show the connector insert.

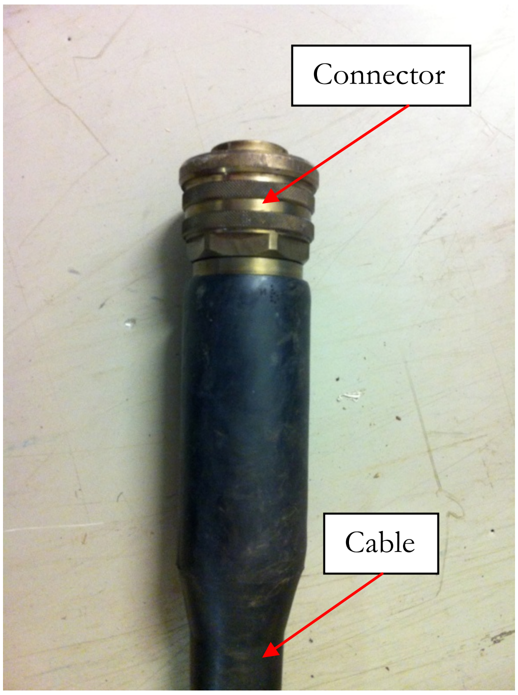


Figure 9-38 Jupiter Connector

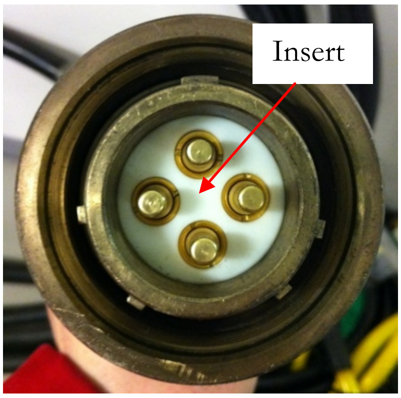


Figure 9-39 Connector insert

See Table 9-3 of an overview of current Jupiter connectors.

	DCA 01	DCA 02	DCA 03	DCA 10	DCA 30	DCA 40	DCA 41	DCA 42	DCA 50	DCA 51
Current connector: JUPITER	High Voltage	Welding Current	Preheat Current	Instrument Power (110Vac)	Power and Communication (24Vdc and Ethernet)	Camera	Sensor	Light	Video Distribution	41-pin cable (Legacy CA)
Pins	4	4	4	4	9	7	3/5	4	-	41
AWG									-	22
Pin size mm2	20	13,4	13,4	0,93	0,38	0,38	0,38	0,38	-	
Voltage rating V	1000	1000	1000	1000	600	600	600	600	-	1500
Current rating A	65	65	65	14	7	7	7	7	-	7
Length to end of potting mm	310	186	186	110	110	110	110	110	-	114
Diameter mm	68	46	46	24,5	24,5	24,5	24,5	24,5	-	46
Sq. Flange mm	76	52	52	32	32	32	32	32	-	52
Mated Pressure bar	100	100	100	100	100	100	100	100	-	100
OF Pressure bar		60	60	30	30	30	30	30	-	60
Standard connector	x	Yes	Yes	x	x	x	x	x	-	x

Table 9-3 Current Jupiter connectors [38]

The HTCU cables are labelled from where the cable are connected and routed to: for instance the label "HTCU-01-01-SJB 02-19-GS 05 CA 06 – (2.5m 01/08)". The cable is located on the HTCU tool with tag HTCU-01-01. The cable is connected to the Sensor Junction Box (SJB) 02-19 and the proximity sensor (GS) 05. CA 06 is the Cable assembly nr, the cable is 2.5m long and produced January 2008 (01/08).

Component upgrade?

Cables:

Extending to ultra-deep water the cables require modifications, testing, verification and qualification. Modifications comprise remoulding and recertification of all cable assembly to withstand water depth beyond 1000 MSW. Each cable needs to improve the transition to the connector and withstand the ambient pressure [37].

Connectors:

For the current Jupiter connectors to be able to withstand ultra-deep water, all connector inserts, see Figure 9-41, for oil filled control boxes will have to be replaced. The insert inside the connector will collapse, see Figure 9-42, either by damaging the cable or loss of internal oil pressure for instance inside the Junction box (JB), see part 3.5 Junction box, which result in water intrusion on the JB [37].

Figure 9-40 New connector insert

Figure 9-41 Collapsed connector insert

According to Isotek Oil and Gas Limited NSGI Depth Increase Study Report [36] the correct type of connector back-shell and cables in the Jupiter range has a maximum working pressure of 300 bar.

In 2011 the connection strategy for the deep PRS system was evaluated [38]. The focus was to reduce the number of cable assemblies required, reduce fault probability, and improve integrity of connections. According to the report the suggested assemblies presented in the report should be the new standard connection for PRS equipment. The report recommends all Jupiter connectors replaced with Burton, Birns or Seacon connectors. For instance Kystdesign AS, which builds and designs ROVs, chooses connectors on client request, e.g the Seacon 55 series. Kystdesign, as well as other subsea suppliers, do not use Jupiter connectors.

3.4 HV switch

HV switch function:

The HV switch (High voltage switch), see Figure 9-43, includes a HV (High Voltage > 1000 V) part and a LV (Low Voltage < 1000 V) part. The HV switch has an input of 1000V (2.4 kV from surface, through TMS transformer) and distribute power to among other the Junction boxes, see part 3.5 Junction box.

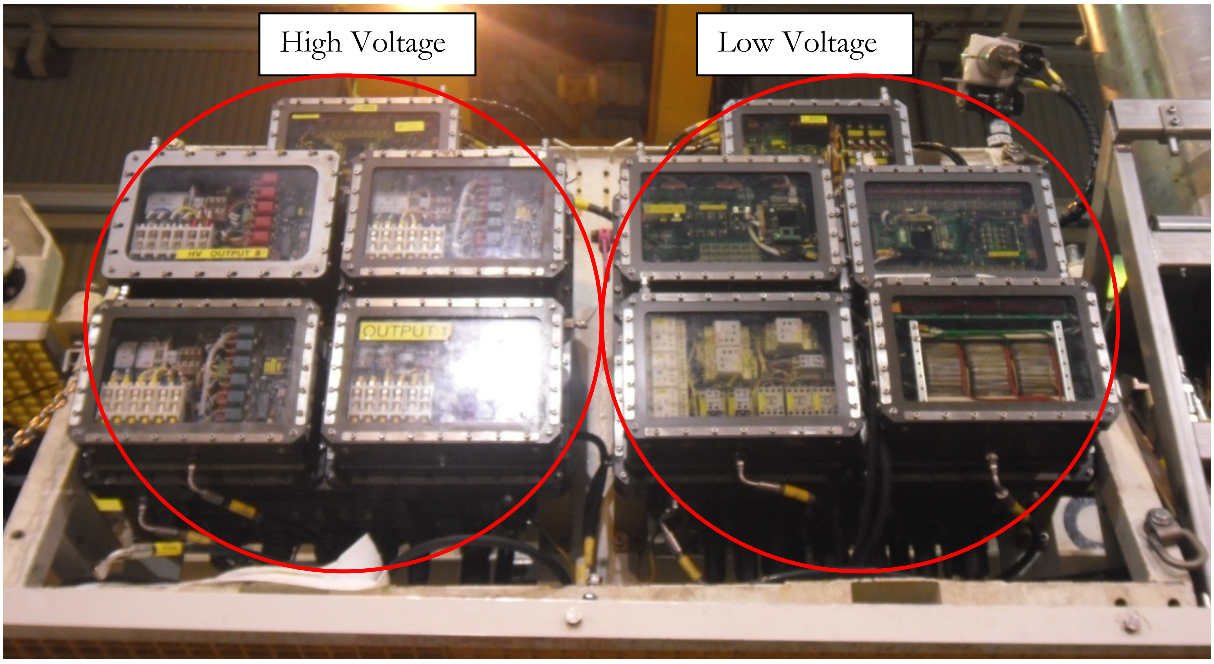


Figure 9-42 HV Switch, with the high and low voltage parts

Component upgrade?

The HTCU has only one HPU which requires high voltage, in addition the HV switch takes a lot of space (8 boxes), it's heavy and increases fault probability. It is therefore recommended to extend to ultra-deep water without the HV switch. This is similar to ROVs present system. To solve this, a cable will be connected from the transformer/motor control centre on deck to the winding on the electric motor which operates the hydraulic pump (start/stop on deck). The voltage drop on a 3000 m cable is large so the electro motor will need an increased voltage in range of 3 or 3.3 kV. The HTCU present electro motor voltage is 1 kV (Higher voltage = less voltage drop). Present ROV systems operate with 3.3 kV.

At Tampen Link, actual offshore operation, the HTCU operated without the HV switch, which was bypassed. Recommending the HTCU to operate without the HV switch is not a concern.

3.5 Junction Box

Junction Boxes function:

Junction boxes (JBs) are electronics in pressure-compensated oil-filled enclosures, electronics and software delivered by Isotek Oil and Gas Limited. The Junction boxes are connection boxes with one supply in and several outputs to for instance lights, cameras, sensors, video and other different boxes. Some boxes are intelligent and have integrated PCs which communicate on Ethernet. Figure 9-44 and Figure 9-45 indicate the intelligent Video Junction Box (VJB01), which provides output to video.

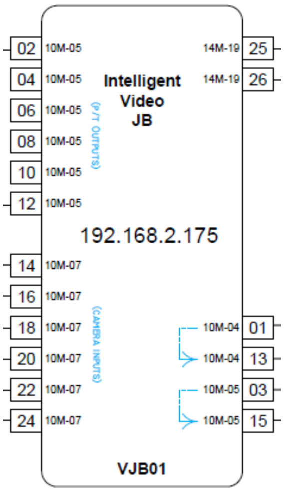


Figure 9-43 Intelligent Video Junction Box (VJB01) - GA Power and comms [39]

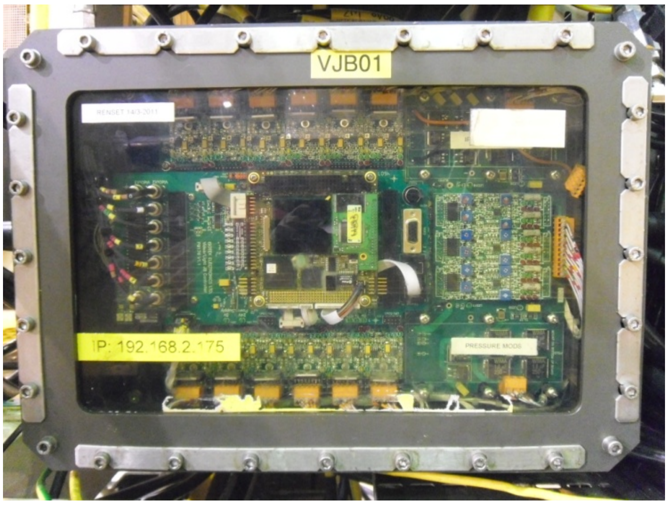


Figure 9-44 VJB01

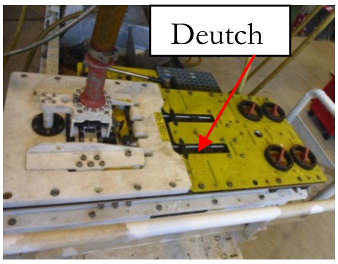
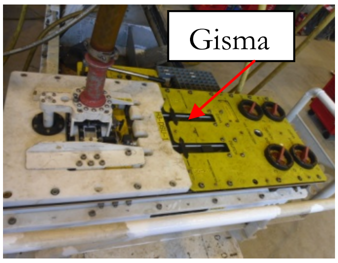
The use of electronic in pressurised oil has been tested to design pressure (1000 MSW). All the Junction boxes are filled with the dielectric Midel 7131 oil.

Component upgrade?

Components inside the Junction boxes (control cards) will need to be replaced to extend to ultra-deep water [37]. For the control cards issue see introduction of section 9.2.1.3.

Standard electrical subsea components

Table 9-1 gives an overview of HTCU standard subsea components not considered in this master thesis.

Component	Picture	Function
Camera and Light		The cameras function is to let the operator have a view of the operation done subsea. ROV cameras are used in addition. The HTCU has several cameras to cover operations such as inspection, alignment, tool shaft end stop, override and isolation panel camera. Types used are Dome, Pan and Tilt and Fixed cameras, some with lights. Current cameras and lights could be a problem extending to ultra-deep water due to atmospheric environment inside and has limitations regarding water ingress in lens ring (glass/ ring/ housing) [37]. An upgrade or replacement is required.
Deutch stab		The Deutch stab is used by ROV to connect power subsea (2.4 kV) via the TTH. The stab is a subsea standard product and is therefore not a concern extending to 3000 MSW.
Gisma stab		The Gisma stab is a main and backup stab used by ROV to connect signal and communication subsea via the TTH. The stab is a subsea standard product and is therefore not a concern extending to 3000 MSW.

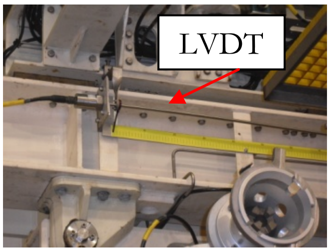
Inclinometer		Inclinometer is an instrument for measuring angles of slope (or tilt) elevation of an object with respect to gravity. Inclinometer used in the HTCU is a +/- 30 deg Dual Axis. Extending to ultra-deep water the inclinometer (monitoring sensor) requires an upgrade or replacement [37].
LVDT		Linear Variable Differential Transducer (LVDT) is a type of electrical transformer used for measuring linear displacement (position). The HTCU has LVDTs for compensators, alignment and feed. Extending to ultra-deep water the LVDT (monitoring sensor) require an upgrade or replacement [37].
Sensors		There is a number of various sensors installed on the HTCU, sensors for pressure/depth (PT - Bar), flow (FL - litre), temperature (TT), longitudinal (LT - mm) and proximity (GS - Digital). Extending to ultra-deep water the pressure transmitters and proximity sensor (monitoring sensors) require an upgrade or replacement [37].

Table 9-4 Standard subsea components

9.2.2 Umbilical

The second subsystem of the HTCU ultra-deep system is the Umbilical (Control system). Today the PIF/HTCU is powered and controlled through the LARS1, see Figure 9-46 and Figure 9-47.

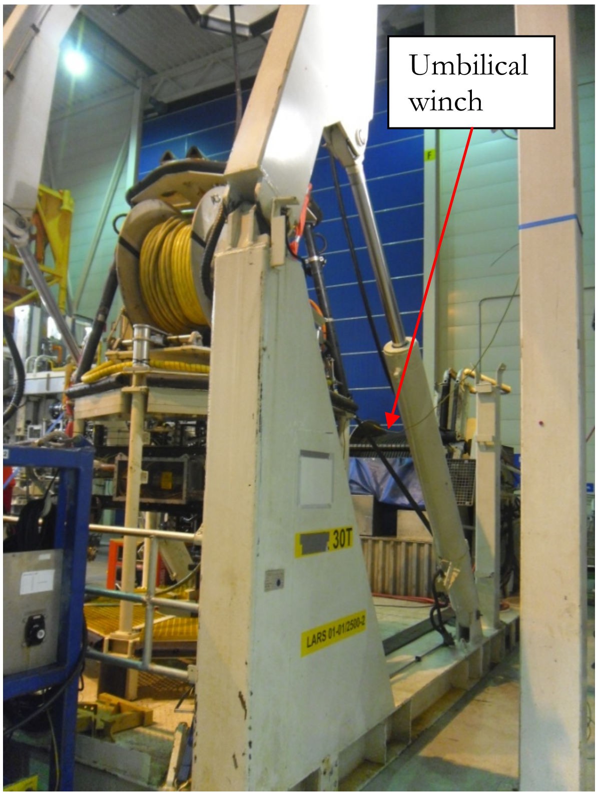


Figure 9-45 LARS1 with TMS

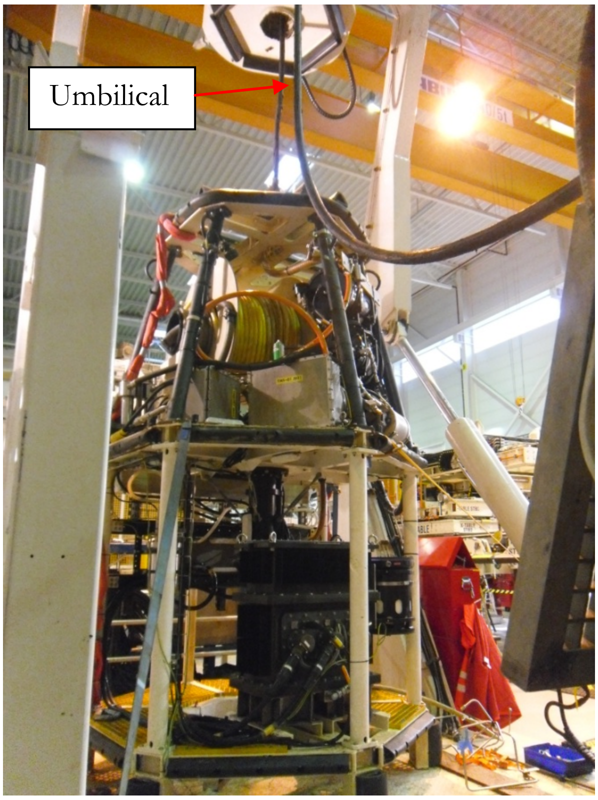


Figure 9-46 LARS1 TMS

The LARS1 has an umbilical range of 1500-1600 m with 2500 m capacity. The umbilical gives a restriction extending to ultra-deep water. From the electrical section 9.2.1.3

Electrical the see Figure 9-48 indicate that the connection between the tool (subsea) and the IPCON (topside) is the umbilical. The umbilical comprise fibre for communication, copper x4 for 2.4 kV possibly 3.3 kV, in addition to 4x back-up power, which is already 3.3 kV.

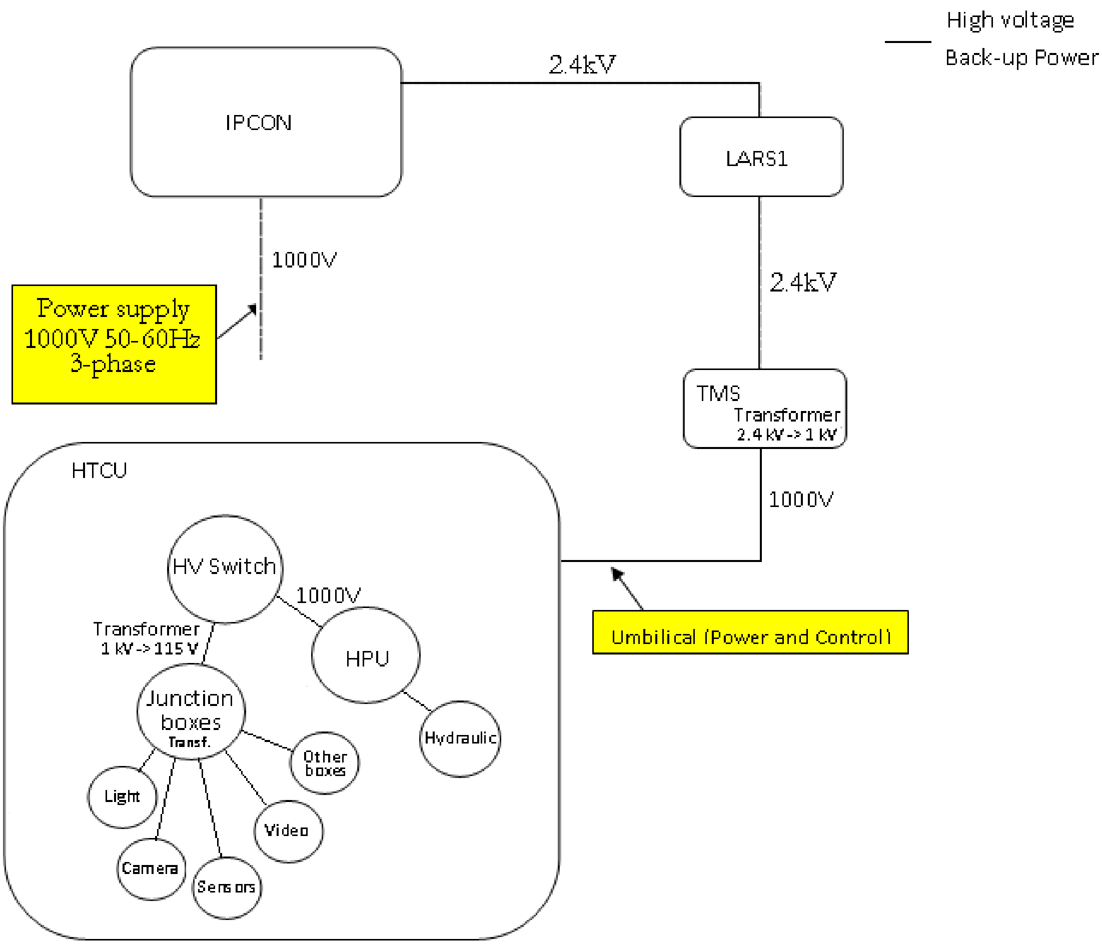


Figure 9-47 HTCU – System simplified power supply

Because of the restriction in umbilical capacity it is recommended to purchase a new winch with umbilical range to 3000 MSW or a new umbilical on the same winch, by widening the winch drum. Purchasing a new umbilical with range to 3000 MSW, implies minor increase in weight or size. The ROVs designed by Kystdesign AS normally uses an umbilical with outer cable diameter of 32.6 mm +/- 1, see APPENDIX 14. LARS1 present umbilical has a diameter of 42.2 mm [40]. A new umbilical, with same diameter, will therefore only result in approximately 1-2 extra layers on the existing umbilical winch. The umbilical manufacturer is rather challenged by the client designing a thinner umbilical with smaller diameter.

Recommending purchasing a new winch, for LARS1, for power supply to 3000 MSW, will increase umbilical length capacity with 1400-1500 m (from 1500-1600 m to 3000 m). As the umbilical gets longer the umbilical will be exposed to forces due to seawater current. Drag is defined as forces acting on an object in the direction of the relative fluid flow velocity. The challenge with 3000 m umbilical and seawater current, 0.3 m/s in this case, is the offset due to drag, see Figure 9-49. The offset could occur between the TMS relative to the vessel position. If offset occurs the vessel will reposition such that the TMS is located on its correct position. The challenge, with offset, is if the vessel crane needs to support the operation subsea and the vessel is relocated for instance 100 m. To cope with this, it is recommended to purchase a new tether umbilical with minimum 500 m range, so that the vessel don`t need to relocate its position. Present tether umbilical range is 150-200 m.

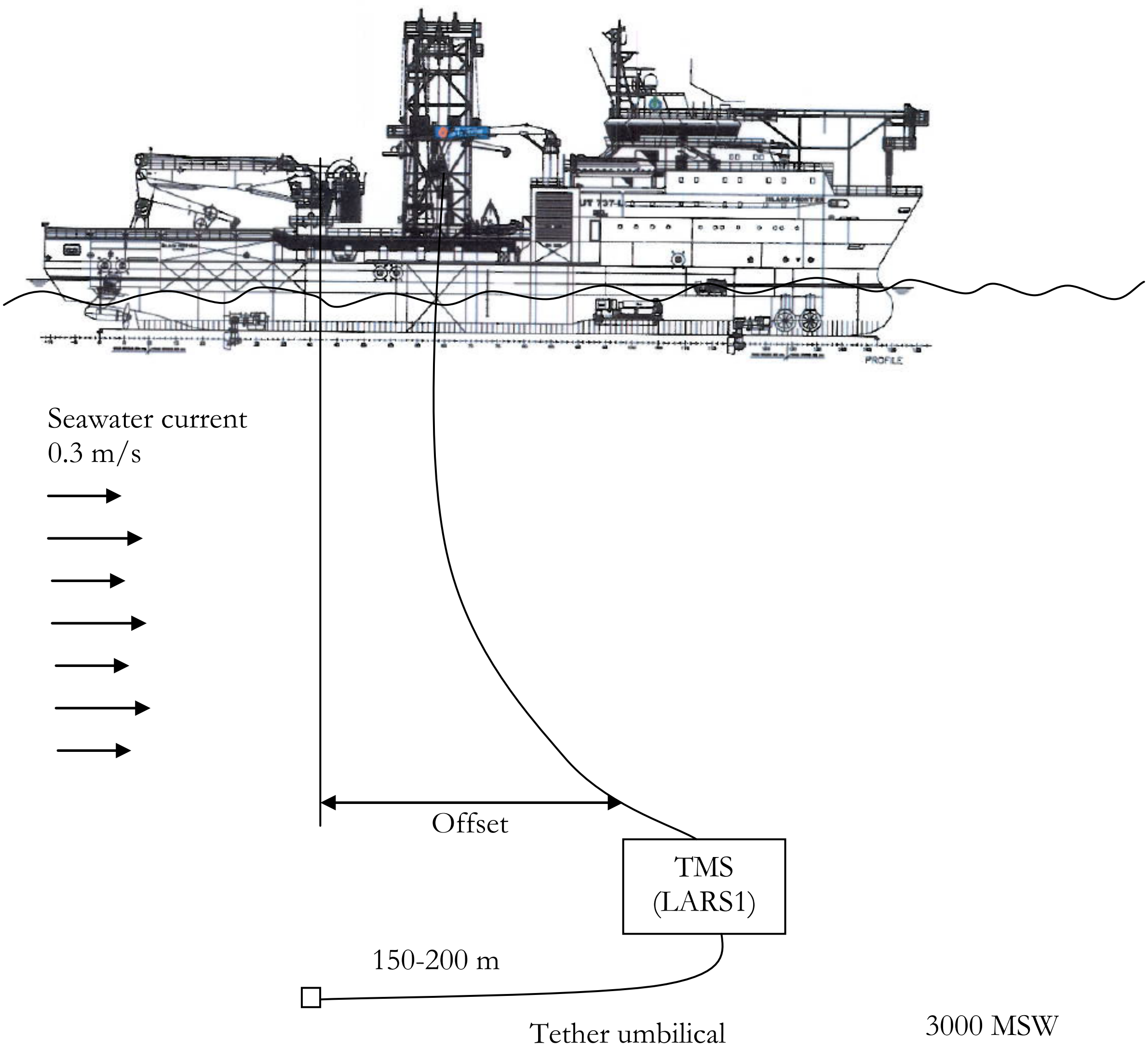


Figure 9-48 TMS (LARS1) offset

9.2.3 ROV support

The third subsystem of the HTCU ultra-deep system is the ROV (Remotely Operated Vehicle) support. ROV is an underwater vehicle, connected to a TMS, remotely manoeuvred from a control room onboard a vessel, see Figure 9-50.

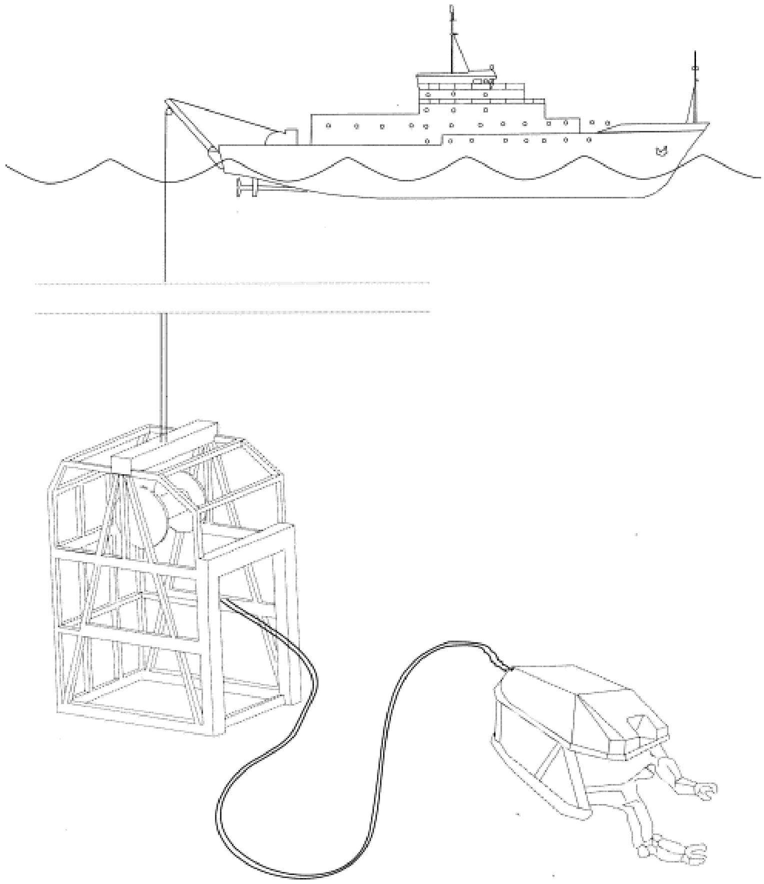


Figure 9-49 Schematic representation of a typical ROV system consisting of a vessel, winch, umbilical tether, cage and vehicle [41]

Figure 9-50 WROV [42]

There are three main types of ROVs, Observation ROV (OBS ROV), Working ROV (WROV), see Figure 9-51, and Survey ROV. The majority of the ROVs are rated for 3000 MSW, some for 4000 MSW and also ROVs for 8000 MSW have been developed [43].

ROV supporting the subsea operation involves being the operators "eyes" through lowering/hoisting operations, operating ROV valves and support during guide wire/guidepost installation/removal. Today ROVs perform all operations previously done by divers. Limiting diver-depth is currently 180m for Norwegian continental shelf.

Possible ROV challenges and requirements extending to ultra-deep water:

- Temperature:
  At 3000 MSW the seawater is 4.4 deg C, see APPENDIX 10. Temperature is not a concern; the ROVs use hydraulic oil which can stand temperatures even lower.
- Visibility:
  Visibility at ultra-deep water is usually good, expect after hurricanes, see APPENDIX 10. In addition it could be used mud mats or gravel dump.
- Positioning:
  According to Kystdesign AS, which designs and builds ROVs, a problem at 3000 MSW is that the acoustic positioning gets poor. To cope with this some systems have Doppler and INS (Inertial Navigation System) to have a more accurate positioning, see APPENDIX 16.
- Lowering and hoisting:
  Lowering and hoisting the ROVs to 3000 MSW is time-consuming, but not a concern.

ROV support will not be an operational issue extending to ultra-deep water simply because ROVs presently operate regularly in 3000 MSW.

Other support in the subsea system is vessel related and will be discussed in the Vessel related issues in section 9.2.4.

9.2.4 Vessel related issues

The fourth and last subsystem of the HTCU ultra-deep system is the part related to the vessel. To define the vessel related issues one need to define which tools/equipment that needs an upgrade. When this is solved the second issue is to define which vessel to be nominated for the operation. Vessel requirements at ultra-deep water:

- Crane: Equipment requires crane lifting capacity. Capacity with necessary outlay, requirements to AHC (Active Heave Compensation).
  The Skandi Arctic has been contacted and according to the vessel`s Diving Technical Manager it's possible to operate at 3000 MSW. The wire capacity is 3000 m on the main crane and ROV winch. For the 50 tons crane, the crane supplier needs to evaluate the wire capacity, refer to APPENDIX 15.
- ROV: Special equipment for ROV. For instance onboard the Skandi Arctic both Work class ROVs are rated for 3000 MSW with over 3000 m of wire on winches [37].
- DP – Class (Dynamic Positioning). DP system would operate on GPS (Global Positioning System), HPR (Hydro acoustic Position Reference) and Fanbeam (laser-based positioning sensor - if available). Different deep water transponders for the HPR may be needed [37].
- NAV screen (Subsea navigation) – is not a concern extending to 3000 MSW. Survey uses several principle of measurement in the NAV-screen program to achieve a good result.
- Guide wires will, as mentioned, not be used to 3000 MSW, due to risk of twisting entanglement of the guide wires itself, the lifting wire or with the umbilical.

Vessel issues will not be an operational concern extending to ultra-deep water, simply because several vessels presently has a rating to 3000 MSW.

10.0 INDUSTRY QUALIFICATION/VERIFICATION SYSTEMS

10.1 Statoil`s management system

The hot tap system comprises five tools, which are qualified. Either through track records or Statoil`s management system (ARIS), APOS FR12 (has replaced the WR1622) and DNV. The new FR12 process focus on "Multi User Implementation" (MUI), which was not mentioned in the WR1622, beyond this the process is similar.

A qualification process comprises; creating a TQP, documentation (drawings, text, data and other relevant documents), detailed test program, have a full-scale prototype built and integration tested and the final TQP Close-out Report. See Table 10-1 for document structure for equipment qualification Åsgard Subsea Compression Project.

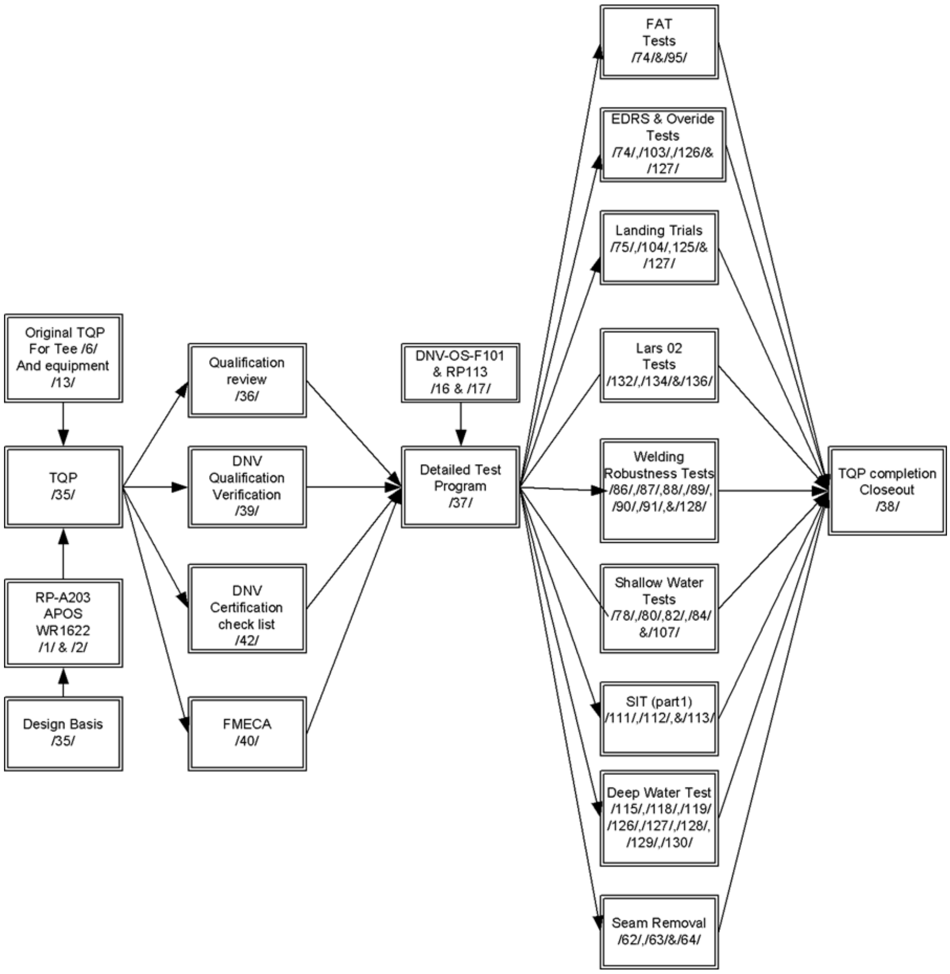


Table 10-1 Documentation structure for equipment qualification ÅSCP [44]

This flowchart indicates the path to TRL (Technology Readiness Level) 5 [44] "Technology integration tested" for ÅSCP. APOS FR12 Work process (Technology Development and Implementation) K-32642 describes Statoil`s functional requirements for technology development and implementation. For TRL level, development stage and hardware development see APPENDIX 17.

10.2 DNV – Det Norske Veritas

Through Statoil`s process qualifying the hot tap system for first use, DNV has participated to certify the technology. The basis for certification comprises standards such as DNV-RP-A203 Qualification Procedures for new Technology [45], DNV-OS-F101 Offshore Standard Submarine Pipeline Systems [46] and DNV-RP-113 Recommended Practise Pipeline Subsea Repair [47].

DNV requires that the new technology shall be unambiguously and completely described, through drawings, text, data, or other relevant documents. The specification is the input to the qualification process.

DNV offers a "Statement of Fitness for Service" which considers the technology documented as fit for service.

10.3 Qualification process ultra-deep upgrades

Upgrading the HTCU extending water depth capability to 3000 MSW will require a re-certification of the tool, a TQP is required.

The TQP would then comprise a detailed test program with components testing, test in tank, full scale wet test at ultra-deep water, dry test, and a full documentation of all qualification activities.

11.0 RESULTS AND CONCLUSIONS

A remotely operated subsea tool designed for complex operations consists of a high number of complex systems for which multiple area skill is required. The review performed in this thesis has had a high ambition of covering different specialist competences, meaning that in-depth discussion of all aspects have not been possible. However, it is felt that the results presented will give a broad overview of issues to be considered in such an upgrade.

The HTCU is designed for operation in 1000 MSW and Statoil is looking into the possibility to upgrade the HTCU to 3000 MSW.

The Mardi Gras pipeline case dimension 24" is already covered by the hot tap system. The main challenge for the modifications to be done is the water depth.

Proposed improvements, not related to ultra-deep water, on present design comprise among other the HTCU to operate independent of PIF. The HTCU operating without the PIF would make the hot tap operation safer and more efficient. In addition there will be substantial economic savings on reduced mobilization/demobilization expenses, IMR expenditure, operator training, spare parts and maintenance. Removing PIF also make it possible for the HTCU to operate in the near-vertical position. A new structure frame is recommended making the tool operable through the moon pool. An optimization on the lowering and hoisting speeds is also an improvement not related to ultra-deep water. The speeds can be increased with water depth.

The ultra-deep upgrades are applicable to four subsystems; Subsea system, Umbilical, ROV support and Vessel related issues. Each subsystem contributes as an important part of the upgrade.

Subsea system:

Extending from 1000 MSW to 3000 MSW the main difference is the ambient hydrostatic pressure. In the Mardi Gras case the hydrostatic ambient pressure (300 bar) is higher than the internal pipeline pressure (215-251 bar), which result in a reversed pressure differential effect. This reversed pressure differential will affect the EDRS, cutting function and seals. Both the EDRS and cutting function require a reinforcement/evaluation in addition to some hydraulic system modifications on the cutting function.

The reversed pressure differential will also affect the SeaTap (the drilling element of the HTCU), which is one of the major concerns extending HTCU to ultra-deep water. It will be a problem for the lower seals due to problems of type (single acting lip seals) and configuration of seals in addition to loading on the Tool Shaft Drive Shaft. This requires a detailed review, redesign and testing to qualify for this set of conditions.

HTCU affected subsystems are mechanical, hydraulic and electrical systems. The mechanical components are all standard subsea components and are not a concern in this ultra-deep water case. The subsea hydraulics on the other hand is dependent on a good compensation. A good compensation is required for the hydraulic components not to be damaged by external ambient pressure. It is the compensators and hoses/pipes (transporting the hydraulic oil) function to achieve this compensation. An evaluation of the compensators capacity in addition to a re-design of the hoses due to the risk of collapse (hose wall material) is recommended.

The HTCU is dependent on all the hydraulic components functioning properly. The cylinders, rated to 1000 MSW, are recommended replaced with new ones, rated to 3000 MSW. The replacement of cylinders is based on the seal rings, which will not maintain sufficient volume to seal properly at 300 bar. In addition some modification on the Injector cylinders is required.

Accumulators become less efficient with pressure. Thus, it is required to install additional accumulators. The entire system must be checked for enclosed volumes to cope with the increased ambient pressure. In addition a new primary HPU will be installed. The pressure gauges need to be re-qualified.

The most critical component extending water depth capability, in addition to the reversed pressure differential effect is the control cards (rated to 1000 MSW). All electronic devices contain one or several cards, for instance the Junction boxes. Testing of control cards in oil to 400 bar, has revealed that the epoxy currently used is inadequate for higher pressures. A new proper professional grade of epoxy must be selected.

Present hydraulic system is run by the HV switch. The HV switch is supplied with high voltage through the LARS1. For extension to ultra-deep water it is recommended to operate without the HV switch since the HTCU has only one HPU requiring high voltage. Removing the HV switch will decrease fault probability. An increased voltage on the HPU electro motor in range 3 or 3.3 kV is required.
Cables and connectors are critical when extending water depth. The cable assemblies will need remoulded and recertified to withstand 300 bar. For the Jupiter connectors all the inserts will need to be replaced, due to the inserts collapsing at an ambient pressure of 300 bar. Instead of replacing all the inserts in present connectors it is recommended to change supplier. Well-known suppliers such as Burton, Birns or Seacon are recommended.
In addition to the above concerns the 1-bar capacitor pods require a new casing. Electrical components such as cameras and lights, Inclinometer, LVDT and sensors will require upgrade or replacement.

<u>Umbilical, ROV support and Vessel related issues:</u>
The present LARS1 has an umbilical range to 1500-1600 m. It is therefore recommended to purchase a new winch with umbilical (range to 3000 MSW) or a new umbilical on the existing winch, by widening the drum. In addition it is recommended to purchase a new tether umbilical with minimum 500 m range.

ROV and vessel is not a concern, extending water depth capability, simply because they presently operate regularly in 3000 MSW.

Extending water depth capability to 3000 MSW will require a full re-certification of the HTCU. The TQP would then comprise a detailed test program with components testing, test in tank, ultra-deep water full-scale test, dry test, and full documentation of all qualification activities.

12.0 REFERENCES

[1] **Varg tie-in via Volve pipeline to Sleipner host Hot Tap Study.** TEX-SMT-PTT-2011-0016

[2] **Hydratight Limited.** [Internet] http://www.hydratight.com/sites/default/files/legacy/uploads/hot-tapping.jpg

[3] **International Organization for Standardization.** Petroleum and natural gas industries – Design and operation of subsea production systems ISO 13628-1:2005

[4] **Statoil ASA.** [Internet] http://www.statoil.com/en/About/inBrief/Pages/default.aspx

[5] **Technip Norge AS.** [Internet] http://www.technip.com/en/entities/norway

[6] **Technip Norge AS.** [Internet] http://www.technip.com/en/about-us/company-profile/technip-glance

[7] **Karmsund Havnevesen IKS.** [Internet] http://karmsund-havn.no/?ItemID=1310

[8] **Marine Insight.** [Internet] http://www.marineinsight.com/marine/types-of-ships-marine/skandi-arctic-the-biggest-saturation-dive-support-vessel/

[9] **PRS - Ormen Lange - Repair contingency - Study Report.** D046-RW-A-RS-0014

[10] **Oilstates/Oceaneering**.

[11] **Claxton/Mirage**.

[12] **TD Williamson.** [Internet] http://www.tdwilliamson.com/en/AboutUs/Pages/Home.aspx

[13] **TD Williamson.** [Internet] http://www.tdwilliamson.com/Documents/TDW_Corporate_Brochure.pdf

[14] **Furmanite.** [Internet] http://www.furmanite.com/Services/ServiceDisplayPage/tabid/54/obj/13/lang/1/Default.aspx

[15] **IK Stavanger AS.** [Internet]

http://www.ik.no/event/productItemList/famid/204362

[16] **Statoil ASA**. [Internet]
http://www.statoil.com/no/NewsAndMedia/News/2011/Pages/29March11MoreFastTrackProjects.aspx

[17] **Operational Procedure – Campaign 3, Hot Tap Execution**.
D110-TEC-Y-KA-0003

[18] **Statoil ASA.** Marine Infrastructure – Norwegian Shelf [Statoil Intranet]
http://st-w1034/marinf/default.aspx

[19] **Design, Fabrication & Installation (DFI) Resume Ormen Lange Phase 3.**
37-1X-TEC-X15-20004

[20] **Pipeline Intervention Frame (PIF), PIF + Hot Tap Module 12", General Assembly – Exploded View.**
D046-RW-PRS-MA-4500_001

[21] **National Institute of Standards and Technology.** [Internet]
http://webbook.nist.gov/cgi/fluid.cgi?T=4.4&PLow=1&PHigh=300&PInc=1&Applet=on&Digits=5&ID=C7732185&Action=Load&Type=IsoTherm&TUnit=C&PUnit=bar&DUnit=g%2Fml&HUnit=kJ%2Fmol&WUnit=m%2Fs&VisUnit=Pa*s&STUnit=N%2Fm&RefState=DEF

[22] **National Institute of Standards and Technology.** [Internet]
http://webbook.nist.gov/cgi/fluid.cgi?T=4.4&PLow=1&PHigh=300&PInc=1&Applet=on&Digits=5&ID=C124185&Action=Load&Type=IsoTherm&TUnit=C&PUnit=bar&DUnit=g%2Fml&HUnit=kJ%2Fmol&WUnit=m%2Fs&VisUnit=Pa*s&STUnit=N%2Fm&RefState=DEF

[23] **BP Global.** [Internet]
http://www.bp.com/sectiongenericarticle.do?categoryId=9030197&contentId=7055755

[24] **The Engineering toolbox.** [Internet]
www.engineeringtoolbox.com/hydrostatic-pressure-water-d_1632.html

[25] **HTCU EDRS Panel – Hydraulic Circuit**.
D046-RW-PRS-LD-5206-001_B

[26] **Mykin Inc.**[Internet]
http://mykin.com/index.php/nitrile-rubber-properties

[27] Ronald J. Schaefer. **Chapter 33 "Mechanical properties of rubber".**

http://85.185.231.196/mekanik/Harris'%20Shock%20and%20Vibration%20Handbook%20(5th%20Edition)/mechanical%20properties.pdf

[28] Sigurd Årland. **"Dirty pack" for ROV for kjøring av hydrauliske verktøy.** [Internet] http://brage.bibsys.no/hsh/bitstream/URN:NBN:no-bibsys_brage_7375/1/Aarland.pdf

[29] Nestun, J. **Hydraulikk i teori og praksis.** (1. utgave, 1. opplag Yrkesopplæringen ans ,Oslo 1999)

[30] **Shell.** [Internet] http://www.epc.shell.com/Docs/GSAP_msds_00083934.PDF

[31] Knut Brautaset. **Innføring i olje hydraulikk.** (1.utgave, 3.opplag Universitetsforlaget, 1990)

[32] **Remote Hot Tap System Hot Tap Cutting Unit Hydraulic Schematic.** D046-RW-PRS-LA-5601-001_A

[33] **Lalit Hydraulic Cylinder.** [Internet] http://www.lalithydraulic.com/hydraulic-cylinder.htm

[34] **Bosch.**[Internet] http://www.boschrexroth.com/country_units/america/canada/en/10_products/technology_areas/compu-spread/technical_documents/a10vo_piston_pump/a10vo_pistonpump_manual.pdf?searchQuery=A10V028

[35] **YouTube.** [Internet] http://www.youtube.com/watch?v=an1HA73Daio

[36] **Isotek NSGI Depth Increase Study Report.** D046-RW-A-RS-0019

[37] **NSGI – Upgrade/Modifications on PRS Equipment for use on NSGI Pipelines.** D046-RW-A-RS-0017

[38] **RPRS Connector and Cable Evaluation Report.** D046-RW-A-RS-5507_1

[39] **Remote Hot Tap Project HTTF Sensor and valve control.** D046-RW-PRS-EA-5004-001_E

[40] **LARS – Launch And Recovery System – Technical Specification.**

D046-RW-A-SF-0004

[41] **Science Direct.** [Internet]

http://www.sciencedirect.com/science/article/pii/S0029801898000766

[42] **Kystdesign AS.** [Internet]

http://www.kystdesign.no/f/632_kystdesign-brosjyre200508.pdf

[43] **OSEA.** [Internet]

http://www.osea-asia.com/ptm/showcat/exhdetail.asp?exhid=OSEA433422

[44] **Technology Qualification Program Close Out Report for Retrofit Hot Tap Tee and System for Åsgard Subsea Compression Project.**

D046-RW-A-RU-7009

[45] **DNV.**

Qualification procedures for new technology

DNV-RP-A203

[46] **DNV**.

Offshore Standard Submarine Pipeline Systems

DNV-OS-F101

[47] **DNV**.

Recommended Practise Pipeline Subsea Repair

DNV-RP-113

APPENDIX 1

PATENT: RØRLEGGER O.H. NETTEBERG AV DRAMMEN

(2 pages)

Patent nr. 20896

Bekjendtgjørelse fra patentkommissionen.

Mellemstykke til anvendelse ved anboring av rørledninger under tryk.

Rørlægger O. H. Netteberg av Drammen.

(Fuldmægtig: Ingeniør Alfred J. Bryn, Kristiania.)

Patent i Norge fra 1ste oktober 1909.

Man har tidligere forsøgt at konstruere apparater til anboring av rørledninger under tryk, men rørlæggerne har paa grund av disse apparaters forskjellige mangler hittil benyttet den gamle fremgangsmaate og avstængt vandet i hovedrøret, naar en grenledning skulde læg- ges fra dette. Da avstængningen av vandet i en hovedledning ofte er forbundet med større ulemper vil ikke saa litet være vundet ved at ha indretninger som kunde muliggjøre anboring uten saadan avstængning.

Et av nærværende opfinder konstruert mellemstykke til anbringelse mellem hovedrøret og den fra dette utgaaende grenledning ved saadan anboring har ved forsøk vist sig særlig tjenlig for opnaaelsen av ovennævnte øiemed. For at lette forstaaelsen av mellemstykkets konstruktion og anvendelse er der paa hosføiede tegning vist utførelsesformer saavel for mellemstykket selv som for anboringsapparater til anvendelse i forbindelse med mellemstykket likesom beskrivelsen av samme grund ikke er begrænset alene til det nye ved opfindelsen.

Fig. 1 viser et snit gjennem den egentlige anboringsindretning.

Fig. 2 viser en modificert utførelsesform for en del av samme.

Fig. 3 viser en utførelsesform for det til anbringelse mellem hovedrør og grenledning efter anboringen tjenlige mellemstykke.

Anboringsindretningen bestaar foruten av den sedvanlige klammer a, der ved skruer gjennem ørene b fæstes paa rørledningen, av en kran c som er indgjænget paa den ene side i klaven a og paa den anden side i en hylse d. Denne hylse er ved sin øvre ende paa i og for sig kjendt maate forbundet med boreapparatet e, som kan være av en hvilkensomhelst tjenlig konstruktion. Boret f føres ned gjennem hylsen d, hvor fuldstændig tætning tilveiebringes ved hjælp av en tjenlig pakning ved g, og ned gjennem kranen c og klammeren a. Hensigtsmæssig benyttes et spiralbor, hvis spiral rækker op i en utvidelse h i hylsen d, i hvilken utvidelse borspaan og, naar røret r er gjennemboret, vand samler sig. Efter gjennemboringen trækkes boret saa langt tilbake, at borspidsen kommer utenfor krankiken, hvorpaa denne dreies, saa vandet ikke kan passere gjennem kranen. Det i utvidelsen h paa hylsen d ansamlede vand samt borspaan kan fjernes gjennem en i utvidelsens væg anbragt kran k.

Før klammeren a fastskrues paa røret kan der mellem dette og klammeren anbringes en tjenlig pakning.

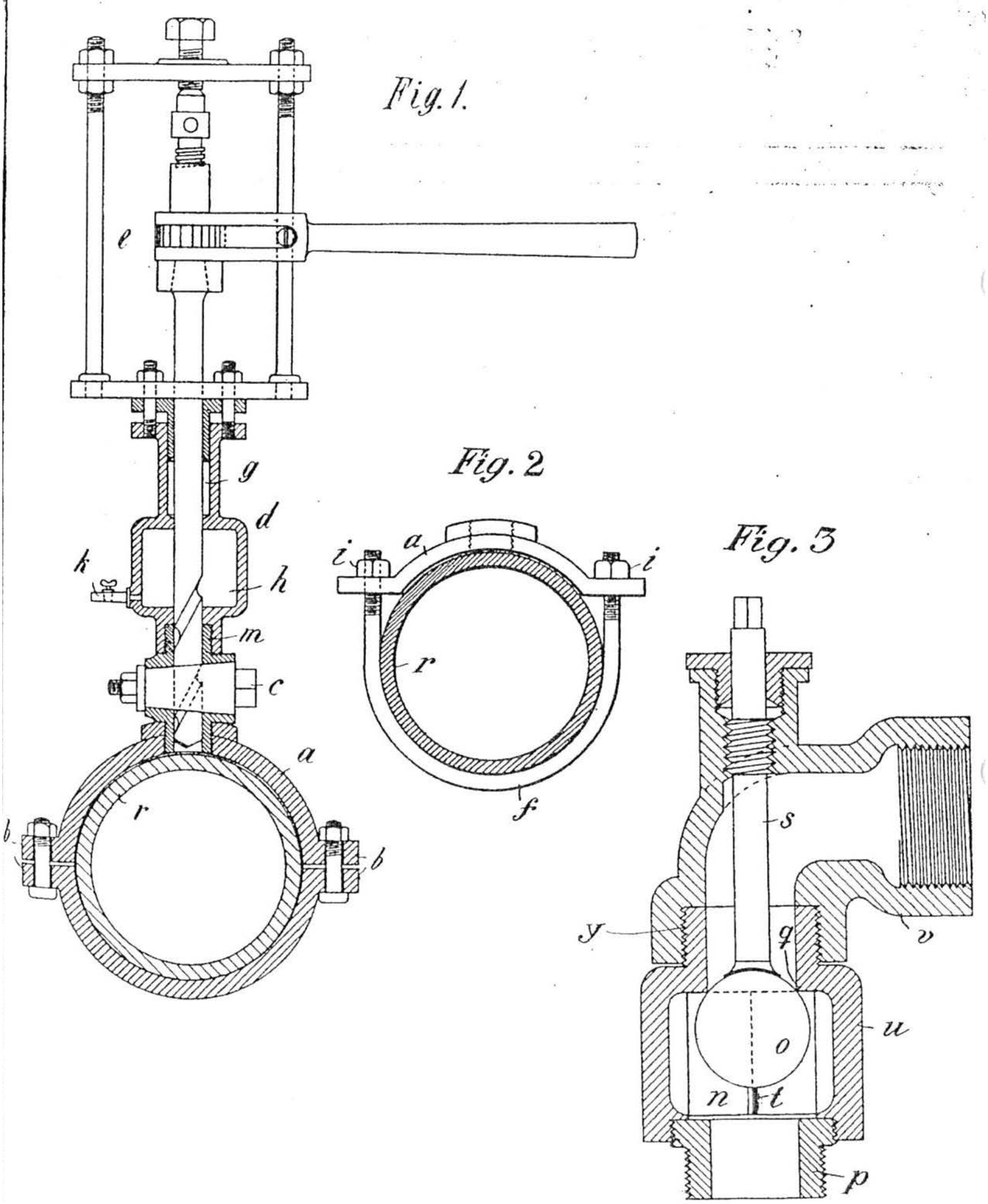
Istedetfor den paa fig. 1 viste todelte klammer med særskilte bolter til sammenskruning av delene kan man med fordel anvende en klammer, som den paa fig. 2 viste, bestaaende av en tætningsplate a, som klemmes fast mot røret ved hjælp av bøileformede bolter f med rektangulært tversnit, som lægges omkring røret og med sine gjængede ender stikkes igjennem ørene b paa platen a og fæstes ved hjælp av møttrikker i.

Naar boringen er utført skrues hylsen d med boreapparatet løs fra kranen c og grenrøret kan da paa kjendt maate indskrues paa dennes gjængede ansats m. Kranen c holdes selvfølgelig avstængt, indtil grenledningen er færdig.

Det nye ved opfindelsen bestaar specielt i de nedenfor beskrevne anordninger til anvendelse ved anboring av rør av større dimensioner, naar anboringsklammeren a ikke skal bli sittende paa røret. Borehullet i røret blir i dette tilfælde efter anboringen forsynt med gjænger hvilket eventuelt kan utføres med en dertil indrettet gjængetap, hvis øverste del utfylder hylsens (d) aapning ved pakningen, saa fuldstændig tætning opnaaes; men opfinderen foretrækker at forsyne det i dette tilfælde ved spidsen noget smalere bor med gjænger, der begynder umiddelbart ovenfor avsmalningen.

19 a — 25148

Patent No. 20896



APPENDIX 2

ARTICLE – HAUGESUND AVIS - VIL REVOLUSJONERE BRANSJEN 14.08.12

(01 pages)

GRUNN TIL Å SMILE: Går operasjonen til Statoil Pipeline Repair System (PRS) på Killingøy etter planen vil teknologien de har utviklet være verdt flere milliarder kroner. Her er fra venstre teamleder Technip Siri Vinje Reiersen, assisterende prosjektleder Statoil Jan Christian Torvastad, prosjektleder Technip Øyvind Vikse og prosjektleder Statoil Kjell Edvard Apeland.

Vil revolusjonere bransjen

På Killingøy jobber et knippe spente ingeniører. Deres nye teknologi kan være verdt milliarder av kroner.

Tekst: JOACHIM BACHA
Foto: HARALD NORDBAKKEN

NÆRINGSLIV: I løpet av de neste tre ukene skal et treårig prosjekt ledet av Statoils PRS-miljø på Killingøy i Haugesund kulminere i en banebrytende undervannsoperasjon som aldri tidligere er blitt utført.

Subsea-verden følger med

Hele subsea-verdens øyne er rettet mot gruppen på Killingøy når den grensesprengende teknologien nå skal i aksjon.

– Vi er svært stolte over det vi er i ferd med å få til. Hele Haugalandet kan være stolte. Vi er de første i verden som gjør dette, forteller Technips prosjektleder, Øyvind Vikse.

Statoils prosjektleder Kjell Edvard Apeland tar enda hardere i.

– Denne basen på Killingøy er best i verden på utvikling og operasjon av subsea reparasjons- og modifikasjonssystemet for rørledninger. Både i størrelse og på teknologi, sier han.

På oppdrag fra Statoil har undervannsentreprenøren Technip, i tett samarbeid med DeepOcean og Statoil, ledet prosjektet med en kostnadsramme på flere hundre millioner kroner.

I den internasjonalt sammensatt prosjektgruppen på 100 personer er flesteparten haugalendinger.

«Hot-tap» – aktiv perasjon

PRS Killingøys oppgave består i å utføre en såkalt «hot-tap» på 265 meters dyp på Åsgard-feltet. De skal sveise et grenrør på et større hovedgassrør, under vann. Gjennom grenrøret skal det bores et hull i hovedrøret.

Det heter «hot-tap» fordi hovedrøret vil være aktivt, som betyr at røret inneholder en gasstrøm under høyt trykk, mens operasjonen utføres.

Operasjonen er en del av prosessen med å opprettholde produksjon fra Åsgard-feltet. Verdens første undervannskompressor skal sørge for trykket, som vil sikre produksjon i lang tid framover. Kompressoren skal kobles på det planlagte grenrøret.

Tradisjonelt sett er dykkere blitt benyttet til slike operasjoner.

– Dykkergrensen er imidlertid i de senere år redusert til 180 meters dyp, sier assisterende prosjektleder i Statoil, Jan Christian Torvastad, og følger opp.

– Teknologien vi har utviklet og kvalifisert gjennom dette prosjektet gjør det mulig å utføre «hot-taps» på upreparerte rør ned til 1.000 meters dyp, sier han.

Enormt potensial

– Potensialet for bruk av teknologien er enorm. Hele bransjen følger med, og vi i Haugesund er de eneste som har denne teknologien, sier Apeland.

Fordelen med slike operasjoner er at en utvider rørledningsnettet under vann, i stedet for å bygge nye rørledninger fra land og ut til det aktuelle feltet. Å bygge nye rørledninger fra fastland medfører store kostnader.

Når en nå kan nå ned til 1.000 meter dype rørledninger, betyr det flere milliarder sparte kroner.

Stor spenning

Utstyret som skal benyttes i operasjonen på Åsgard-feltet er utviklet på Killingøy. Det har allerede blitt prøvd på 940 meters dyp. Testene har gått slik ingeniørene håpet på. Om tre uker er operasjonen planlagt å være ferdig.

Verdens største dykkerskip, «Scandi Arctic», skal løse en gruppe på 21 personer fra PRS i Haugesund ut på feltet.

– Vi er spente. Nå har vi brukt så mye tid og energi på prosjektet, og har god tro på dette, sier Vikse.

Samarbeid er nøkkelen

– Det kritiske punktet i operasjonen er boringen av hullet i hovedgassrøret. Noe som har gått bra på testene, forteller teamleder Siri Vinje Reiersen i Technip, som roser samarbeidet med Statoil.

– Et godt samarbeid med dem har vært nøkkelen til at vi har kommet så langt. God takhøyde og rom for diskusjon har sammen med et godt arbeidsmiljø ført oss her, sier hun.

joachim.bacha@h-avis.no

APPENDIX 3

ARTICLE – STAVANGER AFTENBLAD - KLAR FOR REKORD UNDER VATN 17.08.12

(01 pages)

Ny teknologi Oljeindustrien

Klar for rekord under vatn

➤ Dei siste førebuingar blir nå gjort ved kai i Haugesund før teknologiske grenser skal sprengjast under vatn i Norskehavet.

HAUGESUND

Det store dykkarskipet «Skandi Arctic» er blitt fullasta med spesialutstyr til jobben. Nær 100 personar, særskilt førebudde og trena til denne jobben, blir med om bord når skipet dreg frå Technip og Statoil sin utstyrsbase på Killingøy i Haugesund i morgon.

Etter fleire år med førebuing, teknologiutvikling pluss testing av utstyr på land og i sjø, skal sjølve eksamen skal gjerast på 255 meters djup på Åsgard-feltet.

Gass under trykk

Den store prøva blir å gjennomføra ein såkalla «hot-tap» på dette djupet utan dykkarar på havbotn. I staden for dykkarar blir det nytta fjernstyrte undervassrobotar (ROV) og avansert spesialverktøy senka ned til havbotn og styrt via kabel frå fartøyet på havoverflata.

Ein vellukka «hot-tap» i Norskehavet interesserer ikkje berre nokre få, men heile offshoreindustrien føl spent med.

Utfordringa blir å montera eit greinrøyr (12 tommar i diameter) på eit større hovudgassrøyr (22 tommar), som inneheld gasstraum under høgt trykk. Gjennom det påsveisa greinrøyret skal det monterast ein kuleventil.

Deretter vil ein fjernstyrt boremaskin bli ført gjennom kuleventilen og for å bora hol i hovudgassrøyret. Fleire innebygde barrierar skal hindra lekkasje til sjø. Ein slik operasjon (installasjon av eit greinrøyr i kombinasjon med hot-tap) er aldri før gjort dykkarlaust.

Første gong

Det nye er sveiseroboten som er verdas fyrste i sitt slag. Denne gjer at ein nå kan kopla seg til kor ein vil på ei røyrleidning. Tidlegare måtte ein ha førebudd røyrleidninga med eit greinrøyr den gong røyret blei lagt.

– Blir dette vellukka kan det opna seg ein stor marknad for fjernstyrt «hot-tap» over heile verda, fortel Technips fungerande plassjef på PRS-basen i Haugesund, John Aspen.

Han legg til at dersom alt går etter planen skal sjølve operasjonen på Åsgard-feltet kunne gjennomførast i løpet av tre veker til fem veker. I tillegg til Technip sine eigne folk og Statoils representantar er staben om bord i «Skandi Arctic» og sett saman av tilsette frå DeepOcean, som er Technip sin underleverandør.

Den konkrete «hot-tapen» på Åsgard skal vera med å leggja til rette for verdas første undervasskompressor. Kompressoren skal sikra eit langt liv for gass-produksjonen på Åsgard-feltet. Alternativet til undervasskompressoren ville vera ein stor tradisjonell kompressor på dekk over havflata.

THOMAS FØRDE

Konstruksjons- og dykkarskipet «Skandi Arctic» har tatt om bord utstyr og spesialistar ved Technip og Statoil sin base i Haugesund. FOTO: THOMAS FØRDE

APPENDIX 4

ARTICLE – STAVANGER AFTENBLAD – OBJECTIVE: TO BUILD AN ENTIRE FACTORY ON THE SEABED 13.09.12

(02 pages)

The recent underwater Åsgard field operation took place from subsea contractor Technip's "Skandi Arctic" vessel.

FOTO: Technip

Objective: To build an entire factory on the seabed

A branch pipe has been welded onto a huge gas-bearing high-pressure pipeline on the seabed for the first time-ever.

AV: Thomas Førde

Publisert: 13 september 2012 12:42 Oppdatert: 13 september 2012 12:42

Magnus Grutle from Technip shows drilling equipment which was used while working on the Åsgard pipeline.

FOTO: Thomas Førde

The successful operation took place a few days ago at a depth of 265 metres (about 869.5 feet) on the Åsgard field in the Norwegian Sea.

Statoil has been conducting technological development in preparation for this underwater exam since 1999.

Statoil's Pipeline Repair System facility (PRS-base) at Killingøy in Haugesund, western Norway, has primarily carried out this development.

The recent underwater Åsgard field operation took place from subsea contractor Technip's "Skandi Arctic" vessel.

Future gas transport

Some 100 people were on board while work on the seabed was carried out aided by specially designed and remote-controlled tools and welding machines. No divers were permitted into the sea before the job was completed.

The 18-inch now welded-on branch pipe's role is to facilitate installing the world's first subsea compressor on the seabed for connection to the gas transport system in the summer of 2014.

This subsea compressor will ensure high pressure for future gas transport via the Åsgard pipeline.

Factory on the seabed

Statoil will work towards a new objective for 2020 after the subsea compressor is installed and put into operation in 2015.

"We'll then be able to build an entire factory (a processing facility for oil or gas) for use on the seabed," says Torstein Vinterstø, head of Statoil's underwater compressor project.

APPENDIX 5

ARTICLE – OFFSHORE.NO – REKORD KAN GI MILLIARDGEVINST 13.09.12

(03 pages)

Rekord kan gi milliardgevinst

Publisert 13.09.2012 10:41:52 av Offshore.no redaksjonen

- Som å lande på mars.

For aller første gang har fjernstyrte maskiner og en undervanns sveiserobot montert et nytt tilkoblingspunkt på en gassrørledning i drift uten at røret var forberedt for det.

Denne type operasjoner kan på sikt gi milliardbesparelser for Statoil.

Ti dager

- For en subseaingeniør kan dette kan sammenliknes med det å lande på Mars, sier Kjell Edvard Apeland i en melding. Han er prosjektleder for fjernstyrt hot tap-utvikling i Statoil og leder for operasjonen på Åsgard-feltet.

Installasjonen (hot tap) er den første som er utført i forbindelse med forberedelsene for Åsgard havbunns gasskompresjon i Norskehavet, og er derfor en milepæl for prosjektet. Koblingspunktet ble sveiset på produksjonsrøret til Åsgard B-plattformen på 265 meters dyp.

Etter ti dager på feltet kunne teamet for hot-tap operasjonen om bord på det Technip-eide fartøyet Skandi Arctic konstatere at de hadde lykkes med den banebrytende operasjonen.

Enkelt forklart består en fjernstyrt hot tap-operasjon av at en robot sveiser et T-stykke på røret mens det strømmer gass gjennom det. Når det er gjort, vil en fjernstyrt boremaskin bore hull i det produserende røret mens trykk og produksjon gjennom røret forblir upåvirket.

- Når kompressormodulen og manifolden for Åsgard havbunnskompresjon skal installeres neste år, kobler vi på røret fra disse til hot-tap tilkoblingspunktet, sier Apeland.

Åsgard havbunns kompresjonsprosjekt skal realiseres i 2015 som det første i verden av sitt slag. Kompressorer installeres på havbunnen i stedet for på plattform. Dette øker utvinningen fra reservoarene Mikkel og Midgard med rundt 280 millioner fat oljeekvivalenter.

Store besparelser

Hot tap-teknologien er et teknologisk gjennombrudd og en døråpner for å utvikle marginale felt og forlenge levetid på andre felt. Det at man kan koble seg til hvor som helst på en rørledning uten å stanse produksjonen, gir stor fleksibilitet og store gevinster.

– Siden vi skal koble en ny kompressorstasjon på havbunnen opp mot et eksisterende rørledningssystem på Åsgard, er hot tap-teknologien veldig gunstig å bruke for ikke å forstyrre produksjonen, sier Torstein Vinterstø, porteføljeleder for havbunns kompresjonsprosjekter i Statoil.

– Gevinsten på Åsgard er målt i forhold til hva det ville kostet å gjøre tilsvarende operasjon ved å stenge ned produksjonen i røret man jobbet på. Dette ville også tatt mye lengre tid enn de ti dagene vi nå brukte, sier han.

Egenutviklet teknologi

Metoden er utviklet av Statoil og det finnes ingen tilsvarende teknologi.

Arbeidet med å utvikle teknologien startet i 1999. Den er utviklet i Statoils rørteknologi-miljø på Killingøy utenfor Haugesund. Her er Statoils ekspertise innenfor tilknytning og reparasjon av rørledninger samlet.

Et åpent og godt samarbeid med våre nøkkelleverandører har vært avgjørende for å få dette til.

Hot tap-teknologien er tidligere godt uttestet av Statoil med gode resultater. Fjernstyrt hot-tap er tidligere utført på Tampen Link på Statfjord-feltet i Nordsjøen og på Ormen Lange-feltet i Norskehavet, men da var T-stykket montert på gassrøret på forhånd.

APPENDIX 6

ARTICLE – TU.NO – HER GJØR STATOIL NOE INGEN ANDRE HAR GJORT FØR 13.09.12

(03 pages)

HOT TAP PÅ ÅSGÅRD

Her gjør Statoil noe ingen andre har gjort før

For første gang i historien har noen klart å sveise på et grenrør på et gassrør i drift på havdyp som ikke er tilgjengelig for dykkere.

Av Ole Ketil Helgesen

Publisert: 13. september 2012 kl. 10:55 - Oppdatert: 13. september 2012 kl. 11:19

Fredag 24. august var det en spent stemning om bord på verdens største dykkeskip Skandi Arctic.

Selv om det lå flere år med forberedelser og testing bak, satt prosjektleder Kjell E. Apeland på nåler i 20 lange minutter mens den spesialbygde sveiseroboten sveiset fast et grenrør på et gassrør fullt av gass under høyt trykk.

– Vi var helt sikre på at det ikke var noe fare med tanke på gassen inni hovedgassrøret. Sveisingen har ikke nok energi til at det skulle bli problematisk. Men det var første gang i verden noe slikt ble gjort, så det er klart det var spennende, sier han.

Sveiset sammen rør

Den såkalte «hot-tap»-operasjonen ble utført på 265 meters dyp på Åsgard-feltet. For at plattformen skal kunne ta imot gass fra den store undervannskompressoren som skal installeres på feltet, var det nødvendig å koble på et T-stykke på hovedgassrøret.

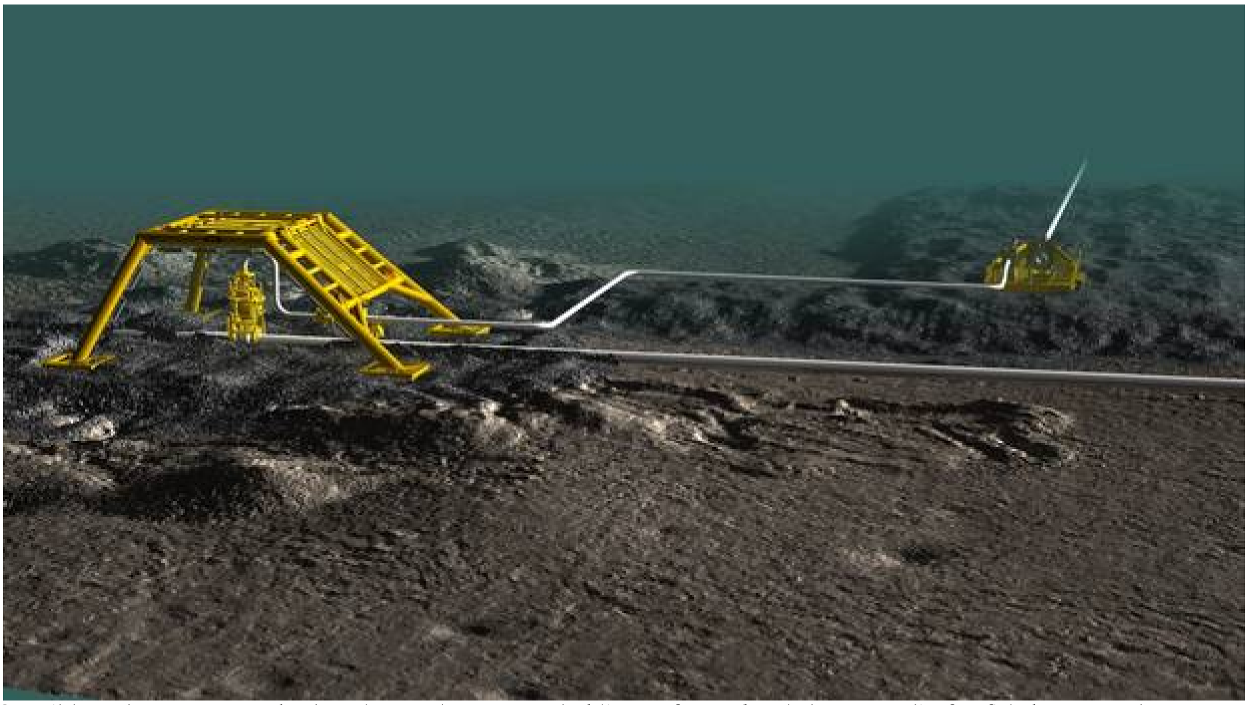
Statoils krav til sikkerhet og regularitet krever at grenrør skal sveises, eller ha en metallbasert tetning for å ha tilstrekkelig levetid. Det er ikke nok med gummipakninger.

Og ettersom det ikke skal brukes dykkere på over 180 meters dyp, måtte operasjonen gjøres fjernstyrt med en undervannsrobot og sveisemaskin.

Stort marked

Apeland mener den vellykkede operasjonen vil åpne et stort marked for fjernstyrte «hot-tap»-operasjoner.

– Tidligere måtte man tenke ut på forhånd hvor man skulle ha grenrør. Dette er både kostbart og krevende ettersom man ikke vet hvor man vil ha behov for nye ledninger i fremtiden. Nå kan man koble seg på hvor man vil på rørledningen, og det gir en helt annen fleksibilitet og store besparelser. Teknologien er kvalifisert for bruk ned til 1000m vanndyp, sier han.



Statoil har plassert en stor beskyttelsesstruktur over t-koblingen for at det skal være mulig for fiskebåter å tråle over den. Foto: Statoil

27 datamaskiner på bunn

Hele offshoreindustrien følger spent med på Statoil og leverandørenes banebrytende arbeid på havbunnen på Åsgard.

– Det er stor interesse. Men i Houston har jeg opplevd at det er noen som sperrer opp øynene og synes dette virker veldig fremmed. De er vant med enklere hydraulisk utstyr,
og de lurer på hva vi skal med alt dette high-tech-utstyret. Det er i realiteten 27 datamaskiner med 118 sensorer og ethernet vi tar ned på havbunnen når vi utfører selve «hot-tap»--boreoperasjonen. Den nye sveisemaskinen har tilsvarende kontrollsystem og instrumentering. Det er altså som et helt kontorlandskap med datamaskiner under vann. Hele dekket på Skandi Arctic var fylt med utstyr for å gjennomføre denne ene operasjonen, forklarer Apeland.

Mange års forberedelser

Sammen med Technip og underleverandøren Deep Ocean har Statoil forberedt seg i årevis på det grensesprengende prosjektet på Åsgard-feltet i Norskehavet.

Ingen ting kunne overlates til tilfeldighetene. Utstyret ble testet på et simuleringsgassrør i Sognefjorden og det ble utført en generalprøve i Nedstrandfjorden.

Alt fungerte perfekt. Men marginene er små, og selve sveiseoperasjonen går så fort at man må være ytterst oppmerksom.

– Den totale sveisetiden er rundt 20 minutter. Hver runde tar rundt tre minutter, og dette gjentas seks ganger. Selve sveiseprosessen er preprogrammert og overvåkes online av et software-basert monitoreringssystem. Sveiseoperatøren kan justere posisjonen på sveisen med en halv millimeter om gangen dersom det trengs justeringer, forklarer Apeland.

Hva blir det neste?

Han har jobbet med hot tap siden han begynte i Statoil i 1999. Nå er han i mål og vet ikke hva han skal finne på.

– Det er alltid noe nytt å ta fatt i. Men akkurat nå vet jeg ikke hva som er det neste, sier han og ler.

APPENDIX 7

ARTICLE – STATOIL.COM – STATOIL MED FJERNSTYRT VERDENSREKORD PÅ ÅSGARD 13.09.12

(02 pages)

Statoil med fjernstyrt verdensrekord på Åsgard

For aller første gang har fjernstyrte maskiner og en undervanns sveiserobot montert et nytt tilkoblingspunkt på en gassrørledning i drift uten at røret var forberedt for det. Denne type operasjoner kan på sikt gi milliardbesparelser for Statoil.

Installasjonen (hot tap) er den første som er utført i forbindelse med forberedelsene for Åsgard havbunns gasskompresjon i Norskehavet, og er derfor en milepæl for prosjektet.

Koblingspunktet ble sveiset på produksjonsrøret til Åsgard B-plattformen på 265 meters dyp.

Etter ti dager på feltet kunne teamet for hot-tap operasjonen om bord på det Technip-eide fartøyet Skandi Arctic konstatere at de hadde lykkes med den banebrytende operasjonen.

Kjell Edvard Apeland, prosjektleder for fjernstyrt hot tap-utvikling i Statoil og leder for operasjonen på Åsgard-feltet. (Foto: Rune Solheim)

- For en subseaingeniør kan dette kan sammenliknes med det å lande på Mars, sier Kjell Edvard Apeland. Han er prosjektleder for fjernstyrt hot tap-utvikling i Statoil og leder for operasjonen på Åsgard-feltet.

Enkelt forklart består en fjernstyrt hot tap-operasjon av at en robot sveiser et T-stykke på røret mens det strømmer gass gjennom det. Når det er gjort, vil en fjernstyrt boremaskin bore hull i det produserende røret mens trykk og produksjon gjennom røret forblir upåvirket.

- Når kompressormodulen og manifolden for Åsgard havbunnskompresjon skal installeres neste år, kobler vi på røret fra disse til hot-tap tilkoblingspunktet, sier Apeland.

Åsgard havbunns kompresjonsprosjekt skal realiseres i 2015 som det første i verden av sitt slag. Kompressorer installeres på havbunnen i stedet for på plattform. Dette øker utvinningen fra reservoarene Mikkel og Midgard med rundt 280 millioner fat oljeekvivalenter.

Store besparelser

Hot tap-teknologien er et teknologisk gjennombrudd og en døråpner for å utvikle marginale felt og forlenge levetid på andre felt. Det at man kan koble seg til hvor som helst på en rørledning uten å stanse produksjonen, gir stor fleksibilitet og store gevinster.

– Siden vi skal koble en ny kompressorstasjon på havbunnen opp mot et eksisterende rørledningssystem på Åsgard, er hot tap-teknologien veldig gunstig å bruke for ikke å forstyrre produksjonen, sier Torstein Vinterstø, porteføljeleder for havbunns kompresjonsprosjekter i Statoil.

Torstein Vinterstø, porteføljeleder for havbunns kompresjonsprosjekter i Statoil. (Foto: Anette Westgård)

– Gevinsten på Åsgard er målt i forhold til hva det ville kostet å gjøre tilsvarende operasjon ved å stenge ned produksjonen i røret man jobbet på. Dette ville også tatt mye lengre tid enn de ti dagene vi nå brukte, sier han.

Egenutviklet teknologi

Metoden er utviklet av Statoil og det finnes ingen tilsvarende teknologi.

Arbeidet med å utvikle teknologien startet i 1999. Den er utviklet i Statoils rørteknologi-miljø på Killingøy utenfor Haugesund. Her er Statoils ekspertise innenfor tilknytning og reparasjon av rørledninger samlet.

Et åpent og godt samarbeid med våre nøkkelleverandører har vært avgjørende for å få dette til.

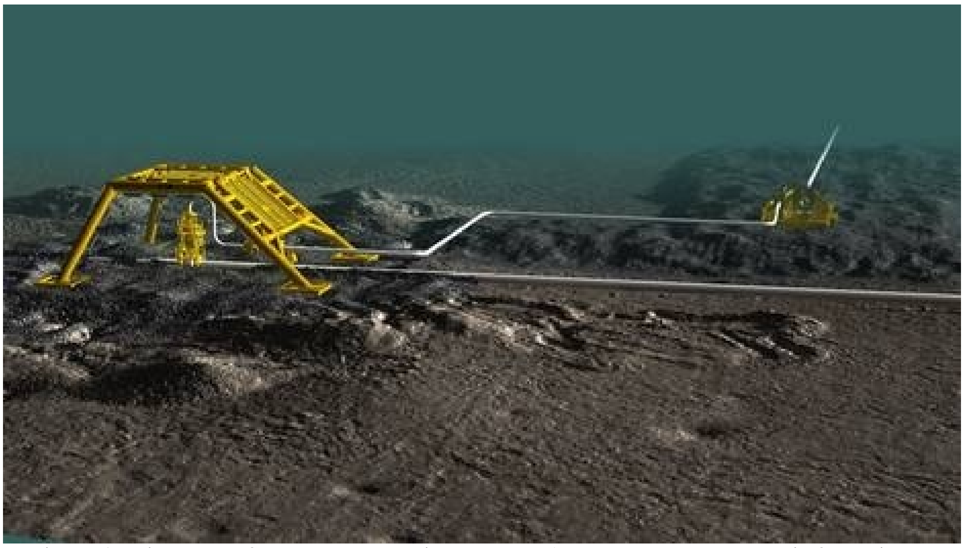
Hot tap-teknologien er tidligere godt uttestet av Statoil med gode resultater. Fjernstyrt hot-tap er tidligere utført på Tampen Link på Statfjord-feltet i Nordsjøen og på Ormen Lange-feltet i Norskehavet, men da var T-stykket montert på gassrøret på forhånd.

Illustrasjon: Åsgard havbunns gasskompresjon.

APPENDIX 8

ARTICLE – TU.NO – NOMINERT TIL ÅRETS INGENIØRBRAGD 13.09.12

(4 pages)



Verdensrekord: Det er første gang i verden at noen har sveiset oå et rør i drift på dyp som ikke er tilgjengelig for dykkere.

ÅRETS INGENIØRBRAGD 2012

Verdens dypeste sveis

Statoils verdensrekord er nominert til Ingeniørbragden.

Av **Ole Ketil Helgesen**
Publisert:2. november 2012 kl. 10:04
Oppdatert:8. november 2012 kl. 11:36

- *Statoil er nominert til Årets ingeniørbragd for sin hot tap-løsning på Åsgard.*

24. august gjorde Statoil noe ingen andre har gjort tidligere. Selv om det lå flere år med forberedelser og testing bak, satt prosjektleder Kjell E. Apeland på nåler i 20 lange minutter mens den spesialbygde sveiseroboten sveiset fast et grenrør på et gassrør fullt av gass under høyt trykk.

Den såkalte «hot tap»-operasjonen ble utført på 265 meters dyp på Åsgard-feltet.

For at plattformen skal kunne ta imot gass fra den store undervannskompressoren som skal installeres på feltet, var det nødvendig å koble på et T-stykke på hovedgassrøret.

Og ettersom det ikke skal brukes dykkere på over 180 meters dyp, måtte operasjonen gjøres fjernstyrt med en undervannsrobot og sveisemaskin.

Stor oppmerksomhet

Operasjonen har fått oppmerksomhet over hele verden ettersom teknologien åpner mange muligheter for å bygge ut mindre felt på store dyp.

Tidligere måtte man tenke ut på forhånd hvor man skulle ha grenrør. Dette er både kostbart og krevende ettersom man ikke vet hvor man vil ha behov for nye ledninger i fremtiden.

Nå kan man koble seg på hvor man vil på rørledningen. Det gir en helt annen fleksibilitet og store besparelser.

Den spesialbygde sveiseroboten fungerte perfekt under operasjonen.

Rørledningsmiljø står bak

Det er Statoils «Pipeline repair systempool» på Killingøy som står bak prestasjonen. Bjørn Kåre Viken, fungerende teknologidirektør i Statoil, mener nominasjonen er fullt fortjent.

– Hot tap-teknologien er et teknologisk gjennombrudd. Det demonstrerte vi til fulle at den er da vi gjennomførte operasjonen på Åsgard-feltet tidligere i år. Det at man kan koble seg til hvor som helst på en rørledning uten å stanse produksjonen, gir oss stor fleksibilitet og store gevinster. Det er en døråpner for å utvikle marginale felt og forlenge levetid på andre felt, sier Viken til Teknisk Ukeblad.
Sammen med Technip og underleverandøren Deep Ocean har Statoil forberedt seg i årevis på det grensesprengende prosjektet på Åsgard-feltet i Norskehavet.

Fagkommentaren
Oljedirektoratet mener teknologien bidrar til at mindre ressurser som er avhengig av eksisterende infrastruktur, kan utvikles og produseres på en mer kostnadseffektiv måte.

– Oljedirektoratet vurderer denne teknologien for å være nyttig og lønnsom. Ved at man nå kan gjennomføre slike operasjoner, er det for eksempel mulig å gjøre fremtidige tilknytninger til eksisterende rør, uten å måtte foreta kostbare nedstengninger, tømme og stenge av røret der hvor den nye koplingen skal på. Hot tapping er en svært kostnadseffektiv løsning, som også vil gjøre det lettere for «tredjeparter» å knytte seg til. Oljedirektoratet forventer at teknologien også tas i bruk på andre felt hvor dette er naturlig, sier kommunikasjonsrådgiver Eldbjørg Vaage Melberg til Teknisk Ukeblad.

De andre kandidatene til Ingeniørbragden:

Prox Dynamics' Black Hornet: Norsk UAV brukes i Afghanistan

Umoe Mandals Skjold-klasse: Ser ut som små fiskeskøyter på radaren

Aker Solutions og Statoils gasskompresjon på havbunnen: Flytter grensen for havbunnsproduksjon

Gasscos New Pipeline Management System:Overvåker gassen over 8000 km

Thin Films trykte elektronikk: – Målet er å selge seks milliarder systemkretser

Hot Tap-løsningen

- Hot tap-løsningen består enkelt forklart av en stor enhet med en T-kobling og store klammer som festes på røret.
- Ved hjelp av en spesiell gass og induksjon blir atmosfæren inni koblingen tørket slik at man kan gå inn med en sveisemaskin. Maskinen sveiser på innsiden, og seks sveisesømmer sørger for at koblingen forblir tett.
- Deretter kan man gå inn med en boremaskin gjennom en ventil og utføre selve hot tap-operasjonen hvor man borer hull inn til det gassførende hovedrøret. Dermed er hot tap-tilkoblingspunktet klart, og man koble til en ny rørledning som transporter gass inn i det opprinnelige hovedrøret.
- Det er Statoils rørledningmiljø ved Pipeline Repair System-basen i Haugesund som har ledet utviklingsprosjektet. Ved denne basen, som Statoil opererer på vegne av flere rørledningsoperatører i Nordsjøen, har man en mengde spesialutstyr og spisskompetanse for å utføre utbygging, modifikasjon og reparasjon av offshore rørledninger.

Årets ingeniørbragd 2012

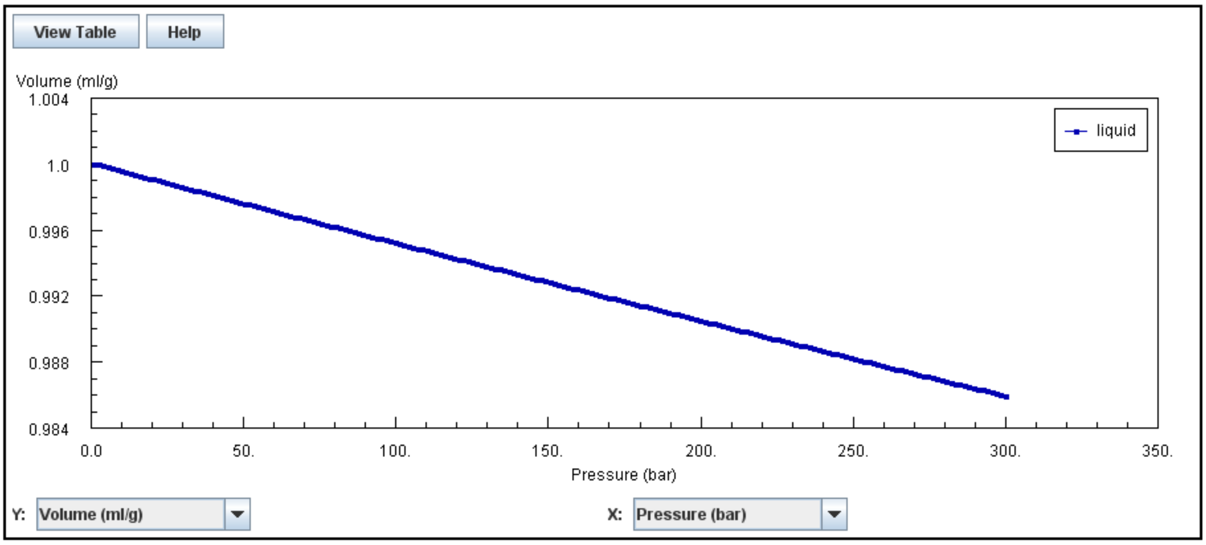
- Ingeniørbragden skal representere en **god ingeniørmessig løsning på et teknologisk eller samfunnsmessig problem** i Norge og være sluttført innen utgangen av året, det vil si 2012.
- Bragden kan også representere et **teknologisk eller kommersielt gjennombrudd** for en bedrift, et produkt eller et særdeles vellykket prosjekt i 2012.
- Vinneren kåres etter avstemming blant Teknisk Ukeblads lesere på nett kombinert med vurderinger fra en fagjury, og juryens tyngde er 2/3.
- Juryen ledes av NTNU-rektor Torbjørn Digernes. Øvrige medlemmer er ledere for de store bransjeorganisasjonene, Abelia, Energi Norge, Norsk Industri, Norsk olje og gass, BNL, RIF, Sintef og ansvarlig redaktør i Teknisk Ukeblad, Tormod Haugstad.

APPENDIX 9

INCOMPRESSIBLE – ISOTHERMAL DATA WATER AND DECAN

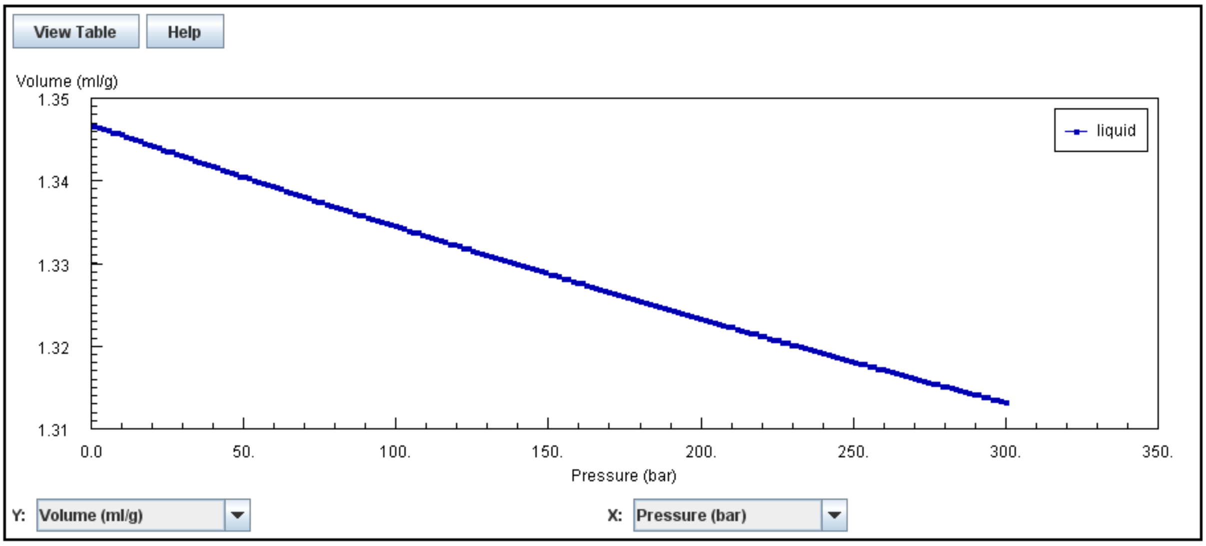
(02 pages)

For water, trapped inside for instance Junction boxes, the volume, at 4.4 deg C, is 1.0000 ml/g at 1 bar and decreases to 0.98595 ml/g at 300 bar, which results in a volume change of 1.4 % at 300 bar, see figure.



Isothermal data for water, T = 4.4 deg C, [21]

The hydraulic oil is being compared with the hydrocarbon Decan. At 4.4 deg C, the volume is 1.3467 ml/g at 1 bar and decrease to 1.3132 at 300 bar, which results in a volume change of 2.4 % at 300 bar, see figure.



Isothermal data for Decan, T = 4.4 deg C, [22]

From this it can be read that water is more incompressible than oil/hydraulic fluid, but neither of the mediums is 100 % incompressible. A system which is 100 % filled with hydraulic oil will be unaffected of pressure (approximately). It is difficult to air bleed (remove air) the hydraulic system, for instance on the Junction boxes, 100 %. Air is the main contributor for the hydraulic compensation requirement.

As the volume change, for water and the hydraulic oil, from 1 to 300 bar is approximately to 0, it is assumed that the fluids (water and hydraulic oil) is completely incompressible.

APPENDIX 10

BP MAIL CORRESPONDENCE

(06 pages)

From: "McDonald, W Leith" <william.mcdonald@bp.com>
To: "Katrine Sandvik" <KSandvik@technip.com>,
Date: 03.12.2012 15:15
Subject: RE: Mardi Gras pipeline system

Katrine,

Attached is a summary diagram of the systems. As you can see, the system operate between water depths between a few feet to over 7,000 fsw. In the GoM, the water temperature below 3,000 fsw is approximately 40 F. It then gradually warms up to about 55-60 at about 300 fsw. The surface can be as warm as 90 F during the summer and is typically in the 60-70 F in the winter. Currents are mostly surface currents that can approach 4 ft/sec in the loop current , but a typically less than 1 ft/sec.

Velocity in the pipelines varies greatly. Through out the operation we've had gas lines operating in excess of 25 ft/sec and oil lines operating as low as 0.3 ft/sec so, I don't think there's an easy answer to provide you in that regard.

If you need anything further, just let me know.

W. Leith McDonald
Offshore Pipeline Engineer
M/C 1114
550 Westlake Park Blvd
Houston, Texas 77079

Office: 281.366.5988
Cellular: 713.410.4997

From: Katrine Sandvik [mailto:KSandvik@technip.com]
Sent: Monday, November 26, 2012 12:52 AM
To: McDonald, W Leith
Subject: RE: Mardi Gras pipeline system

Hi Leith,

In addition to the question sent: What is the approx velocity of flow? and seawater temperature?

Do you have a picture of the Mardi Gras field layout?

Katrine Sandvik
Senior Engineer - Subsea Intervention

Technip Norge AS - Killingøy - 5515 Haugesund - Norway - www.technip.com
Tel (Direct) +47 67 20 26 10 - Switchboard +47 67 58 85 00

Please consider the environment before printing this email or its attachments.

From: "McDonald, W Leith" <william.mcdonald@bp.com>
To: "Katrine Sandvik" <KSandvik@technip.com>,
Date: 13.11.2012 14:08
Subject: RE: Mardi Gras pipeline system

Visibility is usually good beyond 800' of water depth except after hurricanes. Shallow water depth visibility is usually a functional of proximity to the mouth of the Mississippi river delta. The closer to the delta, the poorer the visibility. Generally, the soil conditions are soft clays with pipe embedment of 30-50%.

W. Leith McDonald
Offshore Pipeline Engineer
M/C 1114
550 Westlake Park Blvd
Houston, Texas 77079

Office: 281.366.5988
Cellular: 713.410.4997

From: Katrine Sandvik [mailto:KSandvik@technip.com]
Sent: Tuesday, November 13, 2012 1:19 AM
To: McDonald, W Leith
Subject: RE: Mardi Gras pipeline system

Hi Leith,

Thank you! Do you also have some information about seabed conditions, soil and visibility?

Katrine Sandvik
Senior Engineer - Subsea Intervention

Technip Norge AS - Killingøy - 5515 Haugesund - Norway - www.technip.com
Tel (Direct) +47 67 20 26 10 - Switchboard +47 67 58 85 00

Please consider the environment before printing this email or its attachments.

From: "McDonald, W Leith" <william.mcdonald@bp.com>
To: "Jan Olav Berge (JOLBE)" <jolbe@statoil.com>,
Cc: "Tysseland, Arild" <arild.tysseland@no.bp.com>, "Kjell Edvard Apeland" <kjedap@statoil.com>, <ksandvik@technip.com>, "Les Owen Consulting" <les@lesowenconsulting.com>
Date: 12.11.2012 15:20
Subject: RE: Mardi Gras pipeline system

Apologies for my tardy response, please see information below....

Size OD	Wall Thickness	Material Class & Strength	Coating Type & Thickness	Pressure Rating (PSIG)	Temperature Rating
16"	0.840" - 0.945"	AP5LX-65	FBE 18-22 mils	3565	160 F
20"	0.750" - 1.007"	AP5LX-65	FBE 18-22 mils	3250 - 3565	160 F
24"	0.971" - 1.227"	AP5LX-65	FBE 18-22 mils	3115 - 3630	160 F
28"	1.045" - 1.210"	AP5LX-65	FBE 18-22 mils	3115 - 3630	160 F
30"	0.661"	API5LX-70	- FBE 18-22 mils (non HDD) - 40 mils (HDDs) - 2.75" Concrete over the FBE 18-22 mils	2220	160 F

If you need anyhtign further, please let me know.

W. Leith McDonald
Offshore Pipeline Engineer
M/C 1114
550 Westlake Park Blvd
Houston, Texas 77079

Office: 281.366.5988
Cellular: 713.410.4997

From: Jan Olav Berge (JOLBE) [mailto:jolbe@statoil.com]
Sent: Thursday, October 04, 2012 10:48 AM
To: McDonald, W Leith
Cc: Tysseland, Arild; Kjell Edvard Apeland; ksandvik@technip.com
Subject: RE: Mardi Gras pipeline system

Hello Leith;
I have been recommended by other contacts in BP to contact you regarding Mardi Gras pipeline system data.
We are looking for basic pipeline data like:

- Outer diameter
- Wall thickness
- Material class and strength
- Coating type and thickness
- Pressure rating
- Temperature rating

The data will be used in connection with a MSc student project looking into tooling for remote subsea hot-tapping of deep water pipelines. We would like to use actual pipeline data to give the student a real case to work on. The student is looking into some specific Statoil pipelines and then I was looking for the Mardi Gras system as a typical GoM system.

Would appreciate if you could help me as soon as possible.

Best regards

Jan Olav Berge
PRS Pool Manager
Statoil ASA

From: Tysseland, Arild [mailto:arild.tysseland@no.bp.com]
Sent: 3. oktober 2012 14:59
To: Jan Olav Berge (JOLBE)
Cc: McDonald, W Leith
Subject: FW: Mardi Gras pipeline system

Jan Olav
Ref below from Les –Leith McDonald (CC) should be able to assist

Rdgs
A

Arild Tysseland
Subsea Integrity Engineer
BP Norge
Office (BP) +47 52013922
Mobile +47 93041430
Lync +442034012640
Mail: Arild.Tysseland@no.bp.com
Office Address: BP Norge, Godesetdalen 8 4033 Forus

BP Norge AS, a company registered in the Norwegian Register of Business Enterprises with Enterprise No: 981 355 210

From: Owen, Les L
Sent: 03 October 2012 13:45
To: Tysseland, Arild
Cc: Owen, Les L; King, Michael D; Dove, Martin W; McDonald, W Leith
Subject: Re: Mardi Gras pipeline system

Arild -

Please say hello to Jan Olav for me. I suggest he contacts Leith McDonald, Mardi Gras Operations Engineering who will be able to assist.

Best Regards,

Les Owen

On Oct 2, 2012, at 11:49 PM, "Tysseland, Arild" <arild.tysseland@no.bp.com> wrote:
Les,

Ref note below request from Jan Olav Berg at Statoil PRS –can you help with a contact for his request on the Mardi Gras pipeline ?

I will check what kind of tooling they are doing the study on

For info,
BP has joined Statoil PRS for the Skarv 26" export pipeline.

Rgds
A

Arild Tysseland
Subsea Integrity Engineer
BP Norge
Office (BP) +47 52013922
Mobile +47 93041430
Lync +442034012640
Mail: Arild.Tysseland@no.bp.com
Office Address: BP Norge, Godesetdalen 8 4033 Forus

From: Jan Olav Berge (JOLBE) [mailto:jolbe@statoil.com]
Sent: 30 September 2012 09:26
To: Tysseland, Arild; Dove, Martin W
Cc: Kjell Edvard Apeland; Katrine Sandvik
Subject: Mardi Gras pipeline system

Hello,
Contacting you because I am searching for some data of the Mardi Gras pipeline system in GoM. The data will be used by a student doing the MSc project study on some deep water subsea tooling, and we are looking to use actual pipe data from a real system.
Do you have contact names or access to some data as pipe diameter, wall thickness, design pressure design temperature etc.?
Do you know if Les Owens (BP Houston) still are in business and in case his contact details?

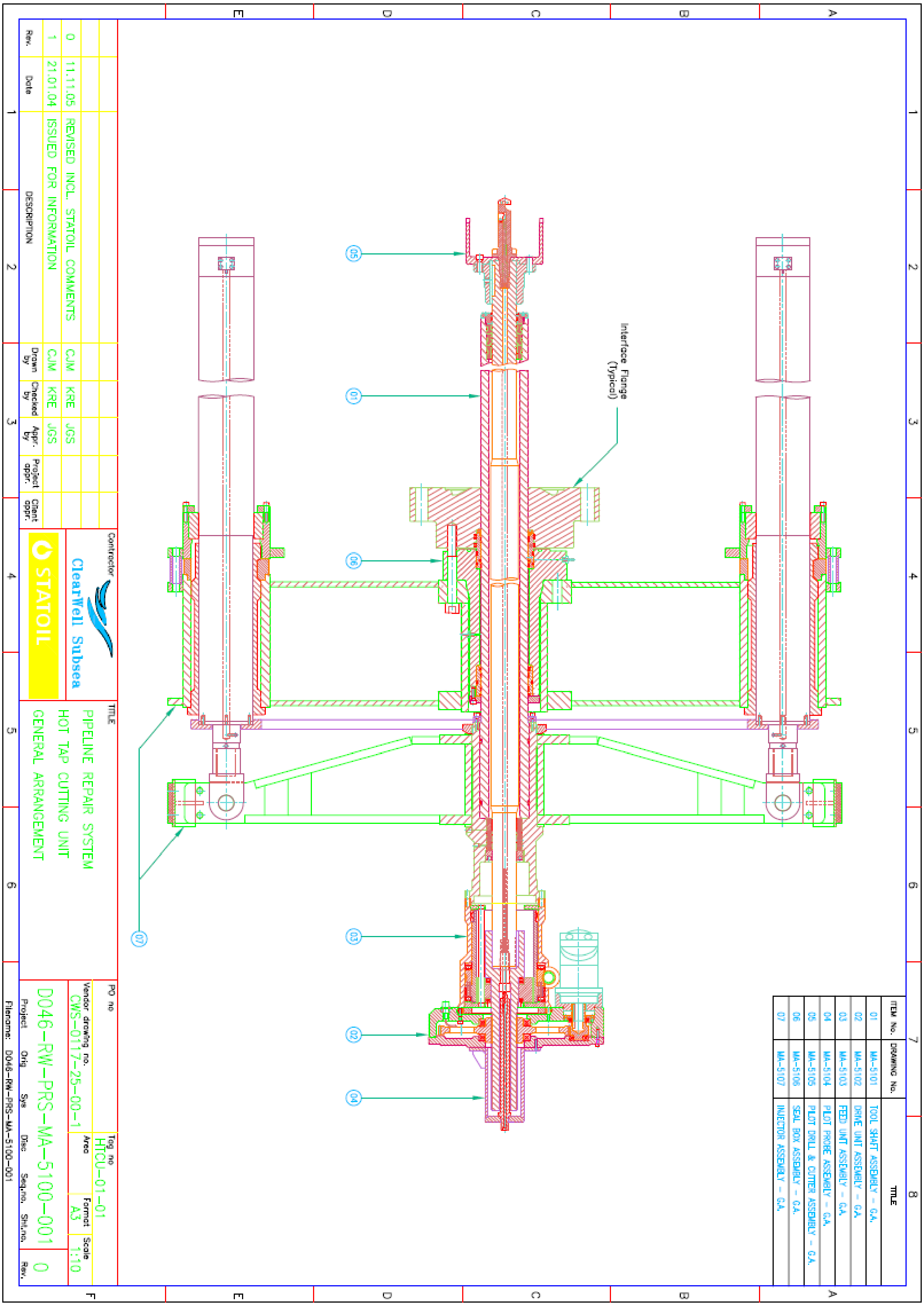
Best regards
Jan Olav

The information contained in this message may be CONFIDENTIAL and is intended for the addressee only. Any unauthorised use, dissemination of the information or copying of this message is prohibited. If you are not the addressee, please notify the sender immediately by return e-mail and delete this message.
Thank you

APPENDIX 11

PIPELINE REPAIR SYSTEM - HOT TAP CUTTING UNIT - GENERAL ARRANGEMENT

(01 pages)



Interface Flange (Typical)
Rev. | Date | DESCRIPTION | Drawn by | Checked by | Appr. by | Project appr. | Client appr.
0 | 11.11.05 | REVISED INCL. STATOIL COMMENTS | CJM | KRE | JGS
1 | 21.01.04 | ISSUED FOR INFORMATION | CJM | KRE | JGS
Contractor
ClearWell Subsea
STATOIL
TITLE
PIPELINE REPAIR SYSTEM
HOT TAP CUTTING UNIT
GENERAL ARRANGEMENT
PO no
Vendor drawing no. CWS-0117-25-00-1
Tag no HTCU-01-01
Format A3
Scale 1:10
D046-RW-PRS-MA-5100-001 0
Filename: D046-RW-PRS-MA-5100-001
ITEM No. | DRAWING No. | TITLE
01 | MA-5101 | TOOL SHAFT ASSEMBLY - G.A.
02 | MA-5102 | DRIVE UNIT ASSEMBLY - G.A.
03 | MA-5103 | FEED UNIT ASSEMBLY - G.A.
04 | MA-5104 | PILOT PROBE ASSEMBLY - G.A.
05 | MA-5105 | PILOT DRILL & CUTTER ASSEMBLY - G.A.
06 | MA-5106 | SEAL BOX ASSEMBLY - G.A.
07 | MA-5107 | INJECTOR ASSEMBLY - G.A.

APPENDIX 12

CLEARWELL INTERNATIONAL LIMITED MAIL CORRENSPONDANCE

(03 pages)

From: Keith Evans <kre@clearwellsubsea.com>
To: Katrine Sandvik <KSandvik@technip.com>,
Cc: Kjell Edvard Apeland <kjedap@statoil.com>
Date: 22.11.2012 15:34
Subject: RE: HTCU seals

Hi Katrine,

I have attached the HTCU General arrangement drawing as a basis for the following discussion re extension of the design envelope for the HTCU from 2,000m water depth to 3,000m water depth.

The HTCU Comprises a number of discrete sub systems which will be effected in different ways, the principle sub systems and effects are described below.

Tool Shaft Assembly (Item 1 - D046-RW-PRS-MA-5100-001)

All of the cavities within the tool shaft that sea external pressure are pressure compensated and would therefore be relatively immune from the external pressure effect provided that the internal pressure of the pipeline is always greater than the external pressure.

In the event that the external pressure is greater than internal pressure, i.e. the pipeline is depressurised below ambient, then some of the seals will sea reverse pressurisation. For the upper seal cartridges this will not be a problem, however for the lower cartridges this will present a problem because of the type and configuration of the seals.

Some modifications to the compensation system and the seal cartridges would be required as well as testing to prove the new configurations.

Any reverse pressurisation would also impose loading on the Tool Shaft Drive Shaft to Feed Unit interface which would require modification of the Drive Shafts both in the Tool Shaft and Feed Units.

Drive Unit Assembly (Item 2 - D046-RW-PRS-MA-5100-001)

All of the cavities within the drive unit that sea external pressure are pressure compensated and would therefore be completely immune from the external pressure effect.

The only area that might effect the Drive Unit would be possible modification of the Feed Unit Drive Shaft that would lead to a potential redesign of the main drive gear within the Drive Unit.

Feed Unit Assembly (Item 3 - D046-RW-PRS-MA-5100-001)

All of the cavities within the feed unit that sea external pressure are pressure compensated and would therefore be immune from the external pressure effect provided.

As for the Tool Shaft any reverse pressurisation would also impose loading on the Tool Shaft Drive Shaft to Feed Unit interface which would require modification of the Drive Shafts both in the Tool Shaft and Feed Units.

Pilot Probe Assembly (Item 4 - D046-RW-PRS-MA-5100-001)

The Pilot probe assembly supplies hydraulic pressure to the pilot drill piston via a port through the tool shaft drive shaft. Re-qualification of the dynamic seals between the pilot probe and the tool shaft seal cartridge will be required. If the seals are out with their PV values then some redesign will be required.

Cutter and Pilot Drill Assemblies (Item 5 - D046-RW-PRS-MA-5100-001)

The hydraulic cavities within the Pilot drill piston area will be compensated by the pilot drill circuit after actuation, some screening for reverse pressure on the piston in a pressure locked position will be required.

All of the cavities within the feed unit that sea external pressure are pressure compensated and would therefore be immune from the external pressure effect provided.

Seal Box Assembly (Item 6 - D046-RW-PRS-MA-5100-001)

The all but one of the inter seal cavities are compensated, subject to a detailed review there should be no significant issues with the seals in the seal box.

Injector Assembly (Item 7 - D046-RW-PRS-MA-5100-001)

Some modification of the control circuit for the injector assembly cylinders may be required to compensate the cylinder bodies during decent and also to ensure that trapped pressure does not over pressure the cylinders on recovery.

General Note.

Some if the system instrumentation is specialist and only has a depth rating of 2,000m at present, it may be possible to extend this through testing but a detailed review will be required to determine if these items can withstand the pressure at 3,000m.

I hope the above information is sufficient, if not please let me know.

Kind Regards – Keith Evans

Siri Permenant Caisson Repair – Facilities Manager Aberdeen

Tel: 01224 527097
Mob: 07710 871997

APPENDIX 13

LARS1 USED FOR 3000 MSW OPERATION

(04 pages)

LARS1 used for 3000 MSW operation

Assume that the LARS1 arrangement is similar as current system. Current umbilical is replaced with a new umbilical 3200 m, similar technical data. The conditions are ideal, so the physical limitation could be neglected (temperature, inductive and capacitive effect, harmonic interference, voltage variation and frequency).

PIF + HTCU power consumption

HPU #1 = 20 kW

HPU #2 = 15 kW

Control system max = 3 kW

= 38 kW

Design surplus capacity + 20%:

= 45.6 kW

LARS umbilical data:

Umbilical resistance pr. 1000m	= 52 Ω/mres
Number of mres pr. Phase	= 3 piece
Umbilical length	= 3200 m
Umbilical voltage	= 3.3 kV
Numbers of phases	= 3 piece

LARS tether data:

Tether resistance pr. 1000 m	= 2.4 Ω/mres
Number of wires pr. Phase	= 2 piece
Tether length	= 250 m
Tether voltage	= 1 kV
Number of phases	= 3 piece

Calculations:

Convert active power for PIF + HTCU to current use for umbilical as well as tether.

Active power:

PIF+HTCU = $P_{PIF+HTCU}$ = 45.6 kW

$$P_{PIF+HTCU} = \sqrt{3} * V * I * \cos 6$$

$\sqrt{3}$ = 3 phase

V = Transfer voltage

I = Transfer current

$\cos 6$ = Phase difference between current & voltage

$$\cos 6 = \Theta_v - \Theta_i$$

Θ_v = phase voltage

Θ_i = phase current

Assume $\cos 6 = 0.9$ (Normative figure)

Umbilical current:

$$I_{umb} = \frac{P_{PIF+HTCU}}{\sqrt{3} * V_{umb} * cos6}$$

$$= \frac{P_{PIF+HTCU}}{\sqrt{3} * 3.3kV * 0.9}$$

$$= 8.86\ A$$

Tether current:

$$I_{tether} = \frac{P_{PIF+HTCU}}{\sqrt{3} * V_{tether} * cos6}$$

$$= \frac{P_{PIF+HTCU}}{\sqrt{3} * 1kV * 0.9}$$

$$= 29.25\ A$$

Umbilical total resistance pr. phase:

$$R_{umb_{phase}} = R_{umb_{ph1}} \parallel R_{umb_{ph2}} \parallel R_{umb_{phase}}$$

$$\frac{1}{R_{umb_{phase}}} = 3 * \frac{1}{R_{umb}} = 3 * \frac{1}{5.2\Omega/km} = \frac{15}{26} km/\Omega$$

$$R_{umb_{phase}} = \frac{26}{15} \Omega/km$$

$$R_{umb_{total}} = 3.2km * \frac{26}{15} \Omega/km = 5.55\Omega$$

Tether total resistance pr- phase:

$$R_{tether_{phase}} = R_{tether_{ph1}} \parallel R_{tether_{ph2}} \parallel R_{tether_{phase}}$$

$$\frac{1}{R_{tether_{phase}}} = 2 * \frac{1}{R_{tether}} = 2 * \frac{1}{2.4\Omega/km} = \frac{5}{6} km/\Omega$$

$$R_{tether_{phase}} = \frac{5}{6} \Omega/km$$

$$R_{tether_{total}} = 0.25km * \frac{6}{5} \Omega/km = 0.3\Omega$$

Voltage loss umbilical:

$$U_{loss\ umb} = I_{umb} * R_{umb} = 8.86A * 5.55\Omega$$

$$\underline{= 49.17V}$$

Umbilical voltage = 3.3 kV

Voltage loss: $\frac{49.17V}{3300V} = 0.0149 \sim 1.49\ \%$

Give a 1.49 % voltage loss which is with-in acceptance criterion of 3 %.

Voltage loss tether:

$$U_{loss\ tether} = I_{tether} * R_{tether} = 29.25A * 0.3\Omega$$

$$\underline{= 8.78V}$$

Tether voltage = 1 kV

Voltage loss: $\frac{8.78V}{1000V} = 0.00878 \sim 0.88\ \%$

Give a 0.88 % voltage loss which is with-in acceptance criterion of 3 %.

APPENDIX 14

ROV UMBILICAL AND DECK CABLE FOR DEEP OCEAN

(06 pages)

Nexans

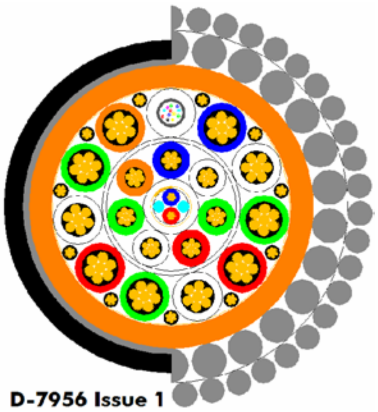
Technical Description

ROV UMBILICAL & DECK CABLE
FOR
DEEP OCEAN

Document no.: RS429

Unit content:

UNIT-P4	Power conductor, 4mm^2, 3.3kV	10 off
UNIT-P1.5	Power conductor, 1.5mm^2, 3.3kV	7 off
UNIT-SP	Screened Pair, 0.35mm^2	1 off
UNIT-FO	Fibre Optic element, 6MM+6SM	1 off



Material description:

Gs(6+6)+ 10x4mm^2+ 7x1.5mm^2+ A1-0.35mm^2 FMV–RP2.8/2.0

Gs(6+6)+ 10x4mm^2+ 7x1.5mm^2+ A1-0.35mm^2 FMBP

Material no.:

Tender no.:

Contract no.:

01T	05.09.05	Issued for Tender	LOM	ANK	IJV
Issue no.	**Date**	**Document status**	**Prepared by**	**Approved by**	**Released by**

Revision / Status Coding:

Issued for Tender	XXT	Issued for Company Comment (Review)	XXR
Issued for DIC / IDC (Draft)	XXD	Approved for Construction	XXE
		As-Built	XXA

Nexans Norway AS, P.O. Box 6450 Etterstad, N-0605 Oslo, Norway

1. SCOPE

This document describes an ROV Umbilical and Deck Cable designed for Deep Ocean.

NOTE: Cable handling and installation shall be performed in accordance with latest revision of Nexans guidelines (see section 2. REFERENCES).

2. REFERENCES

Document:	Document title:
NeNo-TR-01-01 Issue 8	*Handling / Installation guidelines for dynamic cables.*

3. CABLE DESIGN

3.1 Element Details

Process/ Material		**Nom. Thickness (mm)**	**Nom. Outer Diameter (mm)**
UNIT-P4	**Power conductor, 4mm^2, 3.3kV**		
Conductor	Cu, 4mm^2	7x0.88	2.5
Insulation	Semiconducting polypropylene Insulating polypropylene, colour coded		4.0
UNIT-P1.5	**Power conductor, 1.5mm^2, 3.3kV**		
Conductor	Cu, 1.5mm^2	7x0.525	1.55
Insulation	Semiconducting polypropylene Insulating polypropylene, colour coded		3.0
UNIT-SP	**Screened Pair, 0.35mm^2**		
Conductor	Cu, 0.35mm^2	7x0.25	0.75
Insulation	Polypropylene, colour coded		1.4
Filling	Solid filler and petroleum jelly		
Wrapping	Polyester tape		2.9
Screen	Drain wires + Al/polyester laminate	8x0.2	3.2
Sheath	Polypropylene, natural		4.5
UNIT-FO	**Fibre Optic element**		
Optical fibre	6MM (50/125µm) + 6SM (9/125µm)		0.25
Tube	Steel tube with filling compound	0.2	2.3
Sheath	Polypropylene, natural		4.0

3.2 Element Lay-up

Process/ Material		**Nom. Thickness (mm)**	**Nom. Outer Diameter (mm)**
Centre	UNIT-SP, 0.35mm^2, 1 off		4.5
1st layer			
UNIT-P1.5	Power conductor, 1.5mm^2, 7 off	3.0	10.5
Filling	Soft adhesive filling compound		
Wrapping	Build-up tape		11.2
2nd layer			
UNIT-P4	Power conductor, 4mm^2, 10 off	4.0	19.2
UNIT-FO	Fibre Optic element, 1 off	4.0	19.2
Filling	Soft adhesive filling compound		
Screen	Semicond. insul. 0.5mm^2 Cu, 11 off Cu/polyester laminate	1.2	19.4
Sheath	Thermoplastic polyester		23.0
UMBILICAL			
Armouring			
1st layer	Steel wires, 26 off	2.8	28.6
Filling	RBFC (interstices partly filled)		
2nd layer	Steel wires, 43 off	2.0	32.6
DECK CABLE			
Armouring	0.2mm galv. steel tape, 2 layers Outer tape covers the gap of the inner. Average gap less than 20%		24.0
Outer sheath	PVC, flame retardant, black	1.5	27.0

3.3 Characteristics

Physical Characteristics	Unit	Nominal value	±
UMBILICAL			
Cable outer diameter	mm	32.6	1
Weight in air, approx.	kg/m	3.5	
Weight in seawater, approx.	kg/m	2.7	
Minimum dynamic bending diameter	mm	1000	
Armouring breaking strength	kN	490	
Safe working load	kN	130	
DECK CABLE			
Cable outer diameter	mm	27.0	1
Weight in air, approx.	kg/m	1.3	
Weight in seawater, approx.	kg/m	NA	
Minimum dynamic bending diameter	mm	1000	
Armouring breaking strength	kN	NA	
Safe working load	kN	1	

Electrical / Optical Characteristics (target values)	Unit	Nominal value	±
UNIT-P4 Power conductor, 4mm^2, 3.3kV			
DC resistance, max	Ω/km	5.2	
Insulation resistance @ 500 V DC	GΩ·km	>5	
HV test for 5 min.: Conductor - screen	kV DC	11	
UNIT-P1.5 Power conductor, 1.5mm^2, 3.3kV			
DC resistance, max	Ω/km	13.4	
Insulation resistance @ 500 V DC	GΩ·km	>5	
HV test for 5 min.: Conductor - conductor	kV DC	16	
UNIT-SP Screened Pair, 0.35mm^2			
DC loop resistance, max	Ω/km	112	
Mutual capacitance	nF/km	75	5
Insulation resistance @ 500 V DC	GΩ·km	>5	
HV test for 10 sec.: Conductor - conductor	kV DC	2.5	
HV test for 10 sec.: Conductor - screen	kV DC	2.0	

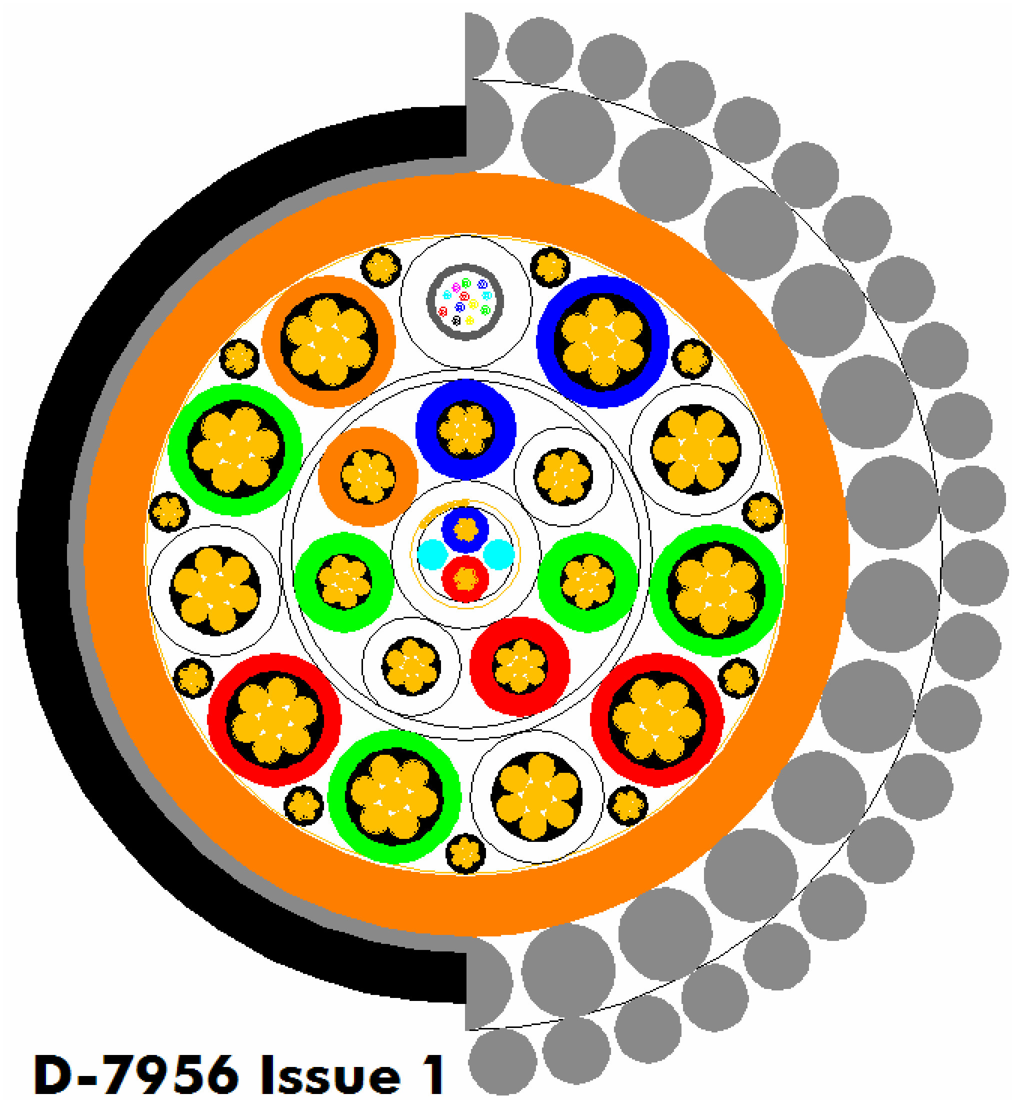
Electrical / Optical Characteristics (target values)	Unit	Nominal value	±
UNIT-FO Fibre Optic element			
MULTIMODE FIBRE:			
Attenuation @ 850nm	dB/km	<4.0	
Attenuation @ 1300nm	dB/km	<1.5	
Bandwidth @ 850nm *)	MHz·km	400	
Bandwidth @ 1300nm *)	MHz·km	600	
SINGLEMODE FIBRE:			
Attenuation @ 1310nm	dB/km	<0.6	
Attenuation @ 1550nm	dB/km	<0.4	
Dispersion @ 1310nm *)	ps/nm·km	<5	
Dispersion @ 1550nm *)	ps/nm·km	<20	

*) Not measured during manufacturing.

3.4 Cable Marking

Element	Marking
UNIT-P4	First conductor: Blue Alternating: White, green, red, white,… Last conductor: Orange
UNIT-P1.5	First conductor: Blue Alternating: White, green, red, white,… Last conductor: Orange
UNIT-SP	Conductor #1-#2: Blue, red Each pair identified with longitudinal numbering tape.
UNIT-FO	Natural — 6MM fibres: **With no rings:** Red, green, blue, yellow, white, natural 6SM fibres: **With two rings every 25mm:** Red, green, blue, yellow, white, natural
SHEATH	<Production order no.> Nexans Norway High Voltage <year>, <meter>

4. CROSS-SECTIONAL DRAWING



5. AMENDMENT LIST

Issue No.	Date	Amendments
01T	05.09.05	First edition (based on RS065-1E, 10042082).

APPENDIX 15

MAIL CORRESPONDENCE JAHN NAKKESTAD

(01 page)

From:	Jahn Nakkestad/NORWAY
To:	Katrine Sandvik/NORWAY@TPGROUP,
Date:	21.11.2012 14:33
Subject:	Skandi Arctic 3000 msw

Katrine

Det er mulighet for 3000 m wirelengde på main crane og ROV winch. Vi er usikker på 50 tonns krana. Dette må vurderes av kranleverandør.

Med hilsen

Jahn Erling Nakkestad
Project Manager & Diving Technical Manager

Technip Norge AS - Jåttåvågveien 7 - 4020 Stavanger - Norway - www.technip.com
Tel (Direct) +47 67 58 87 23 - Switchboard +47 67 58 85 00 - Mobile: +47 48 08 87 23

APPENDIX 16

MAIL CORRENSPONDENCE KYSTDESIGN AS

(01 page)

From: Knut Ståle Storesund <storesund@kystdesign.no>
To: "'Katrine Sandvik'" <KSandvik@technip.com>,
Date: 12.11.2012 09:16
Subject: SV: SV: SV: SV: ROV

Hei

Se nedenfor.

Mvh
Ståle

Knut Ståle Storesund
Mob.: +47 97 51 61 91
Dir: +47 52 70 62 52
K Y S T D E S I G N AS

Fra: Katrine Sandvik [mailto:KSandvik@technip.com]
Sendt: 12. november 2012 08:04
Til: Knut Ståle Storesund
Emne: Re: SV: SV: SV: ROV

Hei igjen Knut Ståle,

Jeg har noen flere spørsmål når det gjelder ROV.

På 3000 m, blir det gjort noe spesielt med tanke på temperatur? Det er vel ikke mer enn +/- 0 grader.
Pleier ikke være et problem. Bruk rett type olje.

Brukes det noe spesielt med tanke på sikt på en slik dybde? Sonar?
Nei, det er mørkt om natten også. ☺
Akustisk posisjonering blir dårligere. Noen systemer har doppler og INS for å få mer korrekt posisjonering.
Det tar lang tid å komme ned el opp.

Håper du kan hjelpe :)

Katrine Sandvik
Senior Engineer - Subsea Intervention

Technip Norge AS - Killingøy - 5515 Haugesund - Norway - www.technip.com
Tel (Direct) +47 67 20 26 10 - Switchboard +47 67 58 85 00

APPENDIX 17

TECHNOLOGY READINESS LEVEL (TRL)

(01 page)

Level	Development stage	Hardware development
TRL 0	Unproven idea/proposal	Paper concept. No analysis or testing has been performed
TRL 1	Concept demonstrated	Basic functionality demonstrated by analysis, reference to features shared with existing technology or through testing in individual subcomponents/subsystems. Shall show that the technology is likely to meet specified objectives with additional testing
TRL 2	Concept validated	Concept design or novel features of design validated through model or small scale testing in laboratory environment. Shall show that the technology can meet specified acceptance criteria with additional testing.
TRL 3	New technology tested	Prototype built and functionality demonstrated through testing over a limited range of operating conditions. These tests can be done on a scaled version if scalable.
TRL 4	Technology qualified for first use	Full-scale prototype built technology qualified through testing in intended environment, simulated or actual. The new hardware is now ready for first use.
TRL 5	Technology integration tested	Full-scale prototype built and integrated into intended operating system with full interface and functionality tests
TRL 6	Technology installed	Full-scale prototype built and integrated into intended operating system with full interface and functionality test program in intended environment. The technology has shown acceptable performance and reliability over a period of time.
TRL 7	Proven technology	Technology integrated into intended operating system. The technology has successfully operated with acceptable performance and reliability within the predefined criteria.

APOS K-32642, Technology Readiness Level (TRL) [1]