Standardizing Subsea Pumping Systems to reduce Lifecyle Costs

Perth

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09/10/2019

Woodside

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Notes on Petroleum Resource Estimates

Unless otherwise stated, all petroleum resource estimates are quoted as at the balance date (i.e. 31 December) of the Reserves Statement in Woodside's most recent Annual Report released to ASX and available at http://www.woodside.com.au/Investors-Media/Announcements, net Woodside share at standard oilfield conditions of 14.696 psi (101.325 kPa) and 60 degrees Fahrenheit (15.56 deg Celsius). Woodside is not aware of any new information or data that materially affects the information included in the Reserves Statement. All the material assumptions and technical parameters underpinning the estimates in the Reserves Statement continue to apply and have not materially changed.

Woodside reports reserves net of the fuel and flare required for production, processing and transportation up to a reference point. For offshore oil projects and floating LNG (FLNG) projects, the reference point is defined as the outlet of the floating production storage and offloading (FPSO) or FLNG facility, while for the onshore gas projects the reference point is defined as the inlet to the downstream (onshore) processing facility.

Woodside uses both deterministic and probabilistic methods for estimation of petroleum resources at the field and project levels. Unless otherwise stated, all petroleum estimates reported at the company or region level are aggregated by arithmetic summation by category. Note that the aggregated Proved level may be a very conservative estimate due to the portfolio effects of arithmetic summation.

'MMboe' means millions (10^6) of barrels of oil equivalent. Dry gas volumes, defined as 'C4 minus' hydrocarbon components and non-hydrocarbon volumes that are present in sales product, are converted to oil equivalent volumes via a constant conversion factor, which for Woodside is 5.7 Bcf of dry gas per 1 MMboe. Volumes of oil and condensate, defined as 'C5 plus' petroleum components, are converted from MMbbl to MMboe on a 1:1 ratio.

Unless otherwise stated all petroleum resource estimates refer to those estimates set out in the Reserves Statement in Woodside's most recent Annual Report released to ASX and available at http://www.woodside.com.au/Investors-Media/Announcements. Woodside is not aware of any new information or data that materially affects the information included in the Annual Report. All the material assumptions and technical parameters underpinning the estimates in the Annual Report continue to apply and have not materially changed.

The estimates of petroleum resources are based on and fairly represent information and supporting documentation prepared by qualified petroleum reserves and resources evaluators. The estimates have been approved by Mr Ian F. Sylvester, Woodside's Vice President Reservoir Management, who is a full-time employee of the company and a member of the Society of Petroleum Engineers. Mr Sylvester's qualifications include a Master of Engineering (Petroleum Engineering) from Imperial College, University of London, England, and more than 20 years of relevant experience.

Subsea Processing JIP – Standardization of subsea pumping

Background:

- Enabler for increased oil recovery
- Considerable potential for subsea boosting
- Challenging to get subsea boosting projects sanctioned

Project objective:

- reduce cost in a lifetime perspective
- contribute to more subsea pumping projects

DNV·GL

Participants

Suppliers

AkerSolutions

BAKER HUGHES a GE company

OneSubsea A Schlumberger Company

TechnipFMC

Operators

Shell

equinor

Woodside

PETROBRAS

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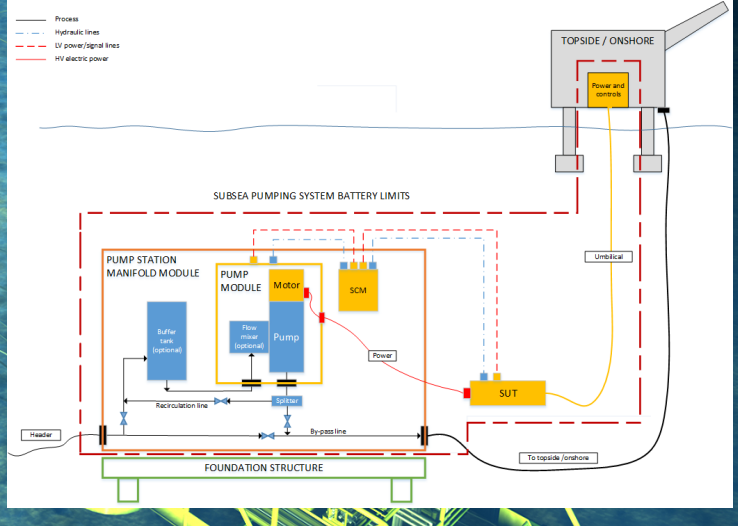
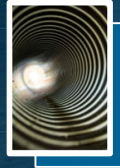
DNVGL-RP-F303 Subsea pumping systems

- Normative and informative technical requirements for the whole subsea pumping system
- Scope:
  - Single phase/hybrid/multiphase
  - 15 kpsi, 3000 m
  - pump station, processing system, SPS, water injection and dual lift



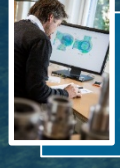
DNVGL-RP-F303 Subsea pumping systems



Section 1
General information

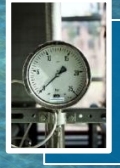
Section 2
Subsea pumping systems overview

Section 3
Technical requirements

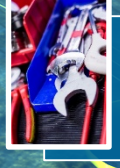


Section 4
Technology Qualification

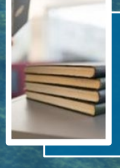
Section 5
Product Quality Management



Section 6
Testing of delivery units



Section 7
Intervention and maintenance



Section 8
Documentation

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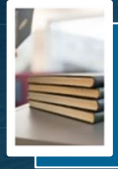
DNVGL-RP-F303 Subsea pumping systems



Appendix A
Normative references organized per discipline area

Appendix B
Relation between API RP 17X and DNVGL-RP-F303

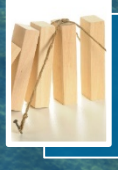
Appendix C
Mechanical Interfaces

Appendix D
Umbilical Configurations

Appendix E
Flow Diagrams

Appendix F
Design guidelines for subsea pressure containing parts

Appendix G
Guidance to DNV GL marine operations standards



Appendix H
Quality management and risk assessment

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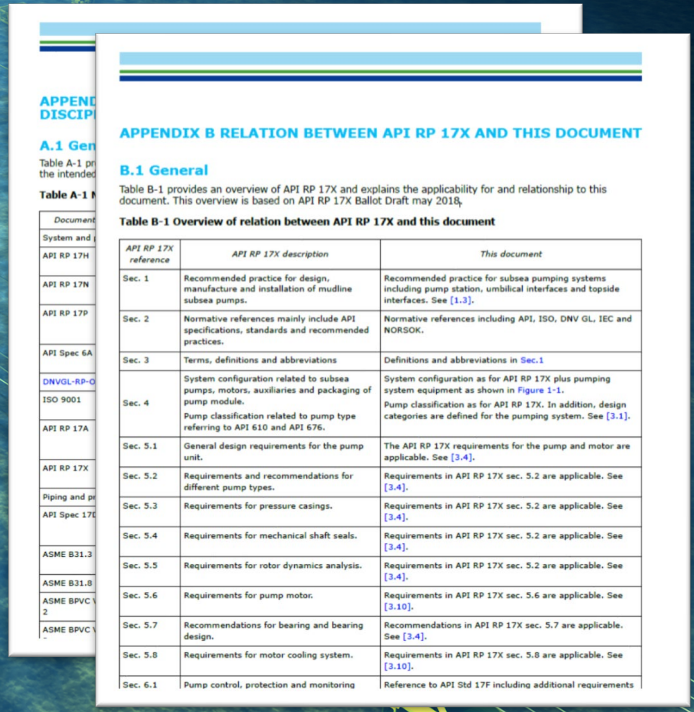
Complement to existing industry standards

- Standards mapped for following discipline areas:
  - System and process
  - Piping and pressure containing components
  - Subsea structures
  - Control systems
  - Materials and welding
  - Electrical power system
- Detailed mapping of API RP 17X ballot May 2018
  - API RP 17X – Subsea pump module systems



APPENDIX B RELATION BETWEEN API RP 17X AND THIS DOCUMENT

B.1 General

Table B-1 provides an overview of API RP 17X and explains the applicability for and relationship to this document. This overview is based on API RP 17X Ballot Draft may 2018.

Table B-1 Overview of relation between API RP 17X and this document

API RP 17X reference	API RP 17X description	This document
Sec. 1	Recommended practice for design, manufacture and installation of mudline subsea pumps.	Recommended practice for subsea pumping systems including pump station, umbilical interfaces and topside interfaces. See [1.3].
Sec. 2	Normative references mainly include API specifications, standards and recommended practices.	Normative references including API, ISO, DNV GL, IEC and NORSOK.
Sec. 3	Terms, definitions and abbreviations	Definitions and abbreviations in Sec.1
Sec. 4	System configuration related to subsea pumps, motors, auxiliaries and packaging of pump module. Pump classification related to pump type referring to API 610 and API 676.	System configuration as for API RP 17X plus pumping system equipment as shown in Figure 1-1. Pump classification as for API RP 17X. In addition, design categories are defined for the pumping system. See [3.1].
Sec. 5.1	General design requirements for the pump unit.	The API RP 17X requirements for the pump and motor are applicable. See [3.4].
Sec. 5.2	Requirements and recommendations for different pump types.	Requirements in API RP 17X sec. 5.2 are applicable. See [3.4].
Sec. 5.3	Requirements for pressure casings.	Requirements in API RP 17X sec. 5.2 are applicable. See [3.4].
Sec. 5.4	Requirements for mechanical shaft seals.	Requirements in API RP 17X sec. 5.2 are applicable. See [3.4].
Sec. 5.5	Requirements for rotor dynamics analysis.	Requirements in API RP 17X sec. 5.2 are applicable. See [3.4].
Sec. 5.6	Requirements for pump motor.	Requirements in API RP 17X sec. 5.6 are applicable. See [3.10].
Sec. 5.7	Recommendations for bearing and bearing design.	Recommendations in API RP 17X sec. 5.7 are applicable. See [3.4].
Sec. 5.8	Requirements for motor cooling system.	Requirements in API RP 17X sec. 5.8 are applicable. See [3.10].
Sec. 6.1	Pump control, protection and monitoring	Reference to API Std 17F including additional requirements

Technical design requirements

RP contains design **requirements** not already covered in other standards.

3.3.3.3 Temperature

a) Maximum design temperature shall consider the highest process fluid temperature that can be achieved from combination of pump suction temperature and temperature increase across the pump, considering all modes of operation, including maximum recycle flow.

3.3.3.4 Bypass

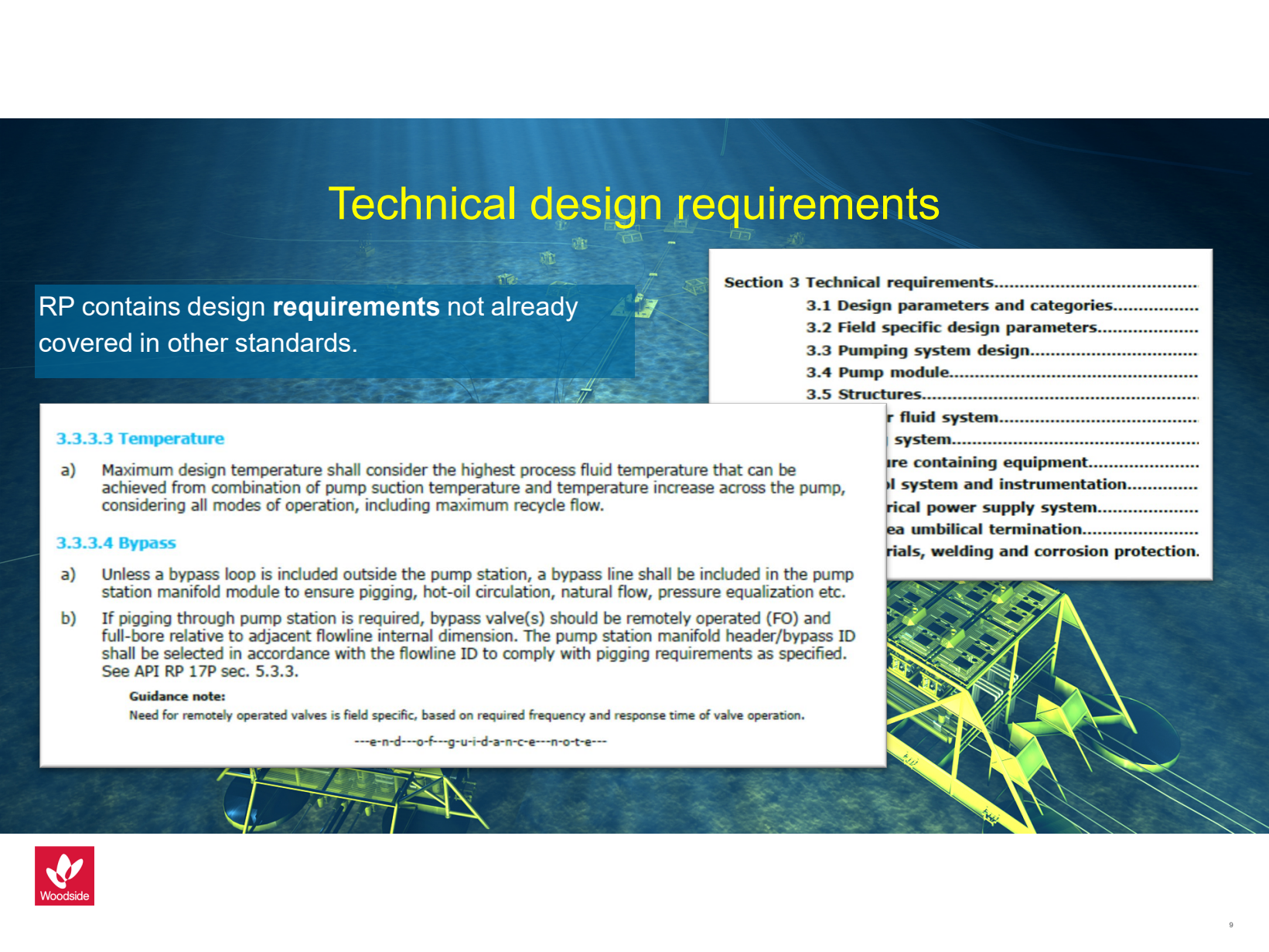
a) Unless a bypass loop is included outside the pump station, a bypass line shall be included in the pump station manifold module to ensure pigging, hot-oil circulation, natural flow, pressure equalization etc.

b) If pigging through pump station is required, bypass valve(s) should be remotely operated (FO) and full-bore relative to adjacent flowline internal dimension. The pump station manifold header/bypass ID shall be selected in accordance with the flowline ID to comply with pigging requirements as specified. See API RP 17P sec. 5.3.3.

Guidance note:

Need for remotely operated valves is field specific, based on required frequency and response time of valve operation.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---



Minimum instrumentation requirements

- Mandatory or optional
- Criticality, redundancy and retrievability

No.	Designation	Instrument description	Location	Instrument function	Criticality rating	Mandatory	Optional
1	PT	Pump inlet pressure transmitter	PMod	Monitoring of pump inlet pressure	2	X	
2	TT	Pump inlet temperatur transmitter	PMod	Monitoring of pump inlet temperature	3		X
3	PT	Pump discharge pressure transmitter	PMod	Monitoring of pump discharge pressure	2	X	
4	TT	Pump discharge temperature transmitter	PMod	Monitoring of pump discharge temperature	2	X	
5	FT	Pump flowmeter	PMod	Monitoring of inlet flow to the pump.	2 (3)	X	
6	XT	Multiphase flowmeter	PSt	Monitoring of flow to the pump	3		X
7	ZT	Recycle control valve position transmitter	PSt	Monitoring of control valve position during recycle.	3	X	
				Monitoring of barrier fluid consumption to pump			

Defined subsea umbilical termination size categories

- SUT classes, for HV power connectors
  - Aligned with API 17 TR9 for control umbilical
- '70-80% solution' – project specific assessments still necessary

Category 1 (Cat C in API 17TR9)

- Max 3.5 m x 1.0 m x 1.0 m
- 1 pump
- Up to 12 kV HV connector

Category 2

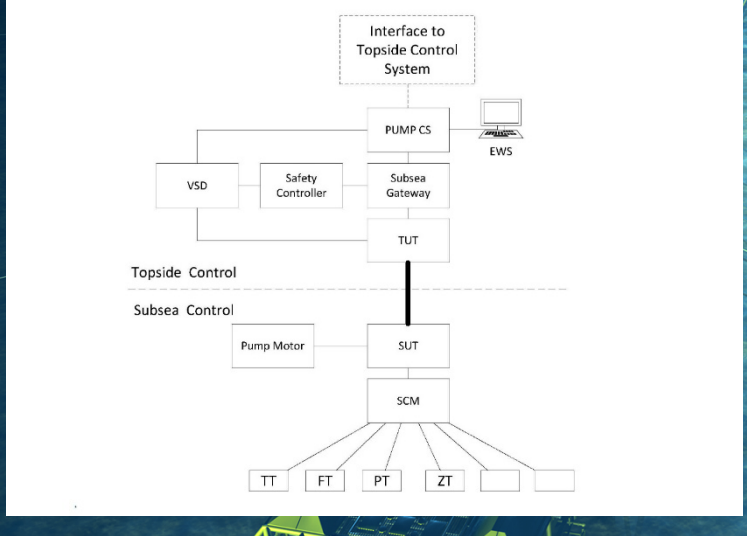
- Max 4.0 m x 1.4 m x 1.4 m
- 1-2 pumps
- Up to 12 kV HV connector

Category 3

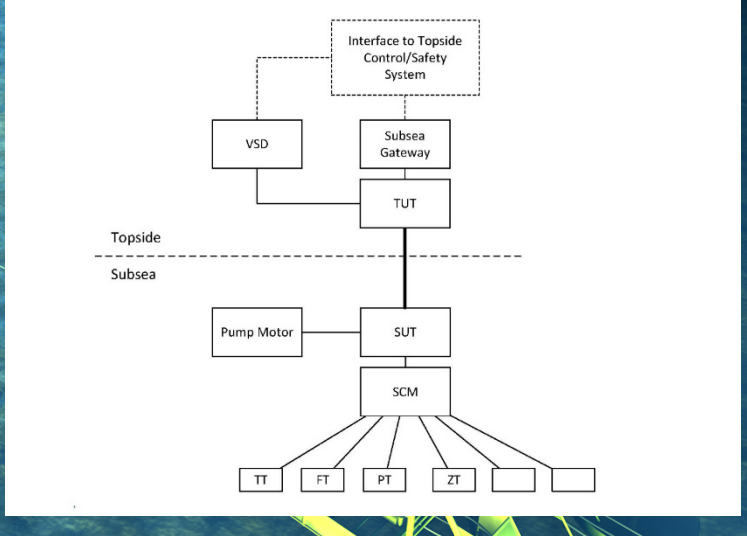
- No max. dimensions
- 1-2 pumps
- Up to 36 kV HV connector

Guidance on two alternative topologies

Dedicated pump control system



Pump control system included in topside DCS



Drive use of standard communication protocols

Topology with dedicated controller	
Communication link	**Recommended communication protocol**
Pump CS - EWS	Vendor specific *
Pump CS - VSD	Vendor specific *
Pump CS – DCS	MDIS OPC UA for green field **
SCM-Pump CS (Umbilical)	Vendor specific based on TCP/IP *
Sensor – SCM	SIIS ***

Topology with topside integrated control system	
Communication link	**Recommended communication protocol**
DCS- VSD	Open industrial standards *
SCM - DCS	Open industrial standards *
Sensor - SCM	SIIS ***

**) Based on recognized industrial standards such as Modbus RTU, RS-485, Industrial TCP/IP (Profinet, Modbus TCP/IP)*

**) MDIS OPC UA Companion Specification Release 1.0

***) 2016-12-14_SIIS_RP

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Increase re-use of technology qualification

RP contains guidance on how to:

- maximize re-use of qualified technology
- minimize project specific qualification
- document the qualification process
- define TRL 4 minimum qualification scope.

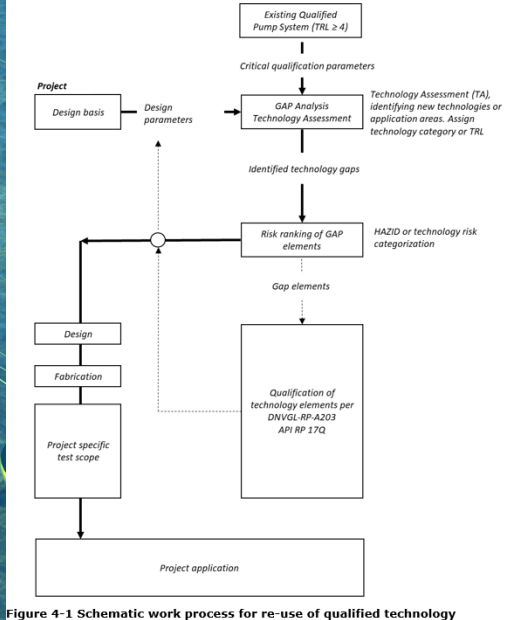
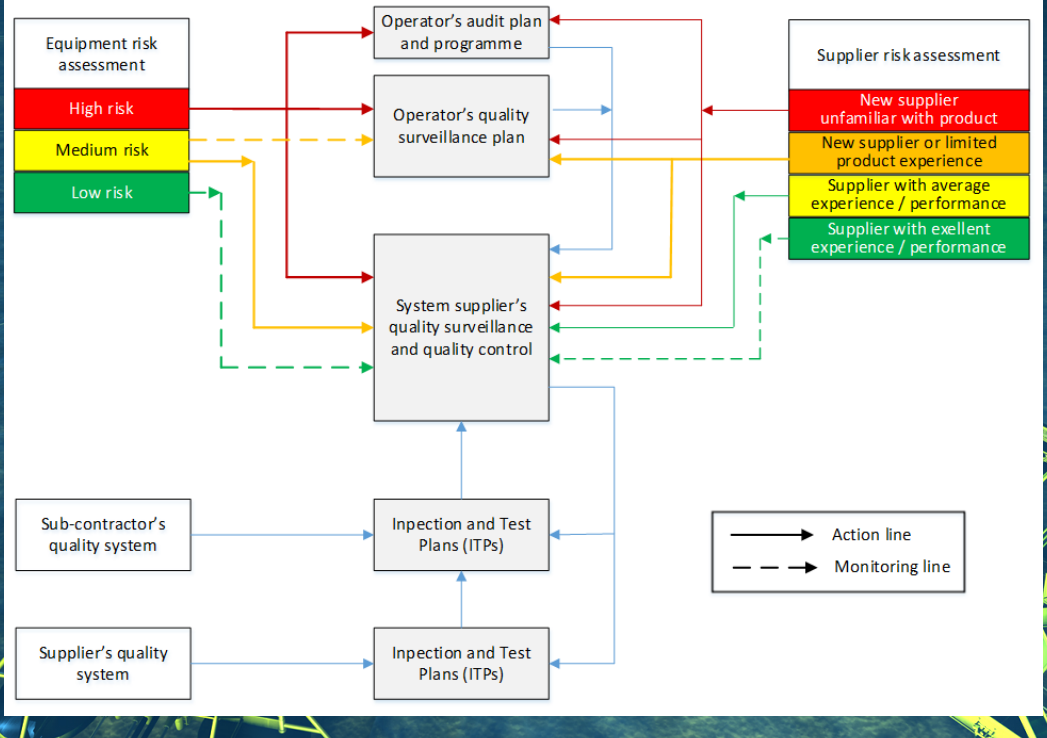


Figure 4-1 Schematic work process for re-use of qualified technology

Right level of quality surveillance activities



Minimum test requirements (TRL >=4)

- Pump unit - Performance Acceptance Test (PAT)
- Pump module - Factory Acceptance Test (FAT)
- Pump station manifold module - Factory Acceptance Test (FAT)
- Control system – Extended Factory Acceptance Test (EFAT)
- Pumping system Test (PST=SIT+SOT)
  - System Integration Test (SIT)
  - System Operation Test (SOT)

Table 6-3 Pump station manifold module - Factory Acceptance Test (FAT)

Test 3)	*Pump station manifold module - Factory Acceptance Test (FAT)*
Objective	Confirmation of pump station manifold module manufacturing and assembly per relevant specification and drawings
Object	Pump station manifold module, including all fixed equipment and components such as piping, connectors, valves, flow conditioning units, cathodic protection and steel structure
Scope	**Minimum test scope** - Large bore piping pressure testing, including components [1)] - Small bore piping pressure testing [1)] - Bonding/electrical continuity check, cathodic protection - Sensors harness function check - Weight, CoG and inclination verification - Dimensions and tolerances verification (overall and critical interface dimensions and tolerances)
Documentation	- FAT Procedure including test set-up - Drawings - Test report including test results - Weight certificate or report - Any witnessing (end user, 3rd party) reports
Notes	1) Test may be reduced to a leak test, if complete pressure testing has previously been performed for all the components and no rework or hot work (e.g. welding) has been carried out during or after assembly that may have affected pressure containment capacity

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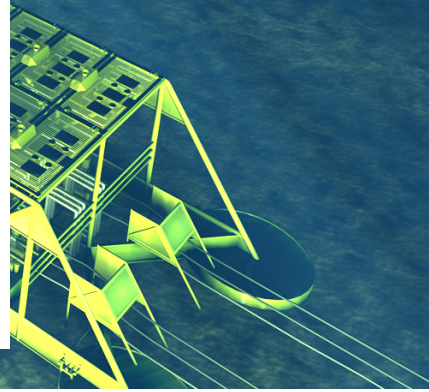
IMR philosophy and minimization of special tooling

33 intervention tasks and associated tools

- ST - Standard tooling
- ST(CU) - Standard Tooling – Custom made
- SP - Special tooling

No	*Task description*	*Tooling*	*Tooling category*	*Access requirements*	*Comment*
12	Pump station manifold - installation and retrieval of pressure cap on pump module up-facing hub - inlet side	Pressure cap installation tool - proprietary	ST(CU)	From top when pump module is retrieved	Pressure cap Installation/Retrieval tool is supplier specific
13	Pump station manifold - installation and retrieval of protection cap on pump module up-facing hub - inlet side	ROV manipulator	ST	From top when pump module is retrieved	



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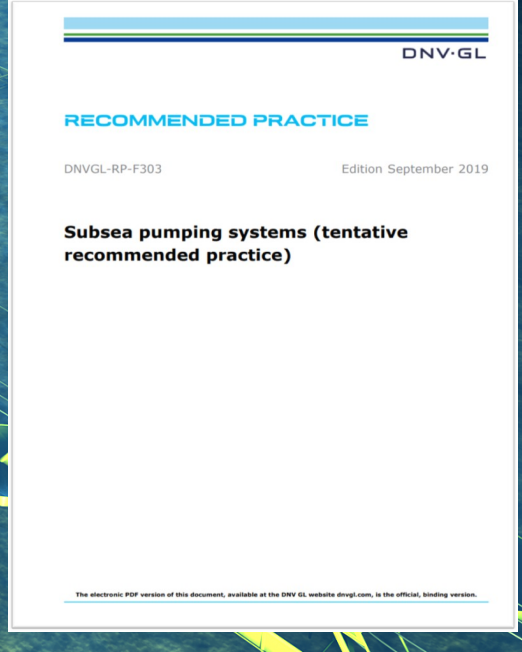
Guidance on technical documentation

Sub-system, assemblies and equipment function:	Design Report	Dispatch dossier	EFAT procedure	Electrical Schematics	Equipment Installation & Retrieval Procedure	FAT Procedure	Flow Schematic	Functional Design Specification	General Arrangement Drawing	Hydraulic Schematic
NOTES	N2	N8	N16			N3 N4		N9	N10	
SUBSEA PUMPING SYSTEM				O						
PUMP MODULE				X				X	O	O
Pump		●				●	X	X	●	
Motor	●	●		X		●		X	●	
Barrier Fluid System						●		X	●	
Flow mixer	●	●				●	X	X	●	
Mechanical Connector		●				●		X	●	
Piping assembly		●				●	X	X	●	
Small bore pipe assembly		●				●	X	X	●	●
Main load bearing structure	●	●				●		X	●	
Support Structure		●						X	●	
Process control valve						●	X	X	●	●
Control valve actuator		●		X		●		X	●	

Way forward

- Published Q3 2019
- Implementation of the document => real benefits in subsea pumping projects
- Give us feedback



Acknowledgements

- AkerSolutions
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- OneSubsea
- Petrobras
- Shell
- TechnipFMC
- Woodside

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Thank you / Questions

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