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COMMITTEE V.8

SUBSEA TECHNOLOGY

COMMITTEE MANDATE

Concern for the safety and reliability of subsea production systems for offshore oil and gas. This shall include subsea equipment for production and processing, flowlines and risers, with emphasis to design, fabrication, qualification, installation, inspection, maintenance, repair and decommissioning. Structural design for flow assurance and safe underwater operations shall be considered.

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CONTENTS

1. DISCUSSION

1.1 Official Discussion by Frank Lim

1.1.1 Introduction

The discusser would like to congratulate the committee chairman and distinguished members for putting together such a comprehensive report covering the subjects mentioned in the mandate and more.

The previous V.8 report published in 2015 was just on Risers and Pipelines, and this year the V.8 scope has been expanded to include other underwater systems and equipment, particularly those related to subsea production and processing which are new contents to the ISSC. Collectively, the materials have been given the title *Subsea Technology*.

The discusser expects the sub-section on Risers and Pipelines to focus on advances made in the last three years since 2015, but the subjects in the rest of the report can be more of an introductory nature and cover longer time periods as necessary.

For ease of reference, the following *Remark* sections are titled and sequenced the same way as in the main *Committee V.8* report.

1.1.2 Subsea Processing Equipment and Fabrication

Section 2 summarises some of the state-of-the-art subsea processing systems in operation and under development in recent years.

The concept of Subsea Factory is attractive as it will solve various flow assurance issues before they can happen, hence maximising productivity from the field. However, the challenges of placing the processing equipment on the seabed and providing power to operate them are quite significant. This is even compounded by the extra complication of needing to service the equipment (either subsea or by retrieval to the surface) to minimise production downtime.

The authors seem to have searched only publications in recent years, but since Subsea Processing is a new topic for ISSC, the discusser believes that the contents should cover some 'older' systems which are relevant. One example is Subsea Raw Water Injection (SRWI).

SRWI realises the retrofit in the seawater injection capabilities of facilities that would otherwise be unable to accommodate the increased infrastructure spending, and reduces the required hull size and the number of rises for floating production units. The term 'raw' refers to the fact that the water is not deoxygenated, which is generally less finely filtered and minimally chemically treated. A significant benefit brought by SRWI is the ability to place injection wells where they are most appropriate from a reservoir management perspective, rather than having their position dictated by available water injection riser & flowline positioning and routing options. Although SRWI provides a cost-effective alternative in comparison to regular seawater systems, mechanical reliability is still a concern. The first such system was installed by Canadian Natural Resources (CNR) International for their Columba E development in the Northern North Sea (SPE paper 109090, 2007, T.J.A. Laing).

The first all-electric Christmas tree was not installed in 2016 as stated in the last paragraph of Section 2.5. A pair of all-electric mudline trees was installed in 2008 at Total's K5-F field in the Dutch sector of the North Sea (OTC paper 25009, 2014, C. Mahler and R. Awo) and have been operating ever since.

Section 2.6 Material for Fabrication of Key Components is merely a summary of common or recommended practices regarding material selection and corrosion allowance, notably from NOSOK M-001, and they are not advances made in material technology in recent years.

Second line on Page 20: Should 'exiting' be 'existing'?

1.1.3 Flow Assurance of Subsea Production Engineering

This statement is made in Section 3.6 – Conclusions: ‘Flow assurance attracts more and more attention due to the harsh environment of subsea’. It would be more meaningful to say ‘Flow assurance becomes a more critical issue in increasing water depth surrounded by colder water temperature and longer step-out distance that allows transported fluids to cool down’.

1.1.4 Testing for Qualification of Subsea Production System

Section 4 starts with an outline of API RP 17Q which recommends that all subsea equipment are subjected to qualification to ensure they meet defined reliability, integrity and operational requirements, as well as API 17 RP 17N which defines eight Technology Readiness Levels (TRL) and Technical Risk Categorisation (TRC).

In the discusser’s opinion, although Testing may be necessary to prove or qualify certain technologies, it is a process not a technology itself!

Sections 4.2-4.5 describe four advanced testing programs. Since they are all related to subsea processing systems and nothing else, they should be moved to Section 2 where they belong.

What is left in Section 4 is then the recommended practices API RP 17N and 17Q. They should go to a new General or Miscellaneous Section where less but more important topics are put together under one umbrella.

There are two sub-sections numbered the same as 4.3.2.

1.1.5 Installation and Operations for Emergencies

There is a mismatch between the two quite different topics ‘Installation’ and ‘Operations for Emergencies’. They should have been divided into two separate sections.

In Section 5.1, common and certain special methods of installing subsea hardware are described. The so-called pencil buoy method in Section 5.1.4 is an imitation of the Heave Compensated Landing System (HCLS) patented by Shell but licensed to DELMAR, an US subsea construction company, to install subsea trees and manifolds.

Figure 1 shows the components of HCLS which is deployed from an inexpensive and commonly available anchor handling vessel (AHV). The AHV brings the subsea equipment to be installed over its intended seabed position, and lower/land it with very little heave motion by adjusting the amount of a weighted catenary chain to counter the buoyancy upthrust.

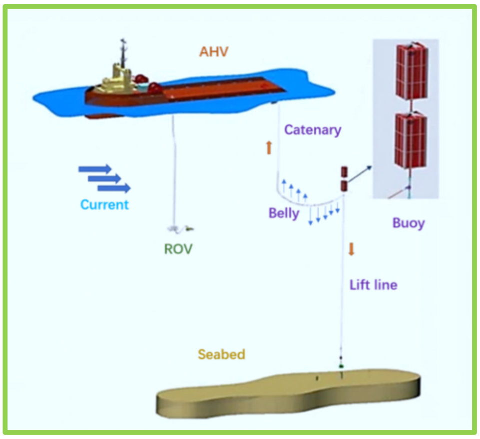

Figure 1: Heave Compensated Landing System

DELMAR first used the HCLS to install subsea trees in 2002 for Shell's Na Kika Development in Gulf of Mexico's Mississippi Canyon in a water depth slightly less than 3,000 m. The installation marked the first time a subsea tree was installed using an AHV. DELMAR has henceforth installed more than 200 subsea equipment using this method all over the world.

1.1.6 Inspection, Maintenance and Decommissioning of Subsea Systems

Again, there is a mismatch between the topics 'Inspection, Maintenance' and 'Decommissioning'. Inspection and Maintenance are commonly grouped with Repair as IMR to make sure things carry on working, and Decommissioning is 'destructive', i.e. taking things apart, opposite to 'Installation', and not quite making things work.

The current Section 5.4 'Responses to Pipeline Emergencies', which essentially describes pipeline repair methods, should be moved here to park under R of IMR.

Decommissioning deserves a section on its own.

1.1.7 Technologies for Hydrates and Other Subsea Resources

Section 7 describes some of the research work carried out in relation to the four well-known methods of dissociating gas and water in methane hydrates:

- Depressurisation
- Thermal Stimulation
- Chemical Inhibitor
- CO_2 - CH_4 Replacement

They are all R&D work of chemical processes to dissociate hydrates, which are not structural. This is understandable as gas production from methane hydrates is far from being ready and very little work is being done on the structural containment of the processes and the transportation of produced fluids. Therefore, the discusser questions the relevance to include these chemical process work in an ISSC report with an emphasis on structures.

An important work on methane hydrates extraction, which the report has omitted, and would have perhaps more structural implications is the method of Solid Fluidisation Production of Methane Hydrates proposed by China National Offshore Oil Corporation (CNOOC). This idea was presented at the 9th International Methane Hydrates R&D Workshop at Hyderabad in 2014, and updated at the recent Offshore Technology Conference in Houston after a successful offshore trial (OTC paper 28759, 2018, S. Zhou et al) in the South China Sea last year.

The main idea of this solid fluidization method is to extract and transfer the non-diagenetic methane hydrate sediments buried in shallow layer at deepwater seabed into a closed multiphase vertical transport system through mechanical crushing and fluidisation. During lifting from the seabed to surface, hydrates will dissociate slowly by the rise of seawater temperature and reduction of hydrostatic pressure in the safe containment of the riser, but the bulk separation of gas and water will be carried out in the controlled facilities on the surface vessel.

1.1.8 Risers, Pipelines and Umbilicals

Section 8 lists the outcome of literature search of academic work on risers, flowlines and umbilicals, but it fails to capture two significant industrial events that happen during the last three years which the report is supposed, more importantly, to capture:

- Realisation of non-metallic Thermal-plastic Composite Pipe (TCP) in real life oil & gas flowline field applications
- Emergence of Steel Lazy Wave Risers (SLWR) as the riser configuration of choice for deepwater developments where simple steel catenary riser (SCR) cannot meet the design requirements

It is exciting to learn that TCP, though long preferred and anticipated by the industry for its light weight and superior chemical/corrosion resistance properties, is finally receiving its well-deserved launch into the subsea hydrocarbons carrying capacity by a couple of forward thinking oil companies.

Figure 2 shows the typical cross section of a TCP: an inner fluid containing liner, an intermediate carbon composite strength enhancing layer and an outer environmental protection layer.

Airborne, a Dutch TCP supplier, has announced on their website that a 6-inch ID TCP flowline, 550m long, has been installed in 2017 for Petronas in Malaysia to transport crude oil.

Magma Global, an UK TCP supplier, has presented at the April 2018 MCE Deepwater Development Conference in Milan that 2-1/2-inch ID subsea jumpers have been installed by ENI for their Firenze field in the Adriatic Sea to overcome the very sour gas problem.

Figure 2: Thermal-plastic Composite pipes

Since Shell installed SLWRs for their Brazilian BC-10 FPSO development, the industry started to view SLWR as a viable choice to deepwater riser solutions with a track record justification, though many R&D papers have been published by various other parties beforehand over the past 20 years.

Figure 3 shows the SLWR configuration. Compared to simple SCRs, the arch bend created by buoyancy modules in a SLWR nearly decouples the platform motion from the touch down zone, thus reducing pipe/soil interactions which plaque the SCR designers. Payload on the platform is less and larger pipe diameter design can be accommodated in shallower water depth (MCE Deepwater Development Conference 2017, Amsterdam, R. Shankaran).

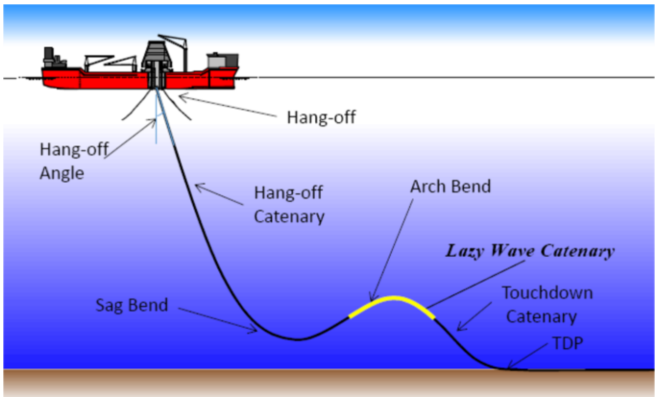

Figure 3: Steel Lazy Wave Riser Configuration

Although the installation procedure with buoyancy modules is complex, many operators are now considering SLWR as the base case for their riser design for a whole range of diameters, water depths and environments.

The only mention of academic research of SLWR in the ISSC V.8 report is wrongly placed under Section 8.5 Special Issues for Flexible Pipes and Umbilicals.

1.1.9 Reliability and Safety in Subsea System

Section 9 is a comprehensive summary of papers presented on risk and reliability assessment methods and case studies. However, the discusser considers that the disproportional mention of the work by Wang *et al*. (2014a, 2014b, 2014c and 2016) in this section is ill-judged. Wang's basis for the optimisation of the layout of subsea cluster manifolds was lowest cost, and it was barely related to reliability and let alone safety.

1.1.10 Conclusions and Recommendations

Suggest the opening statement 'Subsea production system (SPS) is a relatively new concept' should be changed to 'Compared to ship and platform structures and systems, SPS is relatively new'. SPS is no longer just a concept, it has been around for close to 60 years since the first subsea tree was installed in 1961.

1.2 Floor and Written Discussions

1.2.1 Q1: There is no structural concept for Natural Gas Hydrates (NGH). It is needed to extract a concept for production. Will this be taken into consideration by the committee? Could the committee respond to this written question?

1.2.2 Q2: What is the level to which industry is sharing information and knowledge in this committee?

1.2.3 Q3: Installation and inspection of structural components is discussed and covered in recommended practice but will this also include recommended practice for operations in the future?

1.2.4 Q4: Recommended practice for Thermoplastic Composite Pipe (TCP) has been recently published by DNVGL. Could any feedback be given on how good these rules are? What are the effects of recommended practices, particularly for different materials like TCP?

1.2.5 Q5: NGH exists in deep waters (deeper than 500 m); however, the reservoir depth from seafloor is shallower than conventional oil and gas (a few hundred metres). It means that geomechanical response is more significant than conventional oil and gas exploitation. In addition, past onshore and offshore field tests showed that water and sand management is a critical matter to be solved for continuous gas production. These NGH features indicate that low-cost and robust subsea technologies for drilling, gas-water-sand separation, and flow assurance will be required for NGH commercialisation. These subsea technologies are reviewed in the report; and I think that continuation of review and discussion are highly recommended for these subsea technologies from the view point of NGH exploitation.

2. REPLY BY COMMITTEE

2.1 Reply to Official Discusser

2.1.1 Introduction

The Committee appreciate the critical comments and suggestions from Prof. Frank Lim. For the current version of the report, more concerns are put into the overall progress of all aspects of subsea technologies related to oil & gas production.

Questions related to report organisation will not be addressed but the suggestion can be considered in a future committee.

2.1.2 Subsea Processing Equipment and Fabrication

Q1: *The Subsea Factory concept is attractive but*

- *Challenges of placing processing equipment on seabed and providing power to operate them are significant.*
- *Complication of needing to service the equipment.*

R1: Statoil has successfully deployed subsea pumps and subsea separators (Troll Pilot and Tordis) (Radicioni et al., 2016) including the world's first subsea compressors at both Åsgard and Gullfaks fields. And on 4 August 2016, the world's first fully all-electric well of subsea industry, K5F3, has been open to production.

Q2: Subsea Processing is a new ISSC topic, the contents should cover some 'older' systems, such as Subsea Raw Water Injection (SRWI).

R2: A relative development has been to move the water injection equipment away from the topsides and to place it subsea. This realises the retrofit of seawater injection capabilities of facilities that would otherwise be unable to accommodate the increased infrastructure spending. This approach is known as Subsea Raw Water Injection (SRWI). The term 'raw' refers to the fact that the water is not deoxygenated and we agree that it should have been reported.

Q3: The first all-electric Christmas tree was not installed in 2016. A pair of all-electric mudline trees was installed in 2008 in the North Sea.

R3: In 2016, K5F-3 made it the world's first true all-electric subsea well. Total is a pioneer in this technology.

In 2008, the field's first two wells (K5F-1 and K5F-2) were not all electric, since there was no electric Down Hole Safety Valve (e-DHSV) on the market at that time, so the conventional hydraulic control system had to be retained for this equipment.

Q4: Material for Fabrication of Key Components is merely a summary of recommended practices regarding material selection and corrosion allowance, they are not advances made.

R4: We agree on the comment.

2.1.3 Flow Assurance of Subsea Production Engineering

Q5:The statement 'Flow assurance attracts more and more attention due to the harsh environment of subsea' should be elaborated as 'Flow assurance becomes a more critical issue in increasing water depth surrounded by colder water temperature and longer step out distance that allows transported fluids to cool down'.

R5: We have included it as a recommendation.

2.1.4 Testing for Qualification of Subsea Production System

Q6: Testing may be necessary to prove or qualify certain technologies, it is a process not a technology itself!

R6: We understand that the testing process are mandatory for the development of subsea technology.

2.1.5 Installation and Operations for Emergencies

Q7: In Section 5.1, the so-called pencil buoy method is an imitation of the Heave Compensated Landing System (HCLS) patented by Shell.

R7: The principles between HCLS and pencil buoy method are similar. But pencil buoy method improved the pad eye, and produced bigger pencil buoy, so it can install heavier subsea equipment.

2.1.6 Technologies for Hydrates and Other Subsea Resources

Q8: This section describes chemical process research work related to four methods of dissociating gas and water in methane hydrates, they are no structural elements therefore not relevant for an ISSC report.

R8: We agree with the comment. This should have been included as an issue in the flow assurance chapter.

Q9: An important work on methane hydrates extraction, which has more structural implications, has been omitted by the report: Solid Fluidisation Production of Methane Hydrates proposed by China National Offshore Oil Corporation.

R9: This question can be addressed in vol. 3.

2.1.7 Risers, Pipelines and Umbilicals

Q10: Literature search of academic work on risers, flowlines and umbilicals fails to capture two significant industrial events:

- Realisation of Thermal-plastic Composite Pipe (TCP) in oil & gas flowline field applications

- Emergence of Steel Lazy Wave Risers (SLWR) as riser configuration of choice for deepwater developments where simple steel catenary riser (SCR) cannot meet the design requirements

R10: This question can be addressed in vol. 3.

2.1.8 Reliability and Safety in Subsea System

Q11: Disproportional mention of the work by Wang et al, whose basis for the optimisation of the layout of subsea cluster manifolds was lowest cost, barely related to reliability and safety.

R11: We agree on the comment and we will add some remarkable references in vol. 3.

2.1.9 Conclusions and Recommendations

Q12: The statement 'Subsea production system (SPS) is a relatively new concept' should be changed to 'Compared to ship and platform structures and systems, SPS is relatively new'.

R12: We agree on the comment but the report cannot be changed.

2.2 Reply to Written and Floor Discussion

2.2.1 R1: NGH is considered a technology of subsea mining. This report focuses on the equipment for subsea mining but could indeed include this aspect of production as well.

2.2.2 R2: Industry prefers not to share information about failures or difficulties encountered. Only installation or operation are visible. The equipment of industrial partners is confidential which makes it difficult to include detailed information in the ISSC. Many technologies are black boxes. The committee admits that there is a lack of participation in industrial events like OTC or industrial papers.

2.2.3 R3: The approaches which are covered in recommended practice are indeed valuable to include. DNVGL confirms that recommendations for operation will be included in their recommended practices. It should however not be the case that recommended practices are repeated in the ISSC report. Reference should be sufficient.

2.2.4 R4: The ISSC report focuses on new materials like TCP. The standpoint is that new technologies should first be established and proven. Feedback can then be included in recommended practice.

2.2.5 R5: Maybe it can be considered by future committee.

General comment by Segen Estefen (Brazil): subsea technology goes deeper and more autonomous. This is the direction in which the industry is moving. The committee should follow this direction and include aspects/topics such as hydrates and minerals.

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