SPECIAL REPORT

Next Generation Subsea Inspection Tools

Advanced Subsea Inspection Services and Solutions

Structures in the Sea

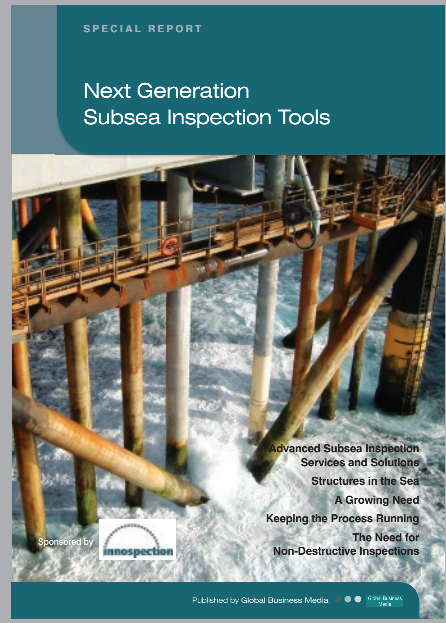
A Growing Need

Keeping the Process Running

The Need for Non-Destructive Inspections

Sponsored by innospection

Published by Global Business Media



Published by Global Business Media

Global Business Media Limited
62 The Street Ashtead Surrey KT21 1AT
United Kingdom

Switchboard: +44 (0)1737 850 939
Fax: +44 (0)1737 851 952
Email: info@globalbusinessmedia.org
Website: www.globalbusinessmedia.org

Publisher
Kevin Bell

Business Development Director
Marie-Anne Brooks

Editor
John Hancock

Senior Project Manager
Steve Banks

Advertising Executives
Michael McCarthy
Abigail Coombes

Production Manager
Paul Davies

For further information visit:
www.globalbusinessmedia.org

Contents

Foreword

Readers of this paper won't need to be told that any operation in the subsea oil and gas sector is expensive. There are numerous reasons for this including that, in the first place, people will not be persuaded to work miles out to sea for weeks on end for no more money than they could earn working onshore. Also, in order to be able to withstand the many challenges of an underwater environment, equipment and structures have to be unusually well built with a number of additional layers of protection that might not be necessary for the same equipment on land. And, it is a similar story with the whole array of services supporting the sector.

This Special Report opens with an article that looks at Innospection, a specialist provider of advanced and innovative inspection services and solutions. It is frequently engaged by oil and gas operators and integrity management suppliers to provide customised inspection solutions and equipment as well as to develop dedicated subsea solutions for the inspection of subsea pipelines, structures and other installations. The article goes on to describe a number of different types of inspection and the family of subsea scanner tools used.

Any loss of production is expensive and, given the conditions that apply in many supply contracts, any unscheduled loss of production will be catastrophically costly. So every method that avoids failures needs to be deployed, including the best systems for inspection and testing of structures and equipment. For these purposes and to avoid the test itself putting undue strain on the item being tested, non-destructive testing is the preferred method for subsea inspection.

The second article looks at the particular issues of wear, maintenance and access around structures that have to be located in and under the ocean. In the third piece, Peter Dunwell considers the growth that is true of the whole subsea energy industry and how that growth translates into even greater challenges for inspection and testing systems. And, where further value can be extracted from a field or additional reserves can be exploited using equipment already in place, Francis Slade reviews some of the challenges that life extension can generate. Finally we set out some non-destructive testing methods for a sector where knowledge is not so much power as money.

John Hancock
Editor

__John Hancock__ joined as Editor of Offshore Technology Reports in early 2012. A journalist for nearly 25 years, John has written and edited articles and papers on a range of engineering, support services and technology topics as well as for key events in the sector. Subjects have included aero-engineering, testing, aviation IT, materials engineering, weapons research, supply chain, logistics and naval engineering.

Advanced Subsea Inspection Services and Solutions

Andreas Boenisch, *Innospection Limited*

The mature and ageing North Sea assets have led the operators to increasingly focus on the integrity management of the offshore installations. The splash zone and subsea components in particular become subjects of increasing inspection demand and extensive condition assessment with the target for lifetime extension and to demonstrate fitness-for-service. As a result, the industry encourages the development of advanced subsea inspection solutions.

Andreas Boenisch, Managing Director of Innospection, a specialist provider of advanced and innovative inspection services and solutions, explains how the next generation of subsea inspection tools developed by Innospection helps operators solve longstanding and niche subsea inspection challenges.

Introduction

The requirement for the advanced inspection of subsea and splash zone infrastructures such as pipelines, structures like platform legs, caissons, rigid risers and flexible risers has grown in the North Sea and offshore operations in other regions due to the increasing focus on the reliability and safety of the offshore assets. This demand is not only the subject of the operators' drive to ensure the fitness-for-service of their assets but also to ensure the safe operation, both for their own interest, as well as to demonstrate proactiveness to the authorities.

Maintaining the integrity of the offshore oil and gas production assets is a huge challenge, especially for the subsea infrastructures, due to accessibility issues and inspection conditions. However, as a result of the increasing number of ageing assets particularly in the North Sea and the increasing prominence of subsea production infrastructures, innovative inspection solutions become necessary.

Traditional subsea inspection methods such as General Visual Inspection (GVI) or Close Visual Inspection (CVI) no longer proved to be sufficient to allow a sensible integrity assessment. At the same time, not all advanced NDT technologies proven for the topside and onshore inspection are suitable or easily deployed in the underwater environment.

A specialist in electromagnetic inspection technologies such as Eddy Current and Saturation Low Frequency Eddy Current (SLOFEC™), Innospection has delivered advanced Non-Destructive Testing (NDT) solutions and services to the worldwide process industries including the oil and gas (on- and offshore) industry, refineries, petrochemical and power plants since 1998.

Prior to the focus on the offshore and subsea inspection business, Innospection supported the onshore petrochemical and nuclear power industries, where advanced Eddy Current inspection solutions first gained recognition and acceptance. From there, the on- and offshore oil and gas industry started to recognise the use of the advantageous fast corrosion screening SLOFEC technique for the inspection of pipes, tubing and pressure vessels.

Gaining the reputation for expertise in advanced NDT solutions in the UK market, Innospection is frequently tasked by the oil and gas operators and integrity management suppliers to provide customised inspection solutions and equipment to longstanding inspection challenges as well as to develop dedicated subsea solutions for the inspection of subsea pipelines, structures, caissons and risers.

Subsea Inspection Focus

Although a challenge at times, effective and detailed NDT inspection data is required for valuable asset integrity assessment and possible lifetime analysis. Very often, a single inspection technology is not able to achieve all the required condition information. In some cases, different NDT technologies are complementary and capable of providing a larger extent of condition data when used in combination.

In comparison to topside inspection, splash zone and subsea inspections have more limitations due to accessibility to assets, possibility of inspection surface preparation

In comparison to topside inspection, splash zone and subsea inspections have more limitations due to accessibility to assets, possibility of inspection surface preparation or simply because of the technique limitation to be applied underwater

or simply because of the technique limitation to be applied underwater.

One of the most suitable techniques for subsea inspection is the Saturation Low Frequency Eddy Current (SLOFEC) technique. This technique has over the past years proven its suitability for splash zone and subsea inspections due to the easy deployability, low surface preparation requirement and high scanning speed. The SLOFEC technique was first offered for subsea inspection as the available equipment allowed but R&D and engineering soon followed to enhance the technology capability and for variation of subsea inspection applications.

The existing SLOFEC technology, new developed technologies and the addition of suitable techniques, form the foundation strategy of Innospection to bring to the market innovative technologies, application development and equipment aimed at providing the clients with optimum and unique inspection solutions to meet the niche inspection challenges presented in the deep water operations in the worldwide oil and gas industry.

The subsea focused business is driven by the development of submersible innovative inspection systems able to deliver the best possible condition data. Branded under the name MEC (Magnetic Eddy Current), this next generation of SLOFEC based subsea inspection tools incorporate supporting inspection techniques such as Ultrasonic, Pulsed Eddy Current, High Frequency Eddy Current, Close Visual Inspection and other inspection techniques to provide the best quality and comprehensive inspection data as well as to add value to a single inspection deployment.

SLOFEC™ – Fast Corrosion Screening Technique

The predominant non-destructive electromagnetic inspection technique offered by Innospection is the SLOFEC technique. Qualified within the oil and gas industry, this technique has been proven in the field as a fast corrosion screening technique with high defect detection sensitivity and reliability for the inspection of ferro- and non-ferromagnetic steel components such as pipes, pressure vessels, storage tank floors, risers, caissons and other steel structures.

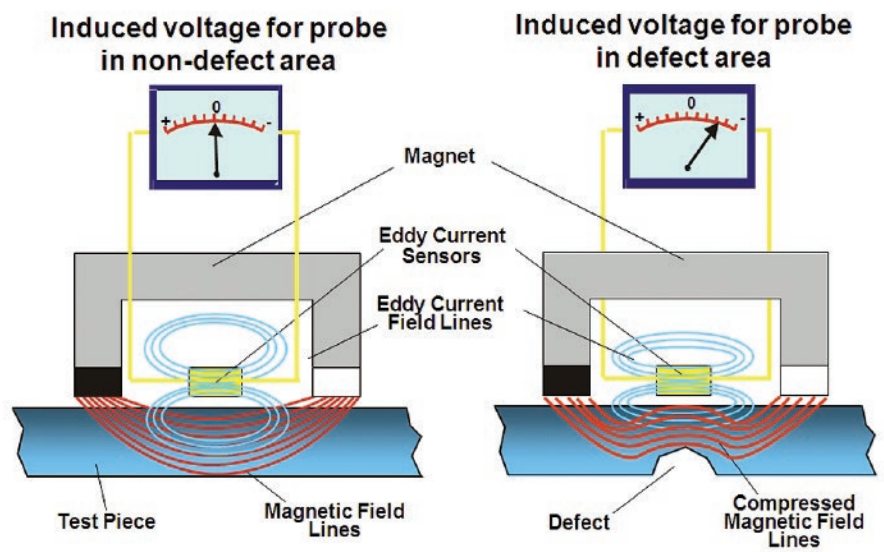
SLOFEC is a dynamic scanning technique which combines a direct current magnetic field with an eddy current field. Utilising superimposed direct current magnetisation, the depth of penetration is increased to such an extent that the sub-surface (internal) corrosion attack (metal loss) can be detected from the external surface.

While defects such as pitting or general corrosion affect the direct current magnetic field lines inside the remaining pipe wall, a change in the relative permeability consequently affects the eddy current field. This is displayed as impedance for each eddy current sensor (in an array) in comparison to the calibration displaying the wall loss in amplitude. The signal phase analysis enables the internal and external defects to be clearly distinguished from each other.

Although comparable to the Magnetic Flux Leakage (MFL) technique at first glance, SLOFEC focuses on sensing the field line density changes rather than the stray flux.

SLOFEC offers the following advantages:

- Lower magnetic field strength than as required by MFL



PRINCIPLE OF THE SLOFEC TECHNIQUE

- Allow the inspection of
  - heavier wall components (experience up to 42mm)
  - components with coating in place (experience up to 15mm)
  - CRA, TSA and Monel coated/clad carbon steel pipes and structures
- Highly sensitive to the detection of general corrosion as well as small pitting corrosion (e.g. CO_2 corrosion, microbiological induced corrosion, etc)
- Direct surface coupling between the sensor system and the inspection object is not necessary, which allows this technique to be utilised as a non-intrusive inspection method
- Cleaning of the inspection surface to the bare metal is not required to produce good quality inspection data, which is a major advantage over Ultrasonic capabilities and makes SLOFEC uniquely suitable for subsea screening inspection applications

MEC M-PS200+ MARINISED SCANNER DURING THE EXTERNAL CAISSON INSPECTION

MEC Subsea Inspection Tools

The MEC subsea scanner family is used to support the condition assessment and inspection of:

- Rigid risers
- Flexible risers
- Caissons
- Subsea structures and manifolds
- Subsea pipelines
- Non-piggable pipelines or pigging verifications
- Ship hulls

Equipped with the advantageous fast corrosion screening SLOFEC technique, these versatile MEC subsea scanners allow the incorporation of supporting inspection techniques, depending on the inspection requirements, to provide comprehensive inspection data within a single inspection deployment.

The MEC subsea scanners can be deployed either from the installation by rope access personnel supporting the launch or from the support vessel by ROV or diver support. The mechanical adaption and the hydraulic driven wheel sets enable the MEC scanners to move along the vertical pipes (risers / platform legs) or horizontal pipelines in defined lines up, down or in axial runs.

Although the electromagnetic inspection technique of the MEC subsea scanners requires no absolute clean and bare metal surfaces, the cleaning preparation may demand the removal of heavy marine growth especially for the splash zone inspection work in order to allow a consistent run on the pipe surface.

The inspection data is instant as the scans are taken online and the first analysis assessment can be performed immediately. The final reports are provided later after the inspection data has been evaluated by the analysis team.

Risers and Caissons Inspection

The **MEC M-PS** series of submersible scanners is used for the condition assessment of rigid risers, caissons and structures including through the neoprene coating and Monel cladding. They allow the smooth transition from the topside directly into the splash zone and subsea area without a break in the continuity of scanning.

Easily adapted for both internal and external inspection, the MEC M-PS scanners have high defect detection capability for localised defects and have demonstrated ideal capabilities for caisson inspection. Due to their smaller size, these scanners can be easily deployed by divers.

The MEC M-PS series of submersible scanners has been successfully deployed for riser and caisson inspection at water depth up to 170m. With scan imaging and matrix data display, the inspection focus is on the detection of external and internal wall loss, pitting, general corrosion and cracks.

For caisson inspection, the inspection track record currently achieved is as follows:

- Diameter range from 10" to 42"
- Wall thickness up to 25.4mm
- Coating thickness up to 15mm

For riser inspection, the inspection track record currently achieved is as follows:

- Wall thickness up to 20mm
- Neoprene coating thickness up to 15mm
- Monel protection layer up to 3mm

Flexible Risers Inspection

The complex layer structure of flexible risers corresponds to challenges in the integrity

Easily adapted for both internal and external inspection, the MEC M-PS scanners have high defect detection capability for localised defects and have demonstrated ideal capabilities for caisson inspection

evaluation of these pipes, especially the various wire layers under various tensional stress levels. There is a market demand for a technology able to deliver an external fast screening of the flexible risers in-situ, with visibility of the multiple wire layers and without the risk of damaging the integrity of the flexible risers.

The inspection techniques available were only able to inspect the near side layers of the flexible risers for wire disruption while the far side layers remained uninspected. Ultrasonic based technologies require the flooding of the annulus with a couplant for the inspection to be performed, which presents a potential risk of damage especially to the inner layers of the flexible risers.

As a result, Innospection developed the patented **MEC-FIT™** technique to provide a reliable and technically advanced solution for the inspection of flexible risers operated from offshore installations.

The MEC-FIT™ technique combines magnetic field lines with eddy current field lines to allow the deeper penetration into the various armour layers of the flexible risers to detect cracks and corrosion in the inner layers. This technique allows the analysis of flaws or occurrence type by signal phase while the signal amplitude defines the severity of the detected flaws. With field strength parameter variation, this technique also allows the definition from which a defect signal is received.

The specifically developed magnetic system and sensors has successfully demonstrated sensitivity in the detection of single or multiple wire cracks and corrosion (corrosion pitting areas or individual pits) in the first and second tensile armour layers and to some extent, damage and interlocking failures in the third pressure armour layer.

As an electromagnetic technique, the principle advantage of MEC-FIT™ is that it is not dependent upon a fluid phase to allow the transmission of signals to make the individual composite layers visible. In addition, no annulus flooding minimises the risk of damage to the inner layers of the flexible risers.

The **MEC-Hug** inspection tool is developed not only to deploy the MEC-FIT™ inspection technique but also to address the very specific challenges of accessing and inspecting the flexible and rigid risers in its working locations.

A sophisticated self-crawling inspection system, MEC-Hug embraces the flexible risers after being deployed into position by ROV or rope access personnel and moves along the flexible risers through the splash zone to perform the external inspection. The ability of this tool to crawl vertically or horizontally along the inspection assets provides greater flexibility in meeting the rigorous demands of the subsea inspections.

MEC-HUG INSPECTION SYSTEM IN DEPLOYMENT FROM THE INSTALLATION AND IN OPERATION AT FLEXIBLE RISER IN THE NORTH SEA

A change out of the sensor system allows MEC-Hug to be used for the inspection of rigid risers and general pipes.

MEC-Hug has been successfully deployed for flexible riser inspection in the North Sea. The inspection track record currently achieved is as follows:

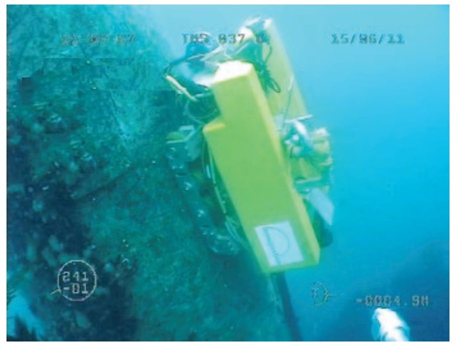
- External scanning
- Inspection of diameter range from 4" to 12"
- Focused on crack or corrosion detection at first and second tensile layers or third zeta layer with wire gap display in some cases

Subsea Structures and Pipelines Inspection

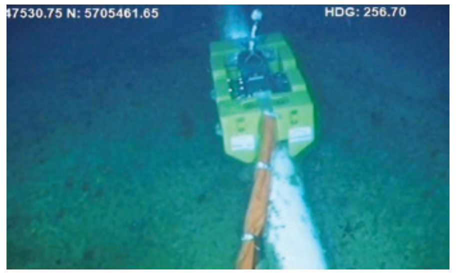
Some inspections can only be achieved if the inspection tool is deployed in a specific manner due to the challenge of location such as the splash zone around a platform jacket which makes diver inspection and rope access deployment impossible.

The **MEC-Combi Crawler** supports the inspection of subsea structures where access from topside is not possible. A versatile self-crawling inspection tool, MEC-Combi Crawler supports the inspection and lifetime assessment of subsea structures ranging in size and complexity from risers, caissons, pipelines, to platform structural legs as well as flat surfaces like ship hulls. It can be deployed either by diver or a work class ROV from a support vessel.

MEC-Combi Crawler combines the advantages of the SLOFEC technique with supporting inspection techniques like Ultrasonic and camera system, and in some cases Pulsed Eddy Current to



MEC-COMBI CRAWLER INSPECTION SYSTEM IN OPERATION ON A SUBSEA STRUCTURE LEG IN THE NORTH SEA



MEC-COMBI CRAWLER INSPECTION SYSTEM (MEDIUM SIZE) IN OPERATION ON A SUBSEA PIPE IN AUSTRALIA

The inspection techniques available were only able to inspect the near side layers of the flexible risers for wire disruption while the far side layers remained uninspected

provide comprehensive inspection data including additional verification and absolute thickness measurement.

Powered by a hydraulic drive unit, the fitted buoyancy and applied magnetic force enable the MEC-Combi Crawler to crawl up the subsea structures including through the splash zone or along the subsea pipelines while performing the external scanning. Information on internal and external defects in terms of size, severity of wall loss and locations is achieved. The fitted camera and light system supports the visual scan while the position encoder system enables its location on the inspection surface to be determined.

MEC-Combi Crawler has been successfully deployed for several platform structural leg and caisson inspections in the North Sea as well as for subsea pipeline inspection in Australia.

For structural legs and caisson inspection, the inspection track record currently achieved is as follows:

- Diameter range from 30" to 55"
- Wall thickness up to 42mm
- Inspection at water depth of 100m
- Focused on internal wall loss inspection for delivery of matrix data for finite element analysis and lifetime calculation

For subsea pipeline inspection, the inspection track record currently achieved is as follows:

- Diameter range from 6" to flat
- Wall thickness up to 32mm
- Coating thickness up to 15mm
- Inspection at water depth of 110m
- Focused on internal pitting / wall loss detection (usually top line pitting or bottom carbon dioxide corrosion) with delivery of scan images and matrix data.

Advanced Subsea Inspection Solutions

Supported by an internal R&D team consisting of highly qualified engineers and development technologists with expertise and know-how in advanced NDT technologies and application development to inspection tasks, the advanced and innovative inspection solutions and services provided by Innospection is unlimited.

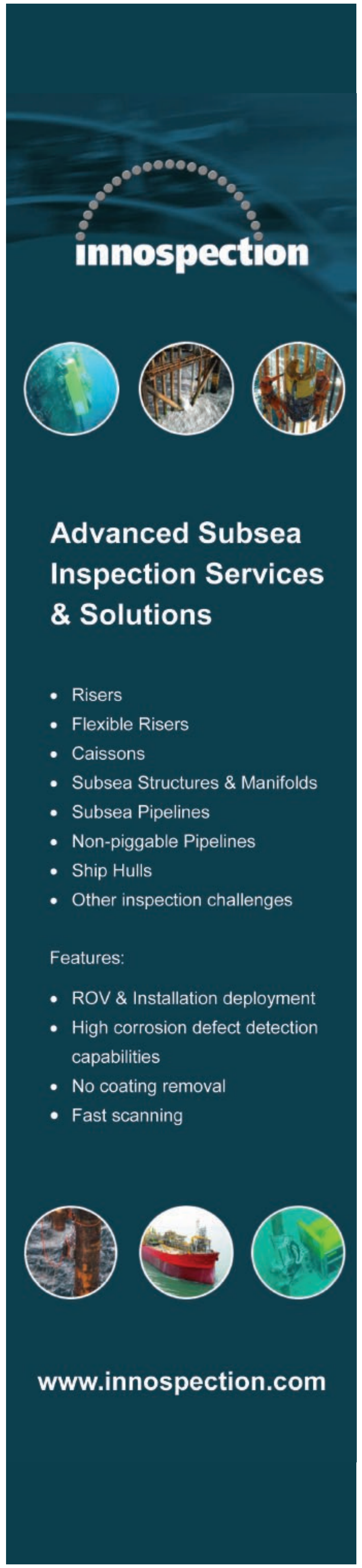
Whatever your subsea inspection challenges are, Innospection is your solution provider.

Contact

Innospection Limited
Unit 1, Howemoss Avenue
Kirkhill Industrial Estate, Dyce
Aberdeen, AB21 0GP
United Kingdom

Andreas Boenisch, Managing Director
Sebastian Hartmann, Sales & Business Development Manager

Tel: +44 (0)1224 724744
Email: info@innospection.com
Web: www.innospection.com



Structures in the Sea

John Hancock, Editor

The offshore subsea sector and its challenges spawned many significant technology developments including non-destructive testing techniques

Subsea energy discovery and production engages many engineering activities and has driven the development of the specialist technology, equipment and operating methods used in activities conducted under water and offshore

Challenges in Every Aspect of Subsea Operation

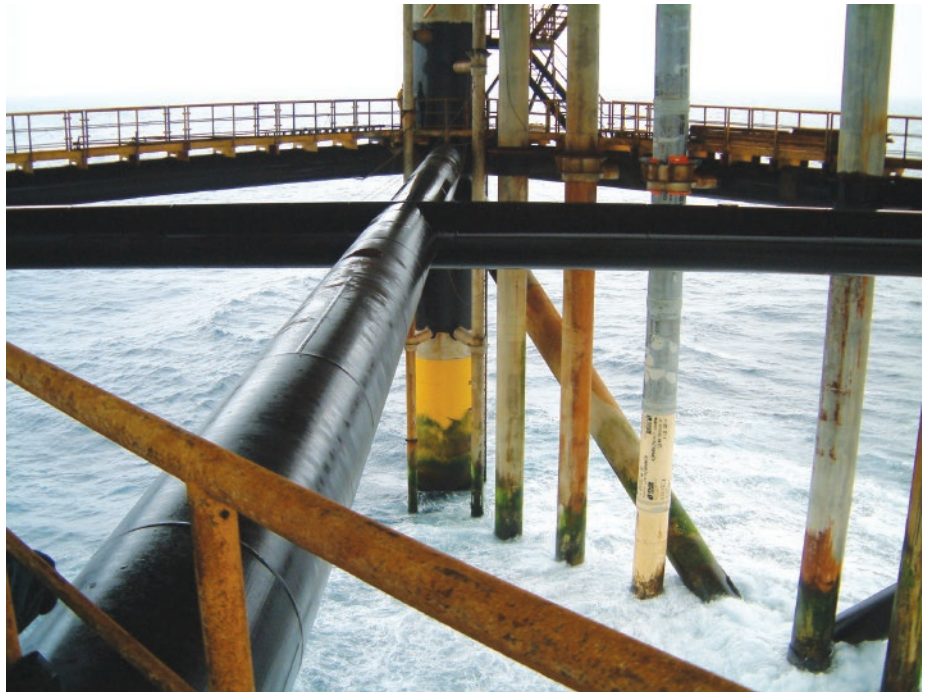
Before considering subsea inspection tools, it will first be useful to examine the global offshore and subsea energy sector; what it does, the stages through which a typical field will pass during its lifetime, what components make up the offshore subsea environment and how, as a result of this, the process of inspection and testing requires some very special skills and techniques. This uniquely challenging, even hostile, environment pitches every challenge that nature can muster to test the engineers and others who design, build and operate industrial structures, on and beneath the surface of the ocean. That, in turn, becomes as great a challenge for the people who have to design tools that can be used to inspect and maintain those structures and systems in often inaccessible places and in usually challenging conditions. So, in comparison to topside inspection, splash zone and subsea inspections have more limitations resulting from restricted accessibility to assets, less possibility of inspection surface preparation and simply from the limitation of techniques that can be applied underwater. But challenging or not, there is an enormous economic incentive to locate, access and exploit reserves of energy to meet the world's ever-growing demands.

"Subsea is a general term frequently used to refer to equipment, technology, and methods employed in marine biology, undersea geology, offshore oil and gas developments, underwater mining, and offshore wind power industries. Oil and gas fields reside beneath many inland waters and offshore areas around the world, and in the oil and gas industry the term subsea relates to the exploration, drilling and development of oil and gas fields in underwater locations. Underwater oil field facilities are generically referred to using a subsea prefix, such as subsea well, subsea field, subsea project, and subsea development."[1]

What is the Subsea Energy Sector?

Subsea energy discovery and production engages many engineering activities and has driven the development of the specialist technology, equipment and operating methods used in activities conducted under water and offshore. Furthermore, "Subsea [activities] are usually split into shallow water and deepwater categories to distinguish between the different facilities and approaches that are needed."[2] For the purpose of this paper, subsea refers to offshore oil and gas facilities and offshore renewable energy: altogether among the most demanding and costliest economic activities undertaken in the world. The oceans are not only 'last frontier' repositories for traditional carbon-based fuels such as oil and gas but are increasingly seen as either the largest generators of renewable energy through wave and tidal power or the best place to economically harness wind power.

Realistically, oil and gas remain by far the largest components in offshore energy with an ever growing inventory of economically viable and exploitable reserves – see next article on sector growth. These are the fuels that have powered the global economy for many decades and are still the fuels most sought after by emerging economies. While there remain significant reserves of both oil and gas beneath the deserts of the Middle East and under many other lands, all too often, the regimes in whose territory reserves are located are either not stable or not regarded as reliable long-term suppliers. Wherever possible, most countries, whether developed or emerging economies, would prefer to meet energy demands from resources within their own jurisdiction: it's secure and it earns export dollars. So, increasing numbers of countries are looking to their own territorial waters as sources of energy and wealth; but the structures used to discover and produce oil and gas in these places will be subject to significant environmental wear and tear which will require reliable tools and techniques for inspection so that maintenance and repair programmes can be suitably informed to ensure consistent operation.



RISERS AND CAISSONS IN THE NORTH SEA

Renewable Energy

All that said, we cannot ignore other energy resources and, in that category, renewables are becoming increasingly important components in the offshore subsea sector. The Royal Institution of Naval Architects (RINA) sums up progress to date3: "Marine and offshore energy offers the potential to meet a small but significant share of the world's renewable energy aspirations. However, the maritime environment also provides many challenges in terms of economics, survivability and reliability of such systems. Offshore wind energy [has] made the most rapid progress and is now starting to move into large scale commercial developments. Wave energy developments have only seen sporadic progress since the 1970s. Tidal and current stream technologies, which began serious development in the 1990s, are now at the prototype and small scale commercial development stage."

Offshore wind power is a particular growth area and, while the turbines themselves might be above the surface, the structures on which they are mounted and the infrastructure that transports their energy to where it can be used will all be subsurface. "The power transmission infrastructure for offshore wind power utilizes a variety of subsea technologies for the installation and maintenance of submarine power transmission cables and other electrical energy equipment. In addition, the monopile foundations of fixed-bottom wind turbines and the anchoring and cable structures of floating wind turbines are regularly inspected with a variety of shipborne subsea technology."[4]

Non-Destructive Testing

One critical issue for those charged with keeping all these structures and infrastructure in working order is that the means are needed to test that they are able to resist the sort of forces to which they'll be subject during their working life but without actually subjecting them to those destructive forces. The technique is called non-destructive testing (NDT) and represents one of the more skilful applications of technology. Effective and detailed NDT inspection data is required to determine the integrity and potential lifetime of equipment and structures.

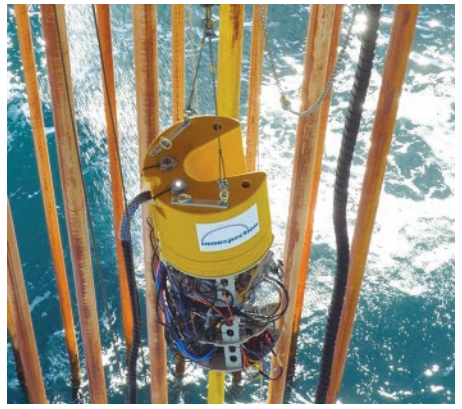
SPECIAL REPORT: NEXT GENERATION SUBSEA INSPECTION TOOLS

A Growing Need

__Peter Dunwell,__ Correspondent

More and older equipment demands more and better means for inspection and testing

Producers will be looking to exploit ever more challenging conditions and depths in order to win every possible drop of carbon-based fuels, while longer term renewable resources are still being developed



IN THE previous article, John Hancock considered subsea energy and the physical challenges posed for those charged with ensuring its continued safe operation. There are also several market forces generating conditions that bring further challenges to the operational equation.

A Growth Sector

The subsea sector is growing: industry analysts Douglas-Westwood[5] have predicted that some $77 billion will be spent on subsea vessel operations, new field development, well intervention, and inspection repair and maintenance (IRM) in the period between 2012 and 2016. Whether it's to support the latest subsea technologies or the on-going maintenance of life-extended subsea installations dating back to the 1980s, the demand for all support services will remain high and growing as the wider industry grows.

According to Infield Systems' latest research published in late February 2013[6], "… the subsea industry is amongst the most promising in the offshore oil and gas world, with subsea capital expenditure (Capex) set to grow at a staggering 14.8% CAGR (compound annual growth rate) to 2017." Douglas-Westwood, again, is projecting a global fleet of more than 7,000 fixed and more than 200 floating platforms, and with 190,000 km of pipeline currently installed plus a number of major modification programmes to push growth in offshore operations and maintenance in the next couple of years.

Offshore production is only possible because of the advances that have been made in subsea technology and subsea technology could not function without subsea services, such as the capability to inspect and test equipment and structures in-situ. The whole industry of subsea inspection, repair and maintenance (IRM) is growing, with global demand for subsea IRM expenditure estimated by Douglas-Westwood (see reference above) at $4.5billion in 2009, and, according to Stork Technical Services, projected to reach nearly $7billion in 2014.[8]

According to Jason Waldie, Associate Director at energy industry analysts, Douglas-Westwood speaking at the 'Subsea Asia Conference', Kuala Lumpur in June 2011[9], the production and use of natural gas is set "to soar" in the period to 2021 with deepwater gas identified "to be of growing importance." Part of the reason for this is the abundance of natural gas available beneath the oceans and part the fact that gas power plants require the lowest capital expenditure for the amount of energy they produce. But whether it's oil or gas being produced, the subsea offshore energy sector is going to be growing for some time into the future and, given the depletion and finite nature of most reserves accessible from land, producers will be looking to exploit ever more challenging conditions and depths in order to win every possible drop of carbon-based fuels, while longer term renewable resources are still being developed.

An Extended Life

It isn't only the growth of new fields, but also the life extension of established fields that is stretching oil and gas production life cycles to extents that were not previously planned and that, in turn, require equipment to be used some way beyond its anticipated working life.

As The Journal of Petroleum Technology[7] put it, "More than half of the offshore oil and gas installations in the UK Sector of the North Sea have been operating for at least 20 years. Most assets are approaching or operating beyond their original design intent. With the rise in oil and gas prices and advances in technology, there is an increasing requirement to extend the operational life of these assets. Safety-case regulations were modified to include a technical justification for extended operation, and the UK Health & Safety Executive (HSE) launched Key Programme 4 (KP4) to ensure that all duty holders have suitable management systems in place to address aging-related issues adequately." Equipment in these life-extended fields will require increasingly stringent and detailed levels of inspection and testing to ensure their continuing operating efficiency and structural integrity.

As well as new field developments and the extended life for older fields, there is a third way in which growth can be achieved. As Offshore Technology explained in the March 2007 article, 'Tieback Time'[10], "Subsea tiebacks connecting new discoveries to existing facilities can extend the life of production infrastructure. They are becoming increasingly viable, both technically and economically… Exploiting new discoveries using existing production facilities is an important way of obtaining maximum value from existing infrastructure." But it also raises the bar on inspection and management of that infrastructure.

Safety is the Watchword

Demand growth is not only driven by the operators' determination to ensure the fitness-for-service of their assets, but also to ensure safe operation for the well-being of workers, for their own interest in maintaining production with as little disruption as possible and to support high levels of corporate integrity as well as to demonstrate a proactive approach to the authorities.

These days, in any industry, safety has to be a principal concern; in a sector like offshore energy, with significant potential to harm both the people who work in it, the immediate environment in which it operates and the wider locale, safety has to be the first operational concern. It is best achieved through assured mechanical and materials integrity which, in turn, requires adherence to a prescribed maintenance schedule and routine inspection and monitoring of the equipment's condition to inform a programme of fault rectification as well as routine maintenance.

But, whatever the individual case, it's all driven by market demand. "The subsea oil and gas market continues to grow at an increasing pace, as oil and gas operators continue to discover reserves in deeper water areas where the only economically viable recovery solution is a subsea development." Is how the Infield 'Subsea Well Intervention Market Report to 2017'[11] puts it.

Processing Under the Sea

As well as exploiting new or extending older fields, another way of improving efficiency and profitability has been moving processing and its associated equipment and structures down to the seabed. This development has been dubbed 'The Game changer' in the Offshore Magazine article of the name[12] in which it is stated that, "… the short-term future for subsea processing is most likely to involve equipment being installed on fields to de-bottleneck topsides facilities. These fields are less likely to be long-distance tie-backs or low-pressure reservoirs and more likely to be deepwater fields or fields with high water content." The article continues to explain that, while the areas where subsea processing is likely to be used has decreased, the likelihood of operators using the technology has increased, with nearly all of them expecting to install some subsea processing equipment within the next five years.

Summary

Subsea operations would be challenging enough in ideal conditions with all new equipment. However, such are the realities of energy economics that, whether driven by market demand, the need for production continuity or by safety requirements, ever increasing and aging fleets of complex equipment are being located on the seabed in conditions that vary from challenging to hazardous. It seems that the requirement for services that can support competent inspection and non-destructive testing of that equipment and the structures that house it will not simply continue but will grow.

Keeping the Process Running

Francis Slade, *Staff Writer*

There's a lot of equipment located under water whose integrity and efficiency must be regularly monitored if the sector is to remain profitable

With the cost of capital items being so great, purchasing new equipment and structures can significantly counteract any economic benefit plus the opportunity to wrest increased productive life from older equipment will be welcome

What is Subsea Hardware?

Wherever recoverable reserves of oil and gas are found beneath the ocean, there will be a great deal of hardware sited on the seabed. It will vary from the obvious complexity and sophistication of a Christmas Tree sited over a well head to the apparent simplicity of a pipeline (they're actually far from simple, see below) to the structures that support platforms and production facilities: and there is the growing trend to site processing facilities on the seabed. All of these will need regular monitoring to ensure not only their economic operation but also their continuing to safely support the processes of the business and protect the environment from the risk of pollution. Structures such as floating production, storage and offloading (FPSO) systems, for instance, have especial potential to be the sources of pollution should any part of the system fail. Monitoring all this will entail inspections and testing in increasingly hostile environments – one application for subsea processing will be to facilitate year round production from Arctic fields that might be under ice for half of the year.

Any inspection routine will need to cover a range of equipment and structures including manifolds, pipelines and structures like platform legs, caissons, rigid risers and flexible risers.

Every piece of equipment plays its role in oil and gas production but arguably the most important is that which delivers the product through the production process and on to the market. As we've already said, pipelines might seem simple but within an offshore subsea oilfield and connecting it to the wider world, they are complex pieces of engineering. PetroMin Pipeliner[13] sums it up; "Unlike an onshore pipeline, a deepwater pipeline usually consists of more than just steel pipe, some valves and several compressor stations. A deepwater pipeline is often attached at each end to a structure called a PLET ('Pipeline End Termination'). The PLET is connected to other components of the subsea development, such as a wellhead manifold, subsea tree or a riser base, by a secondary pipe structure called a jumper. The pipeline, often referred to as a flowline, may be a either a flexible composite structure or a rigid steel pipe."

Life Stages of Subsea Installations

To a great extent, the life stages through which installation pass mirror the life stages of a field… exploration, proving reserves, building and installing structures, production and maintenance, decommissioning, and dismantling or making safe. During every one of these life stages and, although it is often a challenge, effective and detailed data is required for valuable asset integrity assessment and possible lifetime analysis. The best way to obtain that data without interfering with the integrity of a structure is to inspect it using NDT (non-destructive testing) methods. And where a single inspection technology is not able to achieve all the required condition information, different and complementary NDT technologies are capable of providing a larger extent of condition data when used in combination.

Most equipment has a 'design life', the period of operation or number of operations for which the designer and manufacturer anticipated the equipment having to function. These days, a lot of equipment is being operated well beyond its design life. That is achievable; but there are conditions. Where a facility undergoes lifetime extension, the subsequent inspection regime will need to be all the more rigorous for structures operating beyond their original design intentions.

Life Extension Programmes

Demand and economics are the two principal drivers of life extension programmes. Demand is obvious: with growing numbers of economies seeking to move from 'third world' to 'emerging' status (and, ultimately, on to 'developed'), the need to fuel all of those economic expansion programmes means that ever more oil and gas reserves have to be found and produced. That, in part, drives the economic case for field life extension, because when increased demand meets finite resources, prices rise. And when prices rise, reserves whose exploitation might not previously have been worthwhile become economically exploitable. Also, with the cost of capital items being so great, purchasing new equipment and structures can significantly counteract any economic benefit plus the opportunity to wrest increased productive life from older equipment will be welcome.

The Journal of Petroleum Technology, February 2012 edition[14] sums up the situation. "To keep capital and operational expenditures at a minimum, there is an increasing requirement from operators to use existing infrastructure, and, consequently, there is a trend to use subsea tiebacks to existing platforms. Therefore, platforms become 'hubs' and often their operational life is extended. The result is that decommissioning is delayed and equipment that had been maintained at near-minimum levels now requires significant overhaul or replacement to continue service for another 10 to 20 years… Extending the life of existing assets ultimately results in installations operating well beyond their original design life. However, the aging of facilities can have a direct effect on installation integrity and safety… Aging and life extension are major issues for the offshore oil and gas industry… [However,] Aging is not about how old the equipment is; it is about what is known about its condition, how that is changing over time, and how effectively the associated risks are being managed."

The Importance of Inspection

Notwithstanding all of the above, inspection regimes cannot wait until equipment is old or life extended, as Lloyd's Register report 'FPSO Inspection Repair & Maintenance, Study into Best Practice'[15] explains: "[While] The UKCS FPSO [floating production, storage and offloading] fleet is relatively young… This is not to say that I&M [inspection and maintenance] have not a crucial role to play in detecting and rectifying incipient failure. The safety of systems and equipment throughout the operational life of the installation will depend ever more on the maintenance and inspection function being suitable and well implemented." Inspection is always an important element in the management of subsea equipment and structures.

The Need for Non-Destructive Inspections

John Hancock, Editor

Such an array of processes and equipment requires a robust management system to ensure that they function as effectively as possible at all times and that potential failures are caught before they manifest as problems

Subsea Hardware

The development of subsea oil and gas fields requires specialized equipment which must be reliable enough to safeguard the environment and make the exploitation of subsea hydrocarbons economically feasible. The deployment and employment of such equipment requires specialized and expensive vessels and processes. Any requirement to repair or intervene with installed subsea equipment is thus normally very expensive. Such an array of processes and equipment requires a robust management system to ensure that they function as effectively as possible at all times and that potential failures are caught before they manifest as problems.

The process most often used to achieve that continuity of performance is underwater inspection. According to the Naval Facilities Engineering Service Center in California[16], "The fundamental purpose of any inspection is to provide the information necessary to assess the condition (capacity, safety, and rate of deterioration) of a structure."

Part of the Process

In that context, subsea inspection tools cannot be viewed as some appendage to the overall subsea energy extraction process: rather, they are an integral element within that process, of increasing importance, as technology, techniques and lifespans are pushed to greater lengths. Lance Cook, Chief Scientist for well engineering and production technology at Shell explained in August 2012 Offshore Technology[17], "Continuing the push for new technology and techniques to enhance oil recovery and extend asset lifespans is a priority for the industry, and therefore approaches to well integrity must evolve in line with these new production methods. Given that oil fields around the world are maturing, increasing recovery is more important than ever, and so is our technology innovation in this field. Backed by a total R&D spend of $1.1 billion, Shell has a comprehensive EOR [enhanced oil recovery] technology programme that includes initiatives at different stages of maturity."

This is particularly apposite where aged assets are continuing to operate past their designed life. In the February 2012 Journal of Petroleum Technology article 'Offshore Oil and Gas Installation – Aging and Life Extension'[18] the author explains that, "In the end-of-life stage, the safe operating limits for the equipment are approaching, advanced inspection techniques are required at closer intervals to determine fitness for purpose, [author's italics]... The key to longer-term reliability and safety is to establish effective management systems early on to prolong the mature stage, because starting at later stages requires considerably more effort and cost." In other words, monitor equipment properly in its optimal operational stage and it will remain efficient and usable for longer.

Inspection Without Damage

Often, with the type of structures used in offshore energy production, evidence of incipient weakness or impending failure occurs not on the outside of the structure where it can more easily be detected but inside the structure or inside the materials that make up the structure. Finding evidence of weakness using conventional methods (opening, drilling, etc.) might weaken the structure and make failure more likely. To deal with this problem, a range of non-destructive testing (NDT) technologies and techniques have been developed to facilitate inspection without any threat to the integrity of structures or materials. And, alongside of these, an array of specialist inspection tools make sure that testing is possible in even the most challenging of locations and environments. These tools can deal with the challenges posed by deep water… high pressures and extreme temperatures.

Of course, design can address a lot of challenges in the way equipment and structures are built but while, "There are many issues to be addressed… All marine structures require inspection and maintenance in order to preserve them for their working life [author's italics]. Unfortunately the reality is that some [operators] expect marine structures and pipelines to look after themselves." That was the conclusion drawn by James R Dale in his paper 'Subsea Pipeline Inspections.'[19]

RISERS IN OPERATION

Non-Destructive Testing Methods

The simplest form of non-destructive testing is visual observation but, as we have already suggested, many weaknesses are not externally visible. However, if traditional subsea inspection methods such as General Visual Inspection (GVI) or Close Visual Inspection (CVI) are no longer sufficient to meet all the standards required for an integrity assessment, equally not all advanced NDT technologies that might operate perfectly well above the surface and onshore are suitable or easily deployed in the subsea workplace. To this end, several techniques are employed to achieve non-destructive testing of subsea equipment and structures.

Eddy current testing uses electromagnetic induction to detect flaws in conductive materials. There are several limitations with this technology including that only conductive materials can be tested, the surface of the material must be accessible, the finish of the material may cause bad readings, the depth of penetration into the material is limited by the materials' conductivity, and flaws that lie parallel to the probe may be undetectable. But, advantages include… sensitivity to surface defects, ability to detect through several layers and through surface coatings, accurate conductivity measurements, the process can be automated, requires little pre-cleaning, and the equipment is portable. A development from eddy current, 'Saturated Low Frequency Eddy Current' (SLOFEC) uses the eddy current principle with a magnetic field to increase the depth of penetration of the field lines.

Ultrasonic testing "uses the transmission of high-frequency sound waves in a material to detect a discontinuity or to locate changes in material properties."[20] It is sensitive to surface and subsurface faults, offers high levels of penetration, can be used from one side of a structure, accurately identifies the flaw with its size and shape and requires minimal preparation of the part to be examined.

Non-destructive testing (NDT) is a very important component in the management of any subsea equipment or structure and, fortunately, there are a number of NDT options available to suit most purposes.

References:

1. Wikipedia http://en.wikipedia.org/wiki/Subsea_%28technology%29#Oil_and_gas
2. Wikipedia http://en.wikipedia.org/wiki/Subsea_%28technology%29
3. RINA, 'Marine & Offshore Renewable Energy' http://www.rina.org.uk/renewable2010
4. Wikipedia http://en.wikipedia.org/wiki/Subsea_%28technology%29#Oil_and_gas
5. Jason Waldie at the 'Subsea Asia Conference', Kuala Lumpur http://www.subseauk.com/documents/subsea%20asia%20-%20jason%20waldie.pdf
6. Infield Systems, 'Subsea Oil and Gas Sector Set For 14.8% CAGR Growth To 2017' http://www.infield.com/news/subsea-oil-gas-sector-growth-2017
7. The Journal of Petroleum Technology http://www.mydigitalpublication.com/article/Offshore+Oil+and+Gas+Installation%E2%80%94Aging+and+Life+Extension/951953/0/article.html
8. Stork Technical Services, 'Subsea IRM Market' http://www.storktechnicalservices.com/en/markets/subsea/
9. Jason Waldie at the 'Subsea Asia Conference', Kuala Lumpur http://www.subseauk.com/documents/subsea%20asia%20-%20jason%20waldie.pdf
10. Offshore Technology, 'Tieback Time' http://www.offshore-technology.com/features/feature1033/
11. Subsea Well Intervention Market Report to 2017 http://www.infield.com/market-forecast-reports/subsea-well-intervention-market-report
12. Offshore Magazine 'Subsea processing – the gamechanger' http://www.offshore-mag.com/articles/print/volume-63/issue-11/technology/subsea-processing-ndash-the-gamechanger.html
13. PetroMin Pipeliner, 'Deepwater Pipeline Management – Problems and Solutions', http://www.pm-pipeliner.safan.com/mag/ppl0412/t58.pdf
14. The Journal of Petroleum Technology http://www.mydigitalpublication.com/article/Offshore+Oil+and+Gas+Installation%E2%80%94Aging+and+Life+Extension/951953/0/article.html
15. Lloyd's Register report 'FPSO Inspection Repair & Maintenance, Study into Best Practice' http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/OP033.pdf
16. Naval Facilities Engineering Service Center in California http://hmrmarine.com/UWInspection.pdf
17. Offshore Technology, 'Sweating the assets…' http://www.offshore-technology.com/features/featurerecovery-techniques-lifespan-mature-oilfields-shell-engineering-production-assets-integrity-lance-cook-hydrocarbons-wireline-technology/
18. The Journal of Petroleum Technology http://www.mydigitalpublication.com/article/Offshore+Oil+and+Gas+Installation%E2%80%94Aging+and+Life+Extension/951953/0/article.html
19. James R Dale in his paper 'Subsea Pipeline Inspections http://www.dale-consulting.co.uk/docs/subsea-pipeline-inspections.pdf
20. Rigzone Group http://www.rigzonegroup.com/pdf_ndt/ultrasonic%20testing.pdf