Flexible Riser In-service Inspection: RiserSure™ a new solution

White Paper

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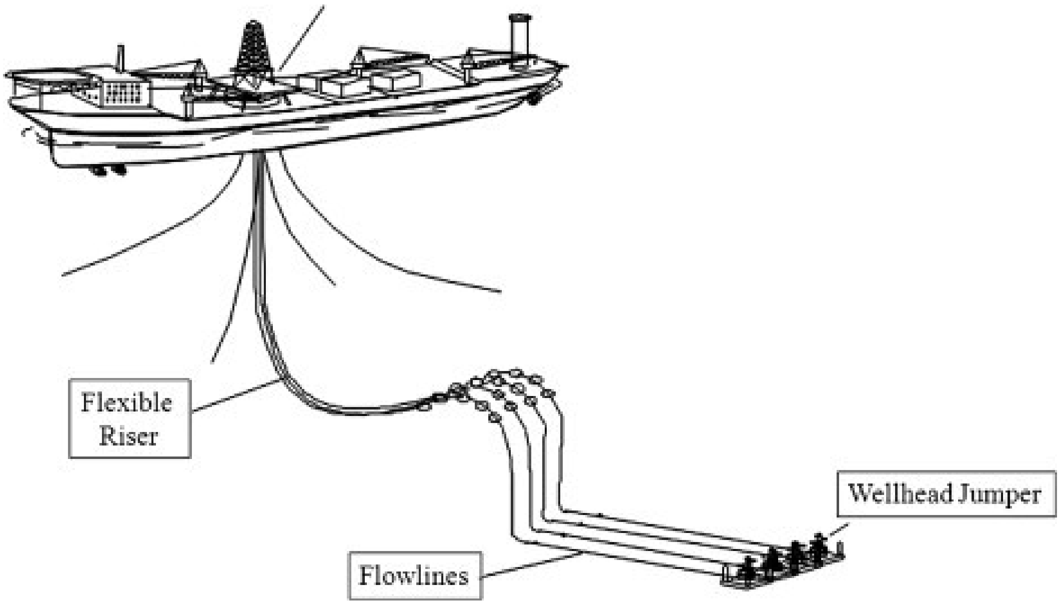
Preface

Flexible risers, in comparison to steel risers, are highly fatigue tolerant and flexible. Their deployment is increasing due to the many benefits of the use of Floating Production Storage and Offloading (FPSO) platforms. However, riser failure is increasing (typically flexible risers are being used outside their forecast service life), is costly and it damages the environment. This is driving the uptake of Non Destructive Testing (NDT) to monitor the condition of flexible risers. The conventional methods of deploying inspection systems around a riser are either by diver or remotely operated vehicle (ROV). RiserSure™ is a newly developed system for assessing the condition of flexible riser pipes widely used in offshore oil and gas production without the need for diver or ROV intervention. This white paper presents the new RiserSure™ solution, meeting the need for effective flexible riser inspection.

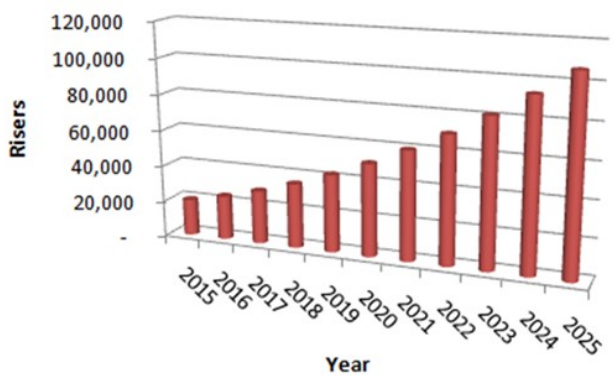
Problem Statement

Flexible risers are used to carry oil and gas from sub-sea wells to Floating Production Storage and Offloading (FPSO) vessels. They have been a successful worldwide solution for flow-line systems, shallow-water and deep water riser systems. However, due to the harsh nature of the environment, these risers are subject to fatigue over their lifetime.



Typical Flexible Riser arrangement [1]

Flexible risers have been used in the oil industry since 1972. They are used for versatile offshore oil and gas applications including production, gas lift, gas injection, water injection, and various ancillary lines including portable water and liquid chemical lines.



Forecast riser installations to 2025 based on Douglas-Westwood data

The deployment for installation of risers is growing fast with forecasts from industry analysts at Douglas-Westwood [2] sales of more than $3bn US per year in 2016 with more than $2.2bn US of expenditure in Brazil alone, equivalent to over 5000km of pipe. This corresponds to a 35% compound annual growth rate in the flexible pipe market, 58% of which is risers. If this growth were sustained, then it would create an installed base of 80,000 flexible risers by 2023. All of these risers will require integrity management and this is not currently satisfactory the goal for the industry must be to develop tools to check the pipe wall integrity as part of their integrity management to ensure regular in-service monitoring is undertaken to track how the asset ages.

Current inspection methods for flexible risers are limited. Existing techniques for inspection of flexible riser integrity are either visual inspection using divers or ROV, or automated systems using electromagnetic (eddy current) or ultrasonic techniques. Visual inspections are slow and expensive and can only detect gross damage after it has occurred. Eddy current techniques only provide information on the very outmost (steel) region of the riser. Ultrasound cannot penetrate the air-filled annulus or other discontinuities in the structure.

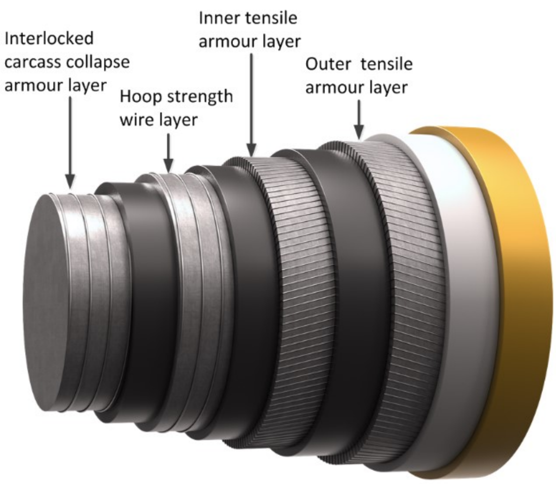
Only radiography can inspect the multiple layers within a flexible riser to provide a volumetric inspection. However traditional radiography deployment is not straight forward. Carrying out radiography, using film, is not suited for general inspection over large areas as it is too time consuming.

Digital radiography based underwater inspection offers considerable time savings over traditional radiography with radiographic images captured in near real time, with no need for the device to return to the surface to develop and process film or scan phosphor imaging plates before image interpretation.

However, commercial sub-sea radiographic inspection is in its infancy. Current systems are still undergoing initial trials and focus on deep-sea deployment using expensive remotely operated vehicles (ROVs). There is an opportunity for a lower cost system focussed on delivering high-frequency ubiquitous inspection of the high risk zone close to the surface, leaving more expensive deep-sea inspection for low frequency assessment of already-damaged, or high risk risers.

Flexible riser failure modes

Flexible risers have a complex structure and comprise a number of alternating layers of steel and polymer. The range of potential failure modes for a flexible riser is relatively large.



Typical flexible riser construction

Research undertaken by the HSE has concluded that damage to the outer sheath was regarded as one of the main reasons for water to enter the annular space and cause corrosion of the armour wires. Water can also enter

the annular space as water vapour from the bore, permeating through the inner polymer liner due the pressure in the bore [3].

An outer sheath breach can occur externally during installation, in which case seawater penetrates into the carcass of the riser with detrimental effects increasing over time. A sheath breach can also arise internally from corrosion-fatigue failure of the armour layers, general corrosion leading to metal loss, and failure of the armour wires and stress-corrosion cracking of armour wires. Ultimately, a sheath breach can be linked as an input and an output to different failure modes of risers.

Failure mode	**Failure mechanisms**	**Occurrence**
Collapse	Excessive tension, external pressure, aging of polymer	Multiple reports worldwide
Burst	Tensile armour rupture, pressure armour rupture, pressure in annulus	Outer sheath rupture is common. Rupture of tensile wires may be problematic in deep water
Tensile failure	Excessive dynamic movement, large tensile loads combined with corrosion	High risk for corroded armour in deep water
Compressive failure	Radial buckling, upheaval buckling	Bird caging of armour is a problem worldwide
Over-bending	Installation error	Used to be a problem (1990s) due to errors in installation
Torsional failure	Large dynamic loads	Risers in very harsh environments most susceptible
Fatigue	Tensile armour rupture, pressure armour rupture, aging of polymer layers, cracking of carcass	Not common unless corrosion or other factors are present
Erosion	Internal erosion of carcass	Risk when bore fluids contain sand
Corrosion	Tensile armour rupture, pressure armour rupture, corrosion of internal carcass	Common problem linked to damage of the outer sheath

Requirements for inspection

Guidelines exist for use by the operators for integrity of monitoring Unbonded Flexible Pipe [4]. BS ISO 13628-11:2007 [5] states that the inspection routines for unbonded flexible risers should be contained within an integrity management programme that is based on the risk of failure modes that the specific riser is subject to. The standard calls for NDT to be utilised for the monitoring and testing of risers. It states that these methods are to be field demonstrated and suitably qualified for measurement. The actual method and frequency of testing is to be determined based on the risk factors for each riser.

Current inspection techniques

Non-destructive testing techniques routinely form a part of the integrity management programmes for flexible risers. However, conventional techniques are ineffective and can only detect problems after they have resulted in a failure, or require removing the riser from service to perform tests internally.

Visual inspection is utilised at regular intervals to assess for gross damage of the outer layers of the pipeline. Although there is the capability, internal visual inspection using camera equipment is not routinely utilised. For inspection past the outer layers of the riser, eddy current is used, in particular for the inspection of the tensile armour wires for corrosion. One negative for both visual and eddy current techniques is the necessity for the cleaning of the pipe prior to inspection. Another limitation of eddy current testing is the depth to which it can be applied.

Radiography is an ideal technique for assessment of flexible risers. Like medical X-rays, the technique can see right through the target structure, irrespective of the number of layers or complexity of construction. Density changes in the flexible riser construction affect the absorption of radiation penetrating the riser volume which will allow the measurement of steel layer layout, detect cracks and ruptures and detect loss of material through corrosion or erosion.

Traditional radiography using film and phosphor plate detection media has been used to view the outer armour wires within the riser, with the possibility of viewing the internal wires, although the images can lack the necessary quality.

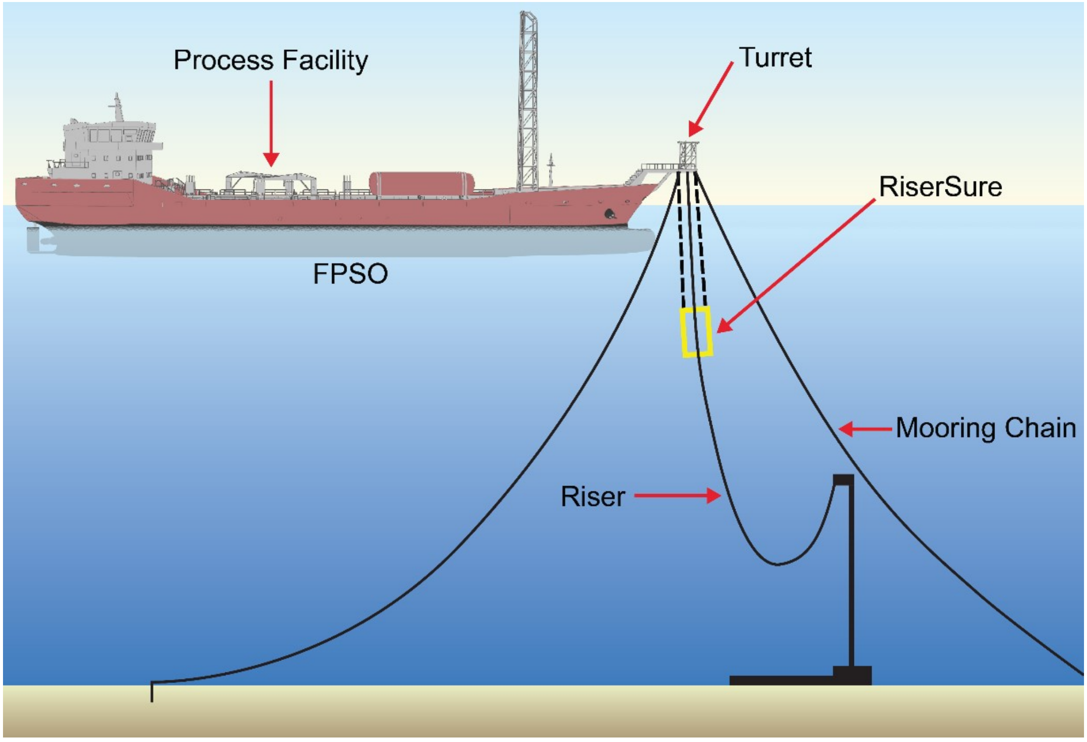
Inspection Method	**Inspection Capability**	**Notes**
Visual inspection	Outer sheath (splits in layer and bulges)	+ Easily deployed by ROV - External flaw detection only - Sea life attached to riser can inhibit visibility
Ultrasound	Detection of flooding	- Only detects defects in outer armour layer if riser annulus is flooded.
Eddy Current	Outer armour layer	+ Rapid inspection - Difficult to interpret results
Traditional Radiography (film and computed radiography)	Inspect through multiple different layers	+ Penetrates all riser layers - Use of film or phosphor plate requires processing and development topside. - Slow collection of data to topside
Digital radiography	Inspect through multiple different layers	- Current systems are still undergoing initial trials and focus on deep-sea deployment using expensive remotely operated vehicles (ROVs).

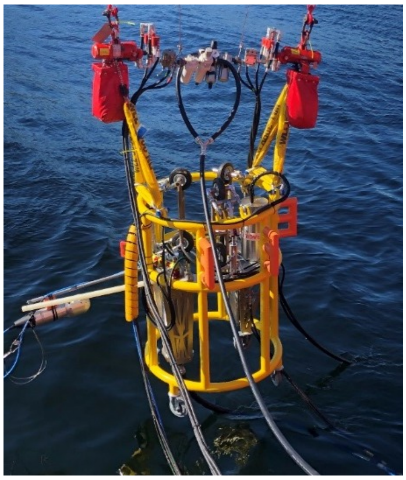
There are pros and cons associated with all of the utilised inspection techniques listed above, in the context of non-destructive testing of flexible risers. However, none of the techniques are able to effectively view all of the multi-material layers, which form the complex structure of the flexible riser, during one inspection. Inspection can also take a significant amount of time due to the length of the riser needing to be inspected. One non-destructive testing technique that has been identified as being highly suitable for the inspection of flexible risers is underwater digital radiography.

Modern digital detection technology can produce a complete image in seconds. Digital radiography is therefore fast and can produce data in real time. However, current systems based on digital radiography are still undergoing initial trials and focus on deep-sea deployment using expensive remotely operated vehicles (ROVs).

Our Approach

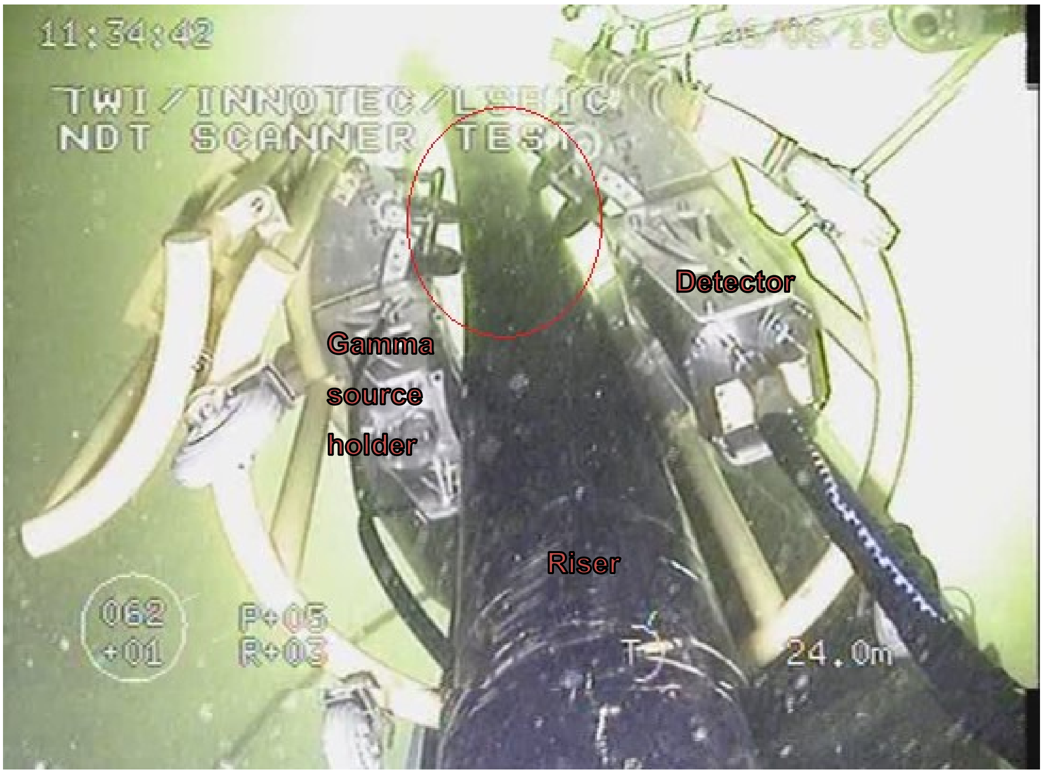
RiserSure™ can test risers without downtime, providing information on degradation in advance of actual failure. By focussing on the critical area from the splash zone down to 100m, RiserSure™ facilitates cost-effective widespread routine testing of high risk zones.



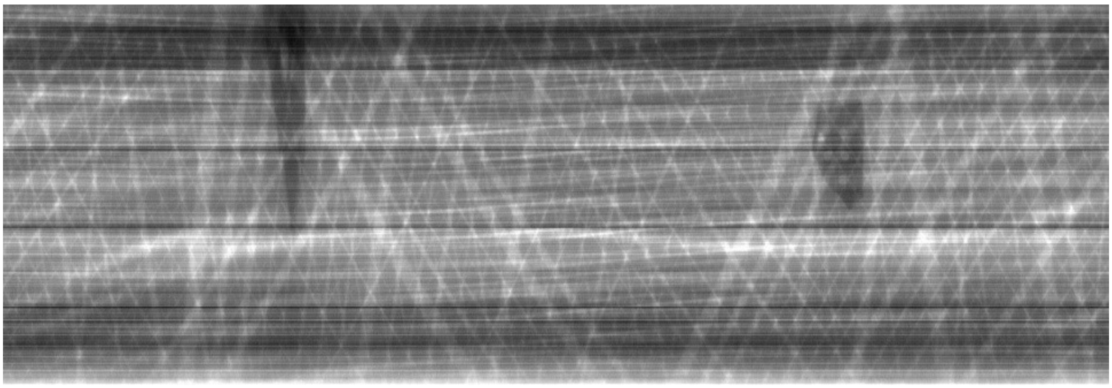


- A robotic scanner solution as used in RiserSure promotes:
  - Safety improvement: human safety as well as asset safety and the environment.
  - Cost reduction.
  - Environmental performance improvement: reduce production of (toxic) waste, prevent leakage and catastrophic events.
  - Overcomes limitations of current non-destructive inspection methods.
  - 8 times faster than current ultrasound scanning systems on the market.
  - Provides results in real time with high resolution.
  - Analyses the riser structure through all of the layers for assessment of any potential damage.

- Simple and cost-effective deployment both sub-sea and within the splash zone.
- Adaptable to different riser diameters from 100 mm to 600 mm, accommodating the full range of riser diameters in operation.
- Can scan a 100 m length of a riser in a few days compared to weeks for alternative ultrasound-based systems deployed by working class ROVs.
- Does not require ROV for shallow sea deployment, due to RiserSure's incorporated winch system



RiserSure^{TM} scanner deployed onto riser

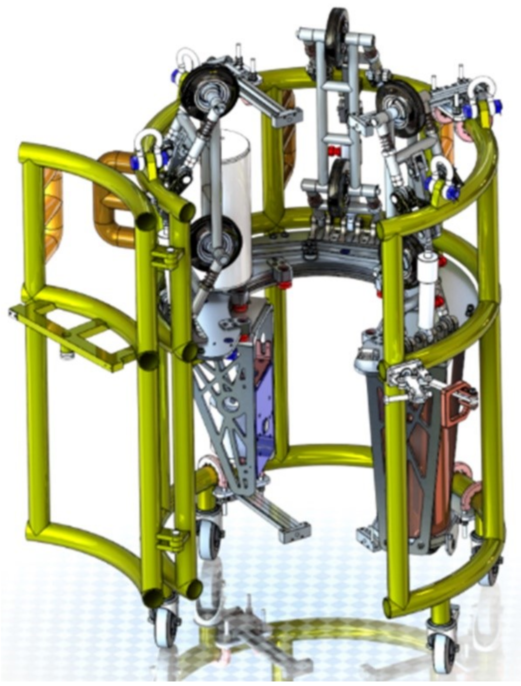


RiserSure^{TM} generated radiographic image for 250mm section length x 180° scan of riser showing artificially introduced defect

System Overview

The RiserSure^{TM} inspection system consists of robotic hardware and the digital radiographic modules. The inspection detector comprises the in-built read-out and processing circuitry. The detector outputs are transferred to the topside dedicated processing software via an Ethernet connection using an umbilical consisting of power supply lines for the detector and four twisted pairs CAT-5E Ethernet interface. The digital detector has a separate DC power supply and controller, which is supplied with the system. The source controller unit contains a pneumatic or hydraulic supply and valve system. This controls the subsea source unit to open or close the shutter for exposure. Pneumatic control can be used for underwater depths up to 20m and hydraulic control is used for depths >20m. A fail safe mechanism in the source holder ensures the exposure position is always closed when there is no pneumatic/hydraulic supply.

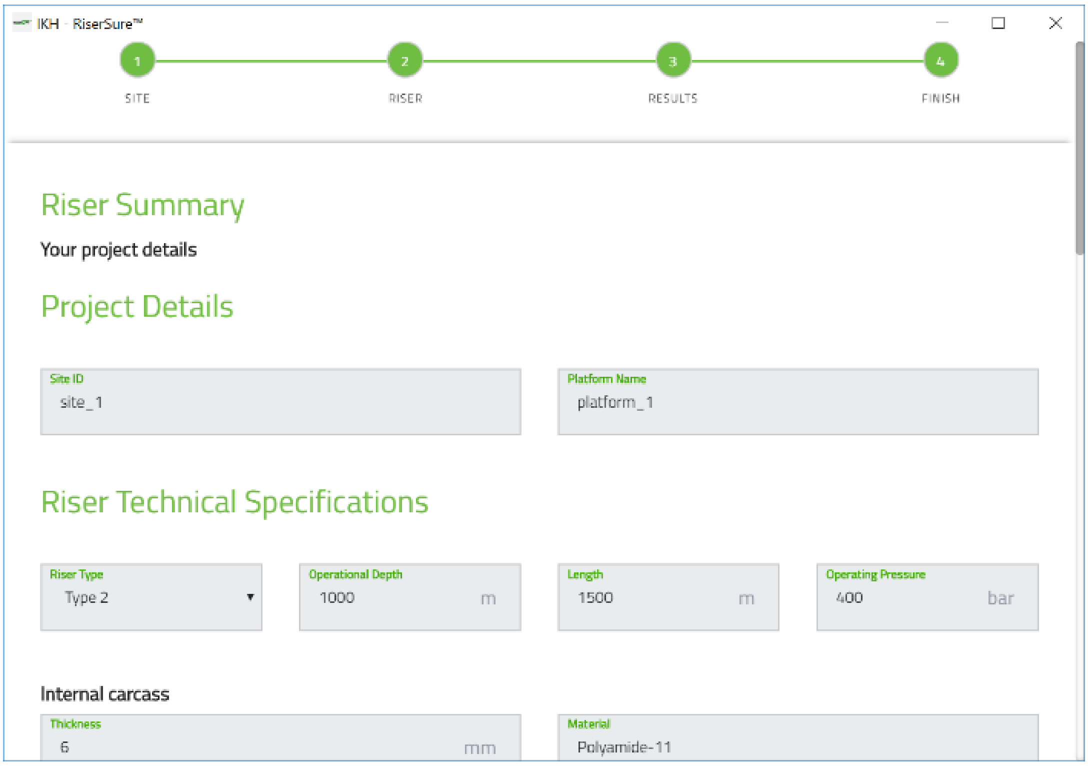
Remotely controlled actuators (3 off) on the scanner open and close to attach the scanner securely to the riser during inspection. A circular track built into the scanner frame facilitates rotation of the Gamma source and detector about the axis of the riser to achieve the digital radiography images using the double wall single image radiography technique.



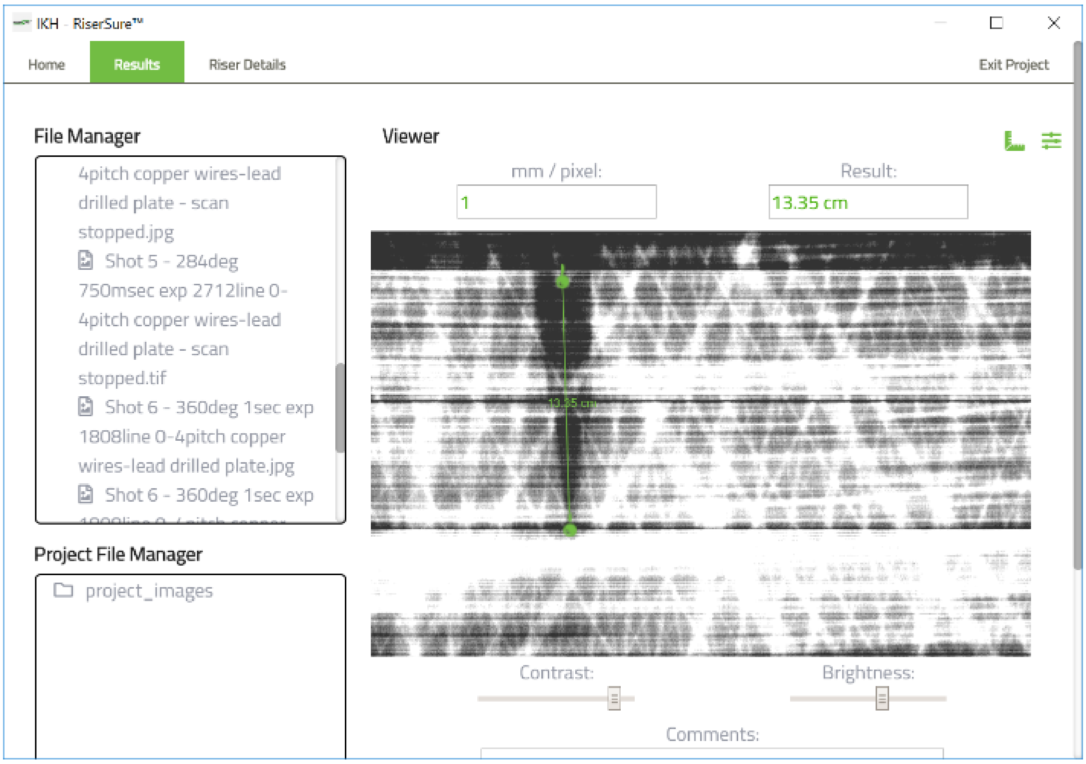
RiserSure^{TM} robot scanner

The supervisory control on the topside is a GUI (graphical user interface) based system. This includes the control of system operational modes based on user inputs and internal system parameters, monitoring of critical parameters of subsea units, display of system status and warnings of system errors.

The system also includes a project-based top-level GUI which allows aggregation of inspection data in the form of scan images, comments. Using this GUI, the end-user is able to create new projects, enter riser details, view camera live streams, organize and post-process scan images in order to examine the riser for defects, as well as generate PDFs of the inspection reports.



GUI software screen shots



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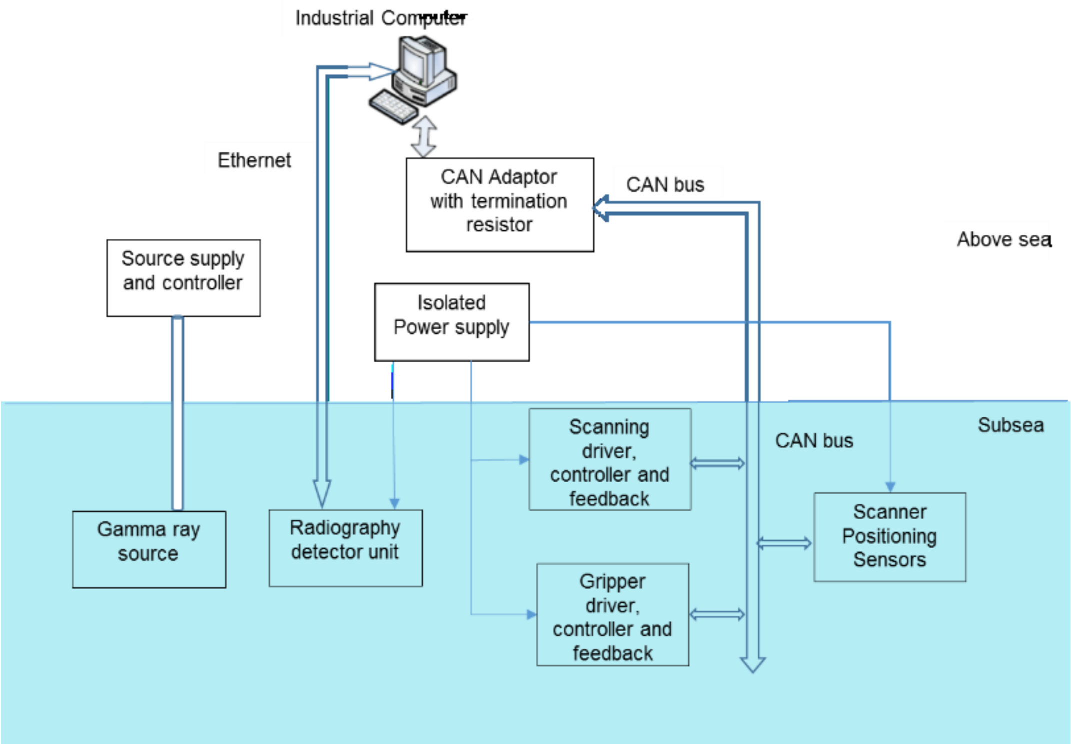

RiserSure™ System overview

Technical Specifications

Target Component:	
Typical Riser diameter	200 - 270mm diameter (Default setup on RiserSure^{TM}). Other diameters accommodated by custom adaptors.
Max. internal metal layer thickness	60-80mm
Scanner deployment:	
Deployment mechanism	Integrated overhead winch system or ROV.
Deck mobility	Four castor wheels
Current operating depth	100m
Scanner:	
Construction	Stainless steel 316L to be compatible with subsea requirements (BS EN ISO 13628:1:2005).
Scanner size	114cm overall diameter, 110cm height
Total weight	Max 170kg (depending on configuration)
Topside supplies required:	Pneumatic (70 psi to 150 psi), hydraulic and 230VAC 50Hz Mains voltage
Inspection method:	
Radiography Technique	Double Wall Single Image
Stand-off distance	20mm between detector/source from riser surface
Gamma radiography energy	Ir192 20Ci - 30Ci
Active detection area	250mm
Minimum scan speed	0.03 rpm
Typical image acquisition time	18 minutes for a 220mm diameter x 250mm long riser section

Market Review

An extensive market analysis, including a PESTEL and SWOT analysis, disclosed that the main drivers for the end users to choose a robotic solution such as RiserSure are:

- Safety improvement; human safety as well as environmental, asset safety.
- Cost avoidance and reduction.
- Environmental performance improvement; reduce production of (toxic) waste, prevent leakage and catastrophic events.

Safety factors: RiserSure is a rapid inspection system, allowing the examination of flexible risers in shorter time frames, reducing the risk to human operators and surrounding assets. RiserSure employs a novel digital radiography detector, which is 8-times faster than ultrasound scanning and can be performed in real-time with high resolution, on the complex flexible riser structures.

Cost determining factors: Competitive systems are still undergoing initial trials and focus on deep-sea deployment using expensive ROVs throughout the whole operation. RiserSure is a lower cost system focussed on delivering frequent ubiquitous inspection of the high-risk zone close to the water zone. Other cost-intensive aspects relate to not needing the transport of a crew to a remote site and the number of People On Board (POB) assigned to the installation/facility is reduced. In terms of inspection time, RiserSure can scan a 100 m length of a riser in a few days compared to weeks for alternative ultrasound-based systems a significant operational cost saving.

Environmental and safety legislation: Sub-sea inspection and maintenance operators have to comply with strict environmental and safety legislation such as the 2013 EU Offshore Safety Directive. By utilising RiserSure, which is able to analyse the riser structure through all of the layers and analyse any potential damage, performing continuous periodic inspections, this legislation is followed.

Conclusion

Current NDT systems on the market are based on visual, ultrasonic, or electromagnetic (eddy current) techniques which suffer a number of drawbacks including inability to penetrate the complex riser structure, requirements for close contact between the scanner and the pipe surface making the system inoperable on fouled pipes, slow or impractical operating modes, and often require large and expensive ROV’s to operate the system.

RiserSure™ is designed specifically for riser inspection, allowing simple and cost-effective deployment both sub-sea and within the splash zone. The novel digital radiography technology provides rapid, real time, high resolution scanning of the complex riser structure.

RiserSure™ offers the following advantages compared to existing solutions:

- 100 m depth range covers the highest risk area of the riser structure where more frequent monitoring of more risers will deliver the maximum benefit in reduced risk of serious incidents.
- Enables operators to demonstrably comply with environmental and safety legislation such as the 2013 EU Offshore Safety Directive
- Reduce the risk of costly environmental damage and improve personnel safety. This will also benefit society by reducing the risk of accidents and environmental damage from offshore oil and gas production.
- Cost-effective solution enables intensive continuous inspection regime for high risk areas.

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