HOIS
Advancing NDT

Issue 1: August 2019

HOIS Joint Industry Project:
Good practice for NDT in the energy industry

Highlights for 2018/19

Membership

The total number of HOIS members was 40. Membership comprised twelve category 1 members (oil & gas producing companies) and twenty-eight category 2 members (inspection service companies, inspection equipment suppliers and notified/appointed bodies). The UK Health and Safety Executive and the Oil and Gas Technology Centre (OGTC) are also members.

The OGTC have provided valuable additional support which allowed several HOIS projects to be expanded in scope and accelerated in delivery.

Category 1 Members	Category 2 Members	
ADNOC Gas Processing (GASCO Abu Dhabi)	Aker Solutions	Innospection
ConocoPhillips	Applus+ RTD	Inspectahire
DOW	Baugh & Weedon, Ether NDE	ISQ
Equinor	Bilfinger	Lloyd's Register
Gassco	Bureau Veritas	Mistras Group
Marathon Oil	CAN	Oceaneering International
Nexen Petroleum U.K. Ltd.	Cybernetix	Olympus NDT
Petrobras	DNV GL	Rosen Group
Repsol Sinopec Resources UK Ltd.	Doosan Babcock Ltd.	SGS
Saudi Aramco	Eddyfi Technologies	Sonomatic Ltd.
Shell	FujiFilm Corporation	Stork, a Fluor Company
Total	GE Inspection Technologies	The OGTC
	Guided Ultrasonics Ltd.	TRAC Oil and Gas
	HSE	TÜV Rheinland Sonovation

Total subscription income was >£700,000. Together with substantial matched funding from the OGTC on three individual projects, the total income was ~£850,000, which gave substantial gearing for each member's subscription (£33k for oil & gas company members, £11k for inspection service/vendor company members, the OGTC and HSE).

Technical Programme

1. Corrosion under insulation (CUI) and external corrosion

Main highlights: Substantial trial programme almost complete. Trial samples were designed to investigate the effects of the severity of corrosion, pipe wall thickness, geometry, cladding type, insulation thickness, hanger supports, heating tracing and chicken wire on detectability and sizing of corrosion under insulation.

This ambitious and strategic project on the inspection of external corrosion under insulation (CUI) and without insulation through corrosion scabs started in 2017 and is expected to conclude in 2019. This project is supported by The Oil and Gas Technology Centre and is designed to develop and focus the HOIS resources and capabilities for conducting rigorously controlled independent evaluation trials and to compare different inspection methods for these challenging problems. CUI occurs due to moisture build-up on the external surface of insulated equipment where any coating has broken down. If undetected, the results of CUI can lead to the shutdown of a process unit or an

entire facility and can lead to a process safety incident. The cost associated with mitigating CUI is high – corrosion is said to cost the UK economy £28 billion every year with that figure rising to £4 trillion globally (OGTC figures).

This HOIS project has greatly improved available benchmarking capabilities through the in-house design and build of an internal UT scanner for corrosion mapping deployed from the inside of a pipe. The probe, scanning, data collection and processing are in full accordance with the HOIS recommended practice for precision UT thickness measurements. This allows accurate measurements of remaining thickness to be made. The scanner has been used to benchmark ex-service samples with external corrosion scabs for which no information on remaining wall thickness has previously been available.

Clad and insulated test components for trials.

Test pieces exhibiting simulated wall loss based upon ex-service corrosion morphologies were designed and manufactured. The purpose of these samples was to investigate the effect of variables such as the amount of wall loss (severity of corrosion), pipe wall thickness and geometry, cladding type (stainless and galvanised steel), insulation thickness (50mm and 100mm), and the presence of hanger supports, heat tracing and chicken wire. All samples have been extensively benchmarked and have simulated scabs over the areas of corrosion. Four of the manufactured test pieces remain un-insulated.

An extensive trial programme is underway with all trials being performed (and reported) with both 100mm of insulation and then 50mm of insulation. The trials performed included three types of pulsed eddy current inspection (Eddyfi Lyft, TUV Sonovation SonoPEC and Maxwell NDT PECT), a developmental electromagnetic technique (giant magnetostrictive sensor arrays, GMR from the Robinson Research Institute), a multi-frequency eddy current technique (Exxam Systems), the Russell NDE Bracelet Probe and three different forms of radiography. The trials were conducted at the HOIS trial facility in Oxfordshire and attracted participants from as far away as New Zealand (Robinson Research Institute), Canada (Russel NDE) and the West Coast of the US (Exxam Systems).

ESR has calculated mean probability of detection (POD) values and false call rates for each trial and derived POD curves using MIL 1823 curve fitting software as in previous HOIS trials. These allow assessment of the effects of wall thickness, insulation thickness and other variables on POD for the CUI in these pipes. Where reported, sizing accuracy has also been assessed. A detailed trial report will be available to HOIS members in 2019 and the final guidance document will be publicly available.

2. Corrosion under pipe supports (CUPS)

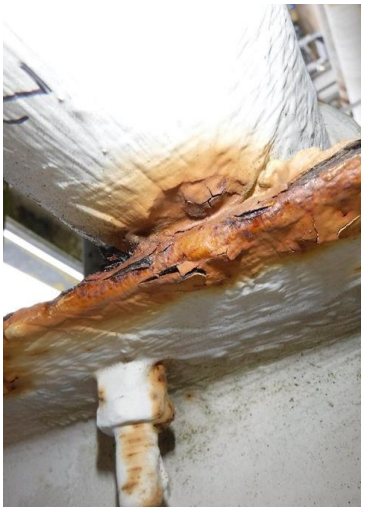
Main highlights: Trial report issued to all HOIS members containing results of trials of Oceaneering and ESR Technology M-skip, an Oceaneering medium range guided wave ultrasonic technique, Applus+ RTD long range phased array, Mistras touch-point corrosion and Guided Ultrasonics' QSR1. The results have informed a major revision of the HOIS guidance for the inspection of corrosion under pipe supports

In-service corrosion under pipe supports is an active area of concern in the energy industry because of the risk of loss of containment – several in-service leaks and ruptures have been attributed to this form of degradation. In 2016 HOIS issued a guidance document on inspection of CUPS based on trial results. However, recent developments have required further independently validated trial data demonstrating the accuracy and detection capability of techniques and equipment new to the market. As a result, a new project was started in 2017 to add to the existing body of HOIS work on inspection of corrosion under pipe supports.

The samples available in the HOIS trial program (including pipes with simulated corrosion based upon ex-service thin-walled samples, where corrosion had occurred between the pipes and supporting flat beams) offer a unique opportunity to do this and, importantly, for the performance of the different techniques to be compared directly on the same samples.

The trials have taken place using the following techniques: M-skip (Oceaneering and ESR Technology), a medium range guided wave ultrasonic technique (Oceaneering), long range phased array (Applus+ RTD), touch-point corrosion (Mistras) and QSR1 (Guided Ultrasonics).

This project has also included a case study on an ex-service component which had visual indications of active corrosion, but subsequent removal and blasting (after multiple inspection trials) have shown only minimal amounts of corrosion. The NDT methods applied in-service indicated the presence of significant corrosion in a small-bore pipe at a U-bolt support which led to its removal from service, following a shutdown. Subsequently it was shown that only minor wall loss was present. Hence those who act on the results from site NDT should be aware that there is the possibility that some areas of significant CUPS reported may have substantially less wall loss than indicated by the NDT.



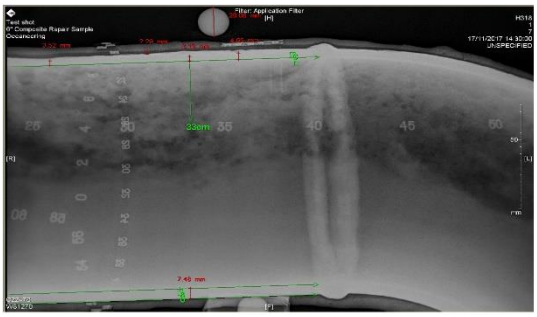
Photograph of 2" U-bolt sample with visible signs of corrosion at the contact point with flat beam support.

Screening and the demonstration of the absence of corrosion can be useful for CUPS NDT but the focus of the HOIS projects has been on the challenging requirement (due to inaccessibility of the corrosion) of the accurate sizing of the remaining ligament. The most promising overall quantitative methods trialled so far in all HOIS CUPS projects include Tangential radiography (for small bore pipes only) but with coverage usually limited to 6 'clock position. For larger diameter, thin walled pipes QSR1 and the ultrasonic M-skip method for thicker walled pipes if probe separation can be small enough to measure skip 2 (avoids double counting of wall loss). Amplitude based ultrasonic methods, based both on bulk and guided waves, some used in pulse-echo and others in pitch catch gave less accurate sizing information.

These results (made available to HOIS members in the report HOIS-R-012) will be used to update the HOIS guidance for the inspection of corrosion under pipe supports. The guidance considered the different forms of inspection that may be required for pipe supports: fast screening (to identify those requiring further assessment), screening, quantitative through wall sizing and demonstration of the absence of corrosion. The updated guidance (HOIS-G-018) was made available to HOIS members in June 2018.

3. Inspection of composite repairs

Main highlights: Completion of a trial programme to evaluate independently the performance of NDT methods used for inspection of composite overwrap repairs. Report issued to HOIS members on trials performed using digital radiography, pulsed eddy current, dynamic response spectroscopy, MEC and shearography.



Digital radiograph of a composite repair (courtesy Oceaneering)

Engineered composite repairs, with a defined life, are being increasingly applied to degraded components on ageing assets, particularly offshore platforms, to continue their safe, reliable operation.

The usage of composite repairs during their lifetime is becoming a focus of regulatory bodies, with a need to demonstrate continuing fitness for service by monitoring any changes to the degradation under the repair, as well as the condition of the repair itself. In addition, there can be pressure from operators to extend defined life repairs as they seek to increase the period between planned outages.

The aim of this project is to develop guidance for the inspection of composite repairs, following completion of a trial programme to provide independent verification of the capability and data quality of composite repair inspection using current industry practices.

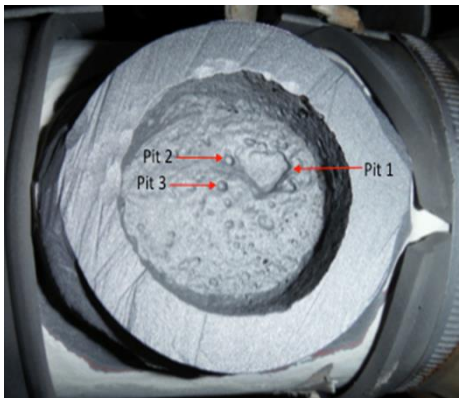
A blind trial inspection programme using a combination of donated ex-service and manufactured components has been completed. Trials were performed using digital RT (CAN, TRAC and Oceaneering), PEC (Eddyfi LYFT deployed by Oceaneering, and CAN; TUV Sonovation SonoPEC, PECT deployed by TRAC), Microwave (Sonomatic & NPL), Dynamic Response Spectroscopy (DRS, Sonomatic), MEC (Innospection), Shearography (NPL).

The reported results (HOIS-R-013) were compared to benchmark measurements following removal of the composite repair. The trial report has been delivered to HOIS members and the hold point lifted to proceed to the development of HOIS guidance for the inspection of composite repairs. This HOIS project has collaborated with an HSE shared research project on engineered composite repairs.

4. Inspection guidance for corrosion at trunnion pipe supports

Main highlight: Open and blind trial sample set established with a mixture of donated ex-service and manufactured samples. Two trials of guided bulk wave techniques already completed with further trials planned.

Pipe support trunnions are a common means to support pipework on process plant and offshore. In common with other pipe support types, trunnions do not permit visual inspection of the areas most susceptible to corrosion. However, the attachment weld around the trunnion and the curvature of the pipe at many trunnion supports are likely to make inspection even more challenging than corrosion at flat beam or saddle type supports.



Case study: ex-service trunnion with challenging to inspection corrosion morphology.

The likelihood of failure of process pipework supported by trunnions, and associated hydrocarbon release, increases with the ageing asset profile on the UKCS. The HSE is increasingly investigating such failures and the approach of duty holders to manage and inspect trunnions on ageing assets/process plant.

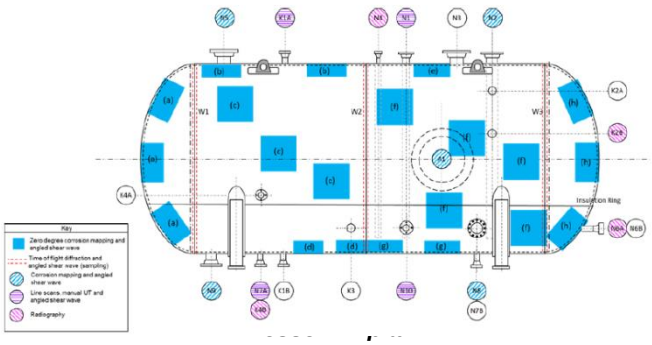
This topic aligns well with the Oil and Gas Technology Centre's priorities and a proposal to them succeeded in securing additional funds to expand the trial phase of the HOIS project.

A set of blind trial samples consisting of donated ex-service components and manufactured samples has been assembled. The samples are designed to investigate the effect of the weld, the location of the corrosion (including proximity of corrosion to the weld) on the ability of potential inspection methods to detect and, if possible, quantify the extent of corrosion within pipe supports. Two trials of guided bulk wave methods have been completed with further trials of the Verkade method, radiography and M-skip planned. The ex-service test pieces have also been examined using video borescopes through the weep holes as a comparison to the information obtained from the NDT trials. The final deliverable will be a guidance document giving an overview of trunnions, potential failure modes and a good practice approach to the management and inspection of trunnions.

5. Updating DNV GL RP G103 and HOIS guidance notes

Main highlight: The submission of a revised version of HOIS DNV GL RP G103 to DNV GL for publication in 2019. Development of HOIS guidance notes to facilitate familiarisation with the key elements of the RP.

DNV GL RP G103 is a widely used industry document which was formulated by HOIS and originally published in 2007 before being updated in 2011. The document provides guidance on the use of non-intrusive inspection (NII) as the primary means of establishing the internal condition of pressure vessels. In these circumstances NII is used as a replacement for, or deferment of, internal visual inspection (IVI).



NII is one of the areas of focus of the OGTC who are working to eliminate the impact of asset integrity on operational uptime and achieve no vessel entry for inspection of the pressure boundary by 2026. NII has both safety and economic benefits.

HOIS has undertaken extensive revisions comprising a simplified approach to inspection strategy selection, updates to inspection techniques, a more quantified approach to inspection performance and coverage requirements, further advice on the storage and management of inspection data and assessment of conformance. There are new appendices to update the review of non-intrusive NDT methods, the design of vessels for inspectability, NII for a first in-service inspection and special considerations for repeat NII, clad vessels and a summary which describes the results of the HOIS NII vs IVI project.

The G103 RP is a comprehensive and detailed document. Effective application of the NII process relies on the user of the RP becoming familiar with the key elements of the document. With financial support from the OGTC, HOIS has developed guidance notes as a user guide to facilitate this familiarisation. The guidance notes highlight the key parts of the process, provide worked examples and address a range of frequently asked questions.

The aim of both these HOIS-developed documents is to increase the consistency of inspections carried out on pressure vessels thereby reducing the risk of loss of containment and minimising risk to personnel during vessel operation. The substantial revised version of DNV GL RP G103 will be published in September 2019. To coincide with this the HOIS guidance notes will be issued and a launch event, hosted by the OGTC, will be held to raise awareness.

6. External pitting and SCC in uncoated stainless-steel components

Main highlight: Information gathering phase has been completed and a phase 1 report issued. Trials of Eddy Current Array technologies planned on ex-service and manufactured samples.

The corrosion resistance of 316 and other stainless steels which come in to contact with saltwater is limited, consequently, the material is at risk of external crevice and pitting corrosion which can be precursors to chloride induced stress corrosion cracking (SCC). On newer assets, this is mitigated by coating components. However, there is a considerable amount of uncoated stainless steel on ageing assets at risk of this form of degradation which is challenging to detect and size in the through-wall direction.

Fine pitting and cracking on a SS component

HOIS has issued a phase 1 report (HOIS-R-016 Issue 2) for this project, which started in April 2018, containing the results of an information gathering exercise. Current inspection practice is generally the use of visual inspection followed by dye penetrant testing (PT) (although this does not provide through wall depth sizing and requires effective surface cleaning/preparation). The main method to trial in the next phase of work will be Eddy Current Arrays. The extent to which ECA can detect and provide depth sizing information for small pits and SCC has not yet been independently assessed.

An appeal for ex-service samples for HOIS blind trials was successful. The trial samples include of two ex-service stainless steel pipes, one plate exhibiting manufactured cracks and two pipes with manufactured small holes of varying diameters and depths to simulate fine pitting.

7. Clad vessel inspection guidance

Main highlight: Publication of a review of the previous trial-based project and the damage mechanisms and the approach to NII for internally clad vessels. Further trials of the most promising techniques identified in the original trial programme. The results will inform the development of HOIS guidance for clad vessel non-intrusive inspection.

Corrosion resistant alloy (CRA) clad vessels pose particular challenges for NII due to the differing types of cladding in use, and their degradation mechanisms which frequently include small pitting and fine stress corrosion cracking (SCC).

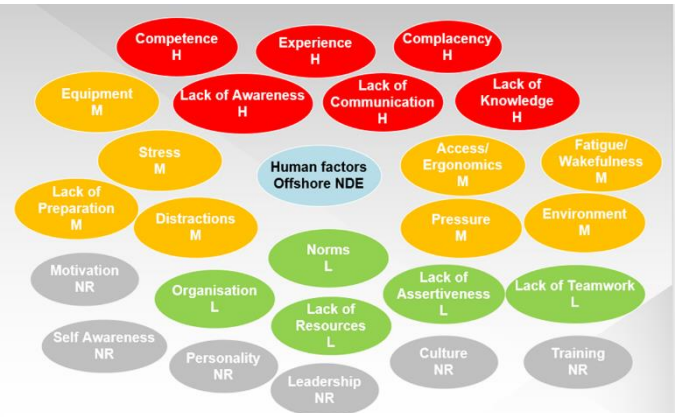
HOIS completed a project which trialled NII methods for detection of in-service and manufactured flaws. Test samples included the ex-service CRA clad vessel, a manufactured weld overlay plate and an ex-service heat exchanger plate with hot rolled cladding. The open and blind trials provided some information on the capabilities of different ultrasonic inspection methods for detection of various forms of degradation in the cladding itself and at the cladding/vessel interface.

Ex-service CRA clad vessel installed at ESR Warrington and micrograph of SCC

This follow on project, which started in April 2018, seeks to use the trial results (issued in HOIS-R-002) to develop guidance on how to conduct NII of this particularly challenging subset of pressure vessels. The first phase of this project issued a report (HOIS-R-014) containing a short review of the damage mechanisms and the approach to NII for internally clad vessels, a review and gap analysis of the previous trial based work, a review and feasibility of alternative and difficult to trial methods and a proposal for further trials using the most promising techniques identified in the original trial programme. These trials are ongoing.

8. Human Factors aspects of non-destructive testing in the offshore Oil and Gas Industry

Main highlights: Four significant human factors in NDT guidance documents have been issued. A human factors working group has been established to maintain a HOIS interest in this area.



Human factors in NDE

Human factors affect all stages of the inspection process and are influenced by environmental factors such as ergonomics, temperature and shift time as well as the ethos of the companies. Prior to this project, there was little guidance on the human factors affecting the various stages of an offshore inspection work scope and how to minimise their effects.

The HOIS human factors project has delivered 4 guidance documents on the mitigation of the effects of human factors on NDT inspection. The reports cover general guidance as well as specific documents on reporting protocol for IVI of pressure vessels, visual inspection for corrosion and also manual UT for corrosion mapping.

Key mitigating factors identified were training on corrosion awareness and the specific in-service inspection methods used; inspectors familiarity with the offshore environment (Competence, Environment, Distraction); access issues addressed and logged prior to inspection and in reporting (Preparation); good briefings and communication by inspection engineer (Communication); and keeping asset database and plant drawings up-to-date (Awareness).

The activity this year has focussed on updating the guidance following comments by HOIS members and experience of their use in the field. A Human Factors Working Group has been established which aims to meet twice a year.

Other projects:

In addition to the above highlighted activities, other HOIS technical management projects comprised:

- **HOIS Interactive Knowledge Base (IKB) on NDT** – Continued updating of information and maintenance.
- **FPSO, flexible risers and subsea working group** – Annual meeting held March 2019.

Sample trial and storage ('NICE') Facility

Inside the NICE sample storage facility

The HOIS trial and sample storage facility (referred to as the 'National Inventory of Corroded Equipment' or NICE) continues to play an important role by providing trial facilities for several HOIS projects.

The facility houses many ex-service components with examples of weld corrosion, flange face corrosion, external corrosion scabs, corrosion under pipe supports and inside trunnions, supplied by several of the category 1 HOIS members.

Several rigorously controlled blind trials of inspection techniques have been performed on these samples by HOIS category 2 members, hosted by ESR Technology, primarily for the HOIS projects on inspection of external corrosion, corrosion under insulation and trunnions.

HOIS members may also commission ESR to host technique validation and inspector competence verification trials outside of HOIS, using this facility. Non-HOIS members may also access the samples, with member agreement and payment of a small access fee to HOIS.

Member Benefits

Members gain access to, and have rights to exploit, the results arising from an annual programme of work, currently with a value of over £850,000 (including additional support from the OGTC). The main aim is to achieve more reliable and cost-effective NDT, and hence improved operational safety.

Members have identified the following key benefits from participation in HOIS:

- Assessment of the capability of existing and developmental inspection technologies from independent, rigorously conducted blind trials.
- Access to HOIS-developed improved procedures and guidance documents on specific NDT applications.
- Better understanding and increased reliability of inspection.
- HOIS is recognised by regulatory bodies as a group that helps to develop best practice and improvements in integrity monitoring of oil and gas plant/equipment. The HSE are active members and HOIS allows insight into HSE priorities. Active participation within HOIS is an example of working towards the development of standards which Duty Holders must demonstrate to comply with SCR 2015 Regulation 32 – Offshore installations (Offshore Safety Directive) Regulations 2015.
- Membership of the leading forum on oil & gas in-service NDT - the three main HOIS meetings a year (one hosted by a HOIS member) provide an opportunity for networking, where oil & gas plant operators and service companies meet and exchange ideas and views on NDT needs and developments. This allows operators to be more informed buyers of services and inspection service providers gain insight into operator priorities.
- HOIS members can propose and support projects which address their own inspection challenges.
- HOIS is a good vehicle to address technology gaps that need medium term technical development, for which individual member companies cannot justify "going it alone".
- HOIS members may commission ESR to host technique validation and inspector competence trials outside of HOIS, using the well benchmarked samples within the NICE facility and the ex-service pressure vessels at ESR Warrington.
- HOIS is recognised as an industry leader in identifying future requirements in both the service sector and research arena. This is of particular interest to many of the larger inspection service providers, who are also able to licence any technological developments arising from projects.
- Access to the HOIS members only website, which contains all information (reports, presentations etc.) generated since the start of the present HOIS Agreement in April 1999.

Interested in joining HOIS?

HOIS has a publicly accessible website at: www.hois.co.uk.

Further information on HOIS can also be obtained from:

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