HOIS Joint Industry Project:
Good practice for NDT in the oil and gas industry

Highlights for 2017/18

Membership

The total number of HOIS members was 40 for 2017/18. 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 is also a member.

The Oil and Gas Technology Centre (OGTC) joined HOIS in 2017/18 and provided valuable additional support which allowed a number of HOIS projects to be expanded in scope and accelerated in delivery.

Category 1 members	Category 2 members	
ConocoPhillips	Aker Solutions	Innospection
DOW	Applus RTD	Inspectahire
Equinor (known as Statoil until 2018)	Baugh & Weedon, Ether NDE	ISQ
Gasco Abu Dhabi Gas Industries Ltd	Bilfinger	Lloyds 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	Sonovation TUV Rheinland
Total	GE Inspection Technologies	Stork, a Fluor Company
	Guided Ultrasonics Ltd	The OGTC
	HSE	TRAC Oil and Gas

Total subscription income in the year 2017/18 was >£670,000 which gave substantial gearing for each member's subscription (£29.85k for oil & gas company members, £9.95k for inspection service/vendor company members and HSE).

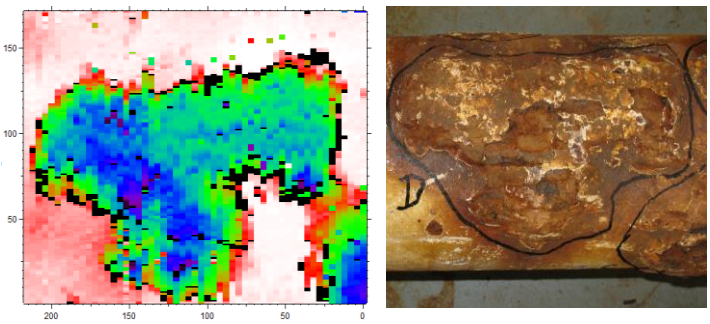
Technical Programme

1. Corrosion under insulation (CUI) and external corrosion

Main highlights: The development of an in-house internal ultrasonic (UT) scanner for corrosion mapping deployed from the inside of the pipe. The substantial extension of the HOIS specimen database through the design and manufacture of specimens with CNC machined areas of wall loss based on real UT data maps of in-service degradation.

This ambitious and strategic project started in 2017 and is expected to conclude in 2019, on the inspection of external corrosion under insulation (CUI) and without insulation through corrosion scabs. 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. 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).



Benchmark internal UT scan of an externally corroded area using the in-house scanner.

This HOIS project has greatly improving 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 scanner has been designed to allow scanning of pipes with outer diameters between 6" and 12. Data is collected using a TD Pocket Scan and 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 specimens with external corrosion scabs for which no information on remaining wall thickness has previously been available.

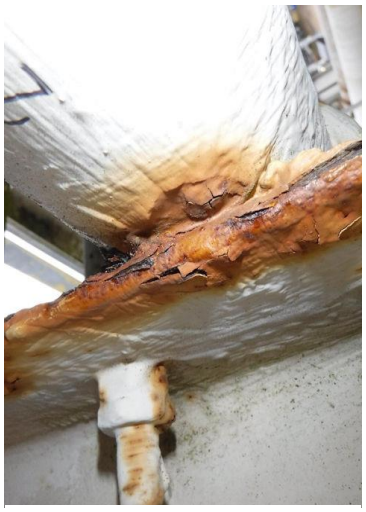
The HOIS specimen database of externally corroded specimens has been substantially extended through the design and manufacture of 12 additional specimens. These have areas of wall loss based on information from ex-service corrosion morphology (obtained previously by internal UT scanning) CNC machined into the external pipe wall. The specimens have been designed to investigate the effect of variables such as the amount of wall loss (severity of corrosion), pipe wall thickness and geometry, cladding type (stainless & galvanised steel), insulation thickness (50mm and 100mm), and the presence of hanger supports, heat tracing & chicken wire. All specimens have been extensively benchmarked and have simulated scabs over the areas of corrosion. Four of the manufactured test pieces remain un-insulated.

The trials are scheduled for the HOIS 2018/19 year and include three types of pulsed eddy current inspection: Eddyfi Lyft, TUV Sonovation SonoPEC and Ether NDE/Maxwell NDT PECT, a developmental electromagnetic technique (giant magnetostrictive sensor arrays, GMR), a multi-frequency eddy current technique (EXXAM Systems), the Russell NDE Bracelet Probe and radiography. CUI trials will be performed first on specimens with 100mm of insulation. After trial participants have reported their results they will be invited back for a second round of trials with thinner (50mm) insulation.

2. Corrosion under pipe supports

Main highlights: Six further trials on newly procured (CNC machined pipes based on laser scanning of service induced degradation) and existing CUPS specimens. Two case-studies have highlighted the possibility that some areas of significant CUPS reported may have less wall loss than indicated by NDT and the application of alternative methods ise recommended.

In-service corrosion under pipe supports (CUPS) is an active area of concern in the oil & gas 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 published a guidance document on inspection of CUPS based on trial results. However recent developments have required further independent validated trial data demonstrating the accuracy and detection capability of techniques and equipment new to the market. A project 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 offer a unique opportunity to do this and, importantly, for the performance of the different techniques to be compared directly on the same specimens.



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

This project has allowed extension of the HOIS specimen database with 22, 1m long, 10” nominal bore samples either schedule 40 or 80. These had areas of corrosion CNC machined into the pipes based on Creaform 3D laser scan data from ex-service thin-walled specimens which had previously been donated to HOIS by Shell. These ex-service samples had corrosion that occurred when pipes were supported by flat beams (i.e. touch point corrosion).

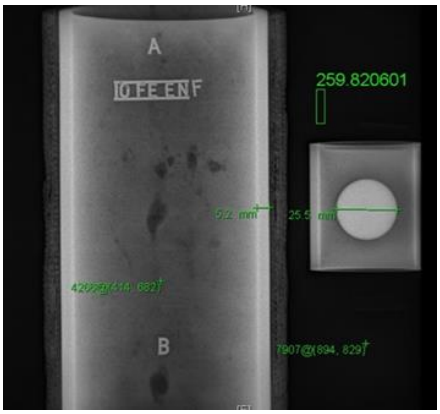
The trials have taken place of the following techniques: Oceaneering and ESR Technology M-skip, an Oceaneering medium range guided wave ultrasonic technique, Applus RTD long range phased array, Mistras touch-point corrosion and Guided Ultrasonics QSR1.

A trial report will be issued early in the 2018/19 HOIS year and the results used to update the guidance document. 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. Application of additional and alternative methods is recommended. For the U-bolt case study, some further NDT trials conducted by HOIS members also indicated the presence of significant levels of corrosion whereas a re-interpretation of the site NDT data led to considerable doubts regarding the amount of corrosion present. Radiography based on improved interpretation and combined double wall double image and oblique tangential images and M-skip did not show any major wall loss. Subsequent destructive examination and laser scanning showed only minor pitting corrosion to be present.

The trial report will inform the development of revised HOIS guidance for the inspection of corrosion under pipe supports.

3. Inspection of composite repairs

Main highlights: The trial programme to evaluate independently the performance of NDT methods used for inspection of composite overwrap repairs is close to completion with results obtained from digital radiography, pulsed eddy current, dynamic response spectroscopy, MEC and shearography. A paper and presentation at the 57th Annual BINDT Nottingham Conference was presented in September 2018.



Digital radiograph of a composite repair (courtesy CAN)

Engineered composite repairs, with a defined life, are being increasing 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 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.

Several test components, mostly ex-service, have been assembled and NDT trials performed using digital RT (CAN, TRAC and Oceaneering), PEC (Eddyfi LYFT deployed by Oceaneering, & CAN; TUV Sonovation SonoPEC, PECT deployed by TRAC), Microwave (Sonomatic & NPL), Dynamic Response Spectroscopy (DRS, Sonomatic), MEC (Innospection), Shearography (NPL) and the GE RotoArray phased array roller probe.

The digital RT was mostly successful in showing the locations and extents of pitting type defects in ex-service components, however a significant miss in a 2” ex-service pipe is under investigation. The DRS trial gave remaining wall thickness data for an ex-service sample and several extended areas of wall loss in a machined component, having good agreement with the benchmark data (differences < 0.5mm). The PEC results on an ex-service component also provided remaining wall thickness data, but undersized the extent of the wall loss due to well-known sensor averaging effects.

Further benchmarking of the ex-service specimens by removal of the composite and mechanical wall thickness measurements is now taking place. A trial summary report will be delivered in 2018 before there is a hold point to decide whether to proceed with the guidance document development.

4. Inspection guidance for corrosion at trunnion pipe supports

Main highlight: Additional funding secured from the OGTC to expand the specimen database and increase the number of trials possible.

Pipe support trunnions are a common means to support pipework on process plant and offshore and, 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 their inspection even more challenging than corrosion at flat beam or saddle type supports.

The likelihood of failure of process pipework supported by trunnions, and associated hydrocarbon release, increases with the aging 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.

Ex-service trunnion pipe support

This project started with an information gathering phase which produced a phase 1 report describing typical trunnion geometries and degradation methods (illustrated with case studies provided by asset owners). It also contained a shortlist of techniques to trial.

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. An appeal for ex-service test components has generated several test pieces which are being supplemented by manufactured specimens. They 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.

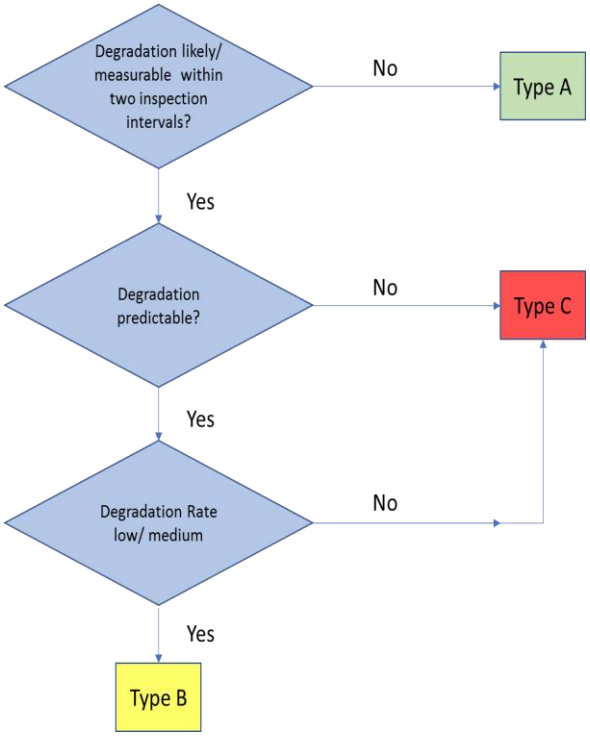
5. Updating of DNV GL RP G103 (C16-01)

Main highlight: The submission of a revised version of HOIS DNV GL RP G103 to DNV GL for review and publication.

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 increasingly receiving high-level recognition for its potential benefits. Indeed, NII is one of the areas of focus of the newly formed Oil and Gas Technology Centre (OGTC) which has joined HOIS for the 2017/18 membership year. One of the OGTC's ambitious objectives is to eliminate the impact of asset integrity on operational uptime and achieve no vessel entry for inspection of the pressure boundary by 2026. A recent example of the benefits of NII came from one Cat 1 member which made a net saving of £1M, (not including additional economic benefit from production uplift) by implementing an NII programme and avoiding the cost of intrusive inspection of several vessels (breaking vessels, cleaning, inspecting and pressure testing). The risk to inspectors was reduced by eliminating vessel confined space entry and as a result vessel inspection was no longer on the critical path, enabling the shutdown duration to be reduced from 21 to 14 days.

Extensive revisions in an updated version of the RP have been submitted to DNV GL and we are awaiting a publication date following a review period. The changes comprise 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



NII strategy selection, dependent on likelihood, predictability and rate.

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

It is hoped intended that the updated document will improve readability and the consistency of the inspections carried out on pressure vessels thereby reducing the risk of loss of containment and minimising risk to personnel during vessel operation.

6. Guidelines for UAV/UAS based external remote visual inspection (RVI) (C16-03)

Main highlight: Development of HOIS Guidance on image quality which covers the usage of UAVs for external RVI within the oil and gas industry.

Unmanned aerial vehicles (UAV) for remote visual inspection are increasingly being used in the industry to obtain information to inform engineering assessments on the external condition of piping, vessels, tanks and structures. However, there is a lack of any guidance concerning the performance of the RVI system as a whole, with no definition of the minimum image qualities needed to make adequate engineering assessments.

UAV RVI image of a flare tip

ESR and members conducted UAV based trials to assess the key variables that affect the conditions under which specific resolution values can be achieved. The key parameter identified was the image pixel size, in terms of millimetres on the target and a consistent relationship between image pixel size and spatial resolution was found for most cameras trialled. This allows prediction of the target distance required to achieve a particular image spatial resolution, given the parameters of the imaging system in use.

The results of the trials have been used to develop HOIS guidance on image quality for UAV/UAS based external remote visual inspection. The aim of this guidance is to ensure that the minimum image quality is adequate for the intended purpose of making engineering assessments of the integrity status of the parts inspected, which can then be used to assess fitness for continued operation. Detailed guidance is given regarding the three UAV RVI applications of highest priority to HOIS members: generation of UAV images having a resolution equivalent to close visual inspection, coating assessment to ISO 4628 and flare tip/stack inspection.

The detailed guidance on image quality includes spatial resolution and methods for verification that the required spatial resolution has been achieved on the end deliverable images. Image signal to noise ratio (SNR) is also addressed as a key image quality criterion and recommendations are made regarding minimum SNR and the arising implications for the maximum ISO setting that should be used with particular models of camera. General guidance on many aspects of UAV based RVI is also given on topics such as viewing direction, ambient light levels and camera settings. File formats and post-processing software for both still images and videos are considered.

7. Non-intrusive inspection of CRA clad Vessels (C14-03)

Main highlight: Three blind trials completed on an ex-service pressure vessel and plates, as well as a manufactured weld overlay clad plate. In the available examples of the hot rolled cladding, the SCC was detected with angled beam ultrasonic techniques, although the SCC in the vessel had different characteristics than that in a heat-exchanger plate and was more difficult to detect. The weld overlay cladding was found to be more challenging to inspect due to the scattering effect of the individual weld beads compared to the more homogeneous layer of hot rolled cladding. A comprehensive trial report has been issued.

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).

This year the project has focussed on trials of techniques for the NII of the internal cladding condition as well as the carbon steel vessel shell. The blind trial components included the ex-service CRA clad vessel, a manufactured weld overlay plate and an ex-service heat exchanger plate with hot rolled cladding. Three blind trials have been completed and the results documented in a trial report.

For hot rolled cladding angled beam shear wave probe measurements were able to detect SCC in the heat exchanger plate, but for the vessel the SCC had different characteristics and to date has only been conclusively detected using low frequency probes (1MHz). The Olympus DMA angled compression probes detected corner and tip signals of some of the SCC on the ex-service heat exchanger plates and gave promising results on the ex-service vessel.

Ex-service CRA clad vessel installed at ESR Warrington

The weld overlay cladding was found to be more challenging to inspect due to the scattering effect of the weld beads compared to the more homogeneous layer of hot rolled cladding: For machined slits in the weld overlay cladding, SV angled beam probes failed to distinguish the corner effects signals from noise, except for the largest slit. The DMA compression probe gave more encouraging results and showed both tip and corner effect signals even for the smallest slits. However, no examples of weld overlay cladding with service induced SCC were available for testing, but the signal response of real SCC compared to the machined slits is likely to be much weaker and therefore problematic for detection given the high levels of background noise.

8. Human Factors aspects of non-destructive testing in the offshore Oil and Gas Industry - Phase 2 (C16-04)

Categories of human factor

Main highlights: A further two substantive human factors on NDT (HF NDT) guidance documents have been produced one giving specific guidance for visual inspection of external corrosion and the 2nd on manual ultrasonics for internal corrosion or wall loss. This is in addition to the previously produced guidance on general human factors and separately on IVI reporting protocol and proformas for pressure vessels. A presentation was made at the 57th Annual BINDT Nottingham Conference in September 2018.

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. There is currently little guidance of the human factors affecting the various stages of an offshore inspection work scope and how to minimise their effects.

This project aims to address this gap by producing specific guidance, four documents have been produced: in the first phase a guidance note on IVI reporting protocol and proforma to minimise the effects of human factors, and a general guidance note and code of practice on human factors on offshore inspection. The work most recently had focussed on the specific applications of visual inspection for corrosion and manual ultrasonics for corrosion thickness mapping. Key mitigating factors identified were training on corrosion awareness and the specific ISI methods used; inspectors familiar with the offshore environment (Competence, environment, distraction); access issues addressed and logged prior to inspection and in reporting (Preparation); good briefings and communication by OIE (Communication); and asset database and plant drawings up-to-date (Awareness) Current work in 2018 is focussed on usability of the HF guidance and facilitating uptake by the industry. The HF NDT guidance is also relevant to onshore installations, storage facilities, pipelines and refineries.

Other projects:

In addition to the above highlighted activities, other HOIS technical management projects in 2017/18 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 2018.

Specimen trial and storage ('NICE') Facility

Inside the NICE specimen storage facility

The HOIS trial and specimen 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 (CUPS) 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 specimens by HOIS category 2 members, hosted by ESR Technology, primarily for the HOIS projects on inspection of external corrosion, corrosion under insulation (CUI) and pipe supports (CUPS).

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 specimens, 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 £783,000 (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, 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, 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 specimens 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.

Further Information

HOIS has a publicly accessible website at: www.hois.co.uk. Further information on HOIS can also be obtained from the HOIS project manager:

Dr Steve Burch
ESR Technology Ltd
22 East Central, 127 Olympic Avenue, Milton Park, Abingdon, Oxfordshire, OX14 4SA, UK.
Phone: +44(0)1235 213402
email: steve.burch@esrtechnology.com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DNV·GL
DOOSAN
Doosan Babcock Energy
DOW
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ETHER NDE
EDDY CURRENT SOLUTIONS
FUJIFILM
GASCO
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HSE
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MarathonOil
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nexen
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