The Oil & Gas Technology Centre and ABB

Non-Intrusive Inspection Survey

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1 Executive Summary

In line with the UKCS MER strategy the Oil & Gas Technology Centre (OGTC) and ABB are progressing an opportunity for Operators in the UKCS to benefit from recent advances in non-intrusive inspection (NII) technology. The first phase of this initiative was a survey to establish the current use of NII technology across the UKCS and the potential for its wider application.

NII enables pressure vessels to be inspected with the equipment on-line and avoids the requirement for entry into confined spaces to perform the examination. The capability of NII technology is increasing year on year.

The survey identified that NII offers the following benefits to the UKCS:

- Safety – up to 80% fewer confined space entries with a corresponding reduction in the number of line breaks and subsequent leak tests
- Financial - increased production and lower maintenance costs worth circa £242 million pa to the UKCS
    - increased equipment availability reducing lost and deferred production
    - shorter Turnarounds – reductions in duration of 33% have been achieved
    - overall cost savings of up to 80% compared to inspections that involve entry into a vessel

The current use of NII within the UKCS is limited with some Operators currently making little or no use of NII. The potential is that up to 80% of vessels could be examined non-intrusively.

The survey has identified that the main barriers to realising the potential of NII are:

- Conservatism in parts of the industry, due to a perception of the lack viable NDE techniques
- Concerns about regulatory compliance and the availability of data within the UKCS
- A lack of management engagement
- A lack of transparency of the overall cost of inspection.

A second phase of the NII initiative is now being progressed to help the industry overcome these barriers and gain the benefits of deploying NII technology across the UKCS.

2 Key Findings

- Take up of NII on the UKCS has been limited to date. The schemes of examination for most vessels still involve intrusive inspection requiring a shutdown and man entry into the vessel
- Most of the NII done on the UKCS so far has been to provide the justification to defer scheduled intrusive inspections
- With current Non-Destructive Testing (NDT) technology coupled with appropriate methodology, it is estimated that between 50% and 80% of process vessels could be wholly inspected using an NII based scheme of examination, i.e. replacing the intrusive man entry inspection
- Significant reductions in TAR durations are possible
- The survey participants agree that using NII could save between 50% and 80% of the inspection costs of a vessel
- The way in which budgets are allocated within the industry means that there is a lack of transparency of the total cost of inspection. Comprehensive and reliable data for the overall cost of inspecting vessels does not seem to be available to many Operators
- Barriers to the greater use of NII include a lack of understanding of the capability of current NDT technology and concerns about maintaining compliance with Regulations.
- The elimination of the man entries into vessels significantly reduces risks to the safety of personnel
- There are some limitations in the current NDT technology which mean that certain vessel features and vessel types are difficult to examine.
- The industry recommended practice document for NII (DNV-RP-G103) is very helpful but is reported to be difficult to apply

- The industry would welcome further support from the OGTC to facilitate the roll out of NII.

3 Introduction

The OGTC is an industry led research and knowledge organisation, backed by both the UK and Scottish governments to fund and direct projects that help to unlock the full potential of the UKCS.

One of the initiatives being promoted by the OGTC is the increased use of Non-Intrusive Inspection (NII) of process vessels installed on the offshore installations. Their goal is to eliminate the need to enter vessels for inspection purposes by 2026.

Traditionally inspection on the UKCS has involved taking pressure vessels out of service, preparing them for inspection and carrying out an internal visual examination, sometimes supplemented by NDT (Non Destructive Testing). However, with recent advances in NDT technology it is now possible, in many instances, to carry out effective inspections without taking the vessels out of service. This is known as Non-Intrusive Inspection (NII). This approach is widely used on the UK mainland in the process industries and it has delivered significant financial benefits without compromising process safety.

It is known that there has been limited use of NII on the UKCS to date and OGTC with the support of ABB has created a project to confirm and realise the potential of NII in the UKCS. Prior to undertaking the survey estimates suggested that NII could deliver the UKCS significant benefits, in the region of 250-500 million US$ per annum. The main financial benefits are derived from increased production. The reduced maintenance costs (in comparison with intrusive inspection) produce lower, but nevertheless significant savings for the industry.

Phase 1 of this project took the form of a breakfast briefing sharing information and good practice on NII, which was followed by a survey in which personnel working in eight offshore and one onshore operating companies were interviewed. The objective of these interviews was to confirm the potential for the deployment of NII within the UKCS and the resulting benefits as well as identifying the perceived barriers to greater use of NII.

This report presents the findings of the survey, which confirms that the application of NII across the UKCS Operators has significant potential for the offshore industry.

A second phase has now been commissioned to carry out pilot studies with a small number of operating companies who have limited experience of undertaking NII. The objectives of this phase are to evaluate feasibility, demonstrate how to apply NII, and to identify the resulting benefits.

4 Background

The inspection of pressure vessels began at a time when carrying out internal visual examinations was the only effective way of establishing the condition of the internal surfaces of the equipment.

The subsequent development of NDT methods, in particular the use of ultrasonic techniques, has permitted the examination of vessel internal surfaces for deterioration without the need to enter the equipment. The advent of ever increasing computing power and the development of new techniques has greatly improved the capability of NDT in recent years.

Current legislation (references 1, 2, 3 & 4) does not specifically require an entry into a vessel to carry out an examination. However, any examination that is carried out has to be effective at detecting the predicted damage mechanisms, and provide sufficient information to assess the vessel's integrity and to determine a safe interval until the next examination. It is accepted that the traditional intrusive inspection approach (a combination of visual inspection plus the appropriate NDT) can do this subject to appropriate controls. If a vessel is to be examined without an entry, there is a requirement to demonstrate that the method chosen is at least as effective as carrying out an intrusive inspection.

In order to carry out an effective examination, a fundamental requirement is to identify the damage mechanisms, where they may occur and their expected rate of progression. Risk Based Inspection (RBI) techniques based on API 580 (reference 5) provide an effective means of doing this. RBI has been adopted by most if not all the Operators in the UKCS. Once the deterioration mechanisms have been identified an assessment may be undertaken to determine whether it is possible to detect all these mechanisms

externally using NDT techniques. However a reluctance to change from established practices coupled with a lack of knowledge about the capability of the available NDT techniques suggested that guidance was required.

The HOIS joint industry project for NDT Best Practice in the Oil and Gas Industry formulated the first guidance on Non-Intrusive Inspection (NII). This was published as DNV-RP-G103 in October 2007 (current version reference 6). As there was no other relevant standards or recommended practice (RP), DNV-RP-G103 has been adopted as the industry standard for NII. It has been extensively used by companies operating onshore process facilities to support the increased use of NII.

DNV-RP-G103 was updated in 2011 to include, amongst other things, the deferment of internal visual examination and is currently subject to a further update to be published in 2018. DNV-RP-G103 is a very comprehensive document with all the information required to justify the use of NDT where vessel entry is to be avoided. The NII screening Procedure and High Level Decision Guidance Chart are widely used to decide whether a vessel is suitable for NII. However many companies prefer to use an RBI process to define the appropriate NDT schemes. It would appear that this may be due to the complexity of the latter parts of the guidance.

The benefits of applying NII have been demonstrated over the years in the onshore process industries. However, to date the take up of NII in the UKCS appears limited.

5 Survey Methodology

A breakfast briefing was held on 9th March 2017 at OGTC's offices in Aberdeen to put forward the case for increasing the amount of NII conducted on the UKCS. Companies who had already benefited from NII shared their learning and engaged in a debate with those who were interested in capturing the potential benefits. As well as operating companies the breakfast briefing was well attended by persons from Inspection and NDT service providers.

A key outcome from the briefing was the identification of a number of Operators willing to collaborate and share information on the amount of NII currently carried out and its relative costs compared to intrusive inspection.

Following this briefing, nine Aberdeen based Operators agreed to be interviewed. The interviews, each lasting approximately one hour, were conducted with representatives from ABB and OGTC in attendance and notes were taken by a technical administrator. From the outset, it was agreed that any information shared would not be attributable and the views of the individuals not disclosed.

The OGTC and ABB would like to express their thanks to all those that contributed during the breakfast briefing and especially to those who gave up their time to be interviewed. The request of the interviewees to remain anonymous is respected.

The interviewees were drawn from the following:

- 6 from companies operating offshore fixed platforms
- 2 from companies operating FPSOs
- 1 from a company operating a gas terminal

With a sample size of nine the survey has covered approximately 25% of Aberdeen based operating companies. Whilst this is a significant proportion of the total, caution must be taken in seeking to extend the results of this survey. The interviewees are a self-selecting group of volunteers rather than a random sample.

All of the participants were Senior Integrity/Inspection Engineers with extensive industry experience. The interviews focussed mainly on those areas of greatest interest; particularly, their current experience of using NII and the associated costs.

In advance of the interview, a pre-interview sheet was sent to the participants to aid preparation. However, owing to busy work schedules, few were able to make use of this.

Following completion of the interviews the notes were analysed and the key learnings extracted and summarised in this report. It was agreed that the report would be circulated to interviewees prior to publication.

The interviewees' views, in the main, are based on their experience and judgement and not on detailed analysis. However, their projections of the benefits to be gained from

adopting a NII regime were consistent; thus providing some confidence that they are representative.

Copies of the breakfast briefing agenda (figure 4), pre interview questionnaire and the interview prompt sheet are included in Appendix A

6 Survey Findings

The survey used a set of key questions as the basis for a discussion with the interviewee. The questions were phrased in such a manner as to gain information about the current of usage of NII in the UKCS, the potential for increasing this and the benefits that this could deliver for the industry. A significant proportion of the interview focussed upon the barriers perceived to be preventing wider deployment.

In each interview the following topics were covered:

- Benefits of deploying NII
- Current use of NII within their company
- Potential for use of NII in the UKCS
- Safety and environmental benefits
- Cost savings derived from deploying NII
- Barriers to deploying NII
- Limitations of NII
- Impact on TARs
- OGTC support to facilitate the deployment of NII

The survey findings for each of these topics are recorded in the following sections. It should be appreciated that the information gathered represents the personal experience and views of the individual interviewees rather than the position of their respective company.

6.1 Benefits of Deploying NII

The benefits of using NII were discussed and identified at the breakfast seminar, they include:

- Increased equipment availability/uptime
- Reduced overall cost of inspection i.e. removal of costs associated with the preparation and reinstatement of equipment
- Turnaround complexity and durations can be reduced as NII has the potential to be undertaken outside the event
- Man entry into confined spaces, a known hazardous activity, is avoided
- Disturbance to the vessel and associated pipework flanged joints, with the potential for hydrocarbon leakage, is avoided
- Damage to the internal coatings of vessels is avoided
- No vessel cleaning residues to manage
- Leak testing and purging of the vessel with inert gas prior to recommissioning is avoided

These benefits were further confirmed in the course of the discussions during the survey interviews.

6.2 Current use of NII

At the start of the interview the interviewees were asked to provide information on the extent of the use of NII on the assets in their company. The responses to this question are recorded in figure 1, on the next page.

Two of the nine interviewees reported that their company had yet to deploy NII.

Five of those interviewed stated that NII is used on some vessels or to enable the deferment (postponement) of intrusive inspections.

One company has adopted a policy of the alternate use of NII and intrusive examinations on approximately 70% of their vessels.

Only the gas terminal can be regarded as having fully-embraced NII and is moving to an NII only strategy for circa 90% of vessels.

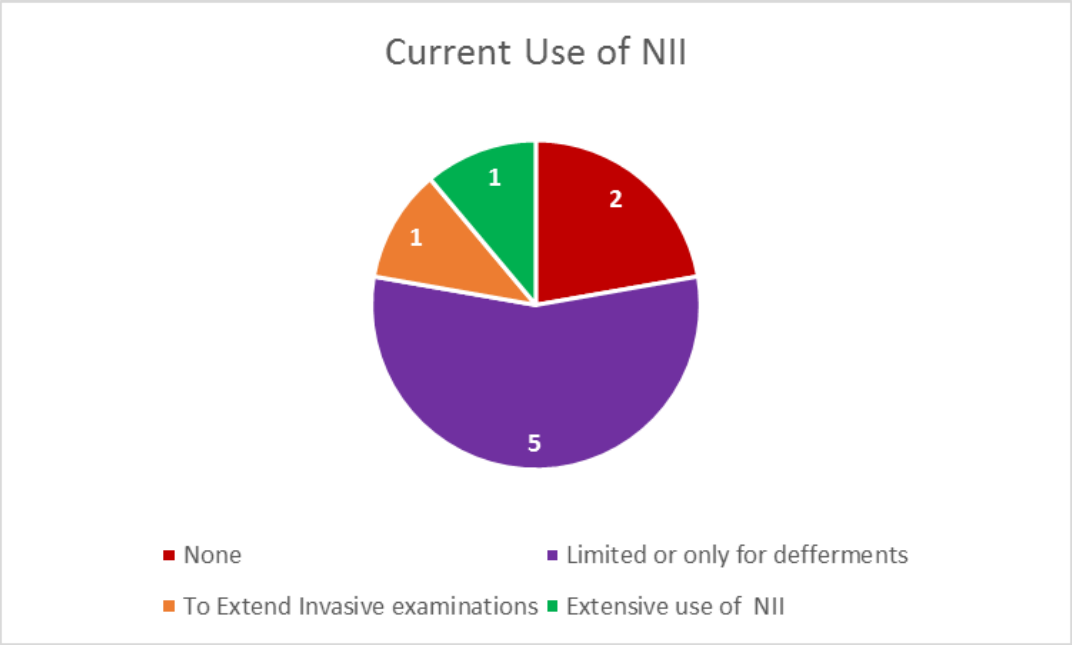

Figure 1: Current use of NII

It is notable that of the eight companies operating offshore assets only one is making any significant use of NII.

6.3 Potential for use of NII in the UKCS

Having established the extent of use of NII, the participants in the survey were asked to give their estimate of the percentage of vessels on their assets that could be moved to a full NII programme. The figures quoted are shown in figure 2, on the next page.

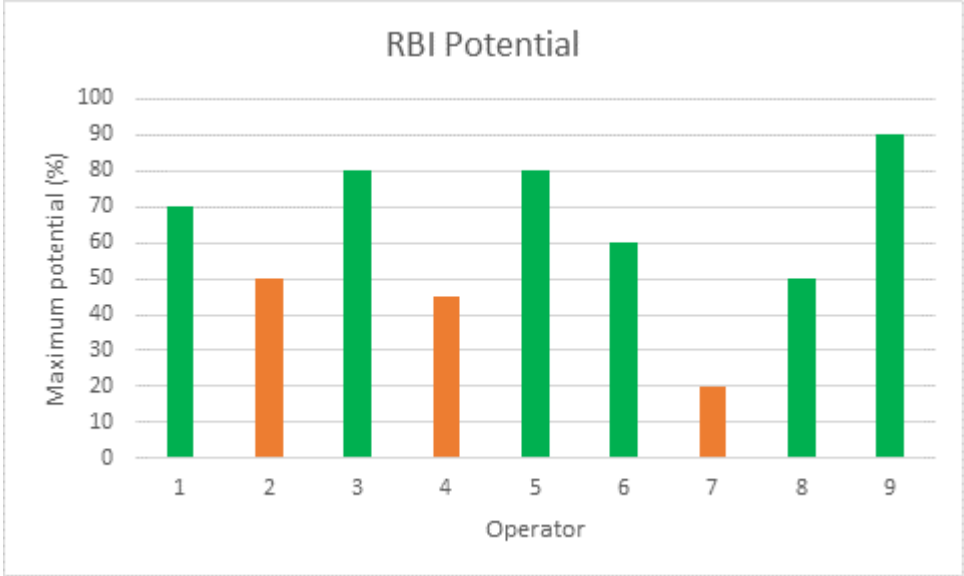

Figure 2: Scope for the potential application of NII

The estimated figures shown in Green were made by the interviewees with some experience of NII.

Those shown in Orange are the estimates made by the interviewees with no experience of NII.

For the eight companies with offshore assets the estimates of the maximum number of vessels that could be moved to a wholly NII strategy are the region of 50-80%. It was noted that those interviewees who had limited or no experience of NII tended to provide lower estimates of the potential than those who already had experience of using NII for deferments or as a substitute for intrusive inspection.

In contrast the onshore gas terminal, which is currently half way through a major RBI review/NII assessment programme had been able to move 90% of the vessels assessed to date to a wholly NII strategy, albeit with a generally less demanding duty than for vessels installed offshore. The interviewee from this company also has experience of offshore installations and expressed the view that the outcome for the gas terminal would be at the higher end of the range.

6.4 Safety & Environmental Benefits

One clear benefit that all the participants in the survey recognised is that as a direct result of deploying NII there will be a reduction in the number of confined space entries required.

The consequences of an accident in a confined space can be very severe due to the difficulties associated with rescuing the injured party: too often, the actual rescue attempt results in further injuries or fatalities being sustained. When asked, none of the interviewees were aware of any accidents or incidents that had arisen from intrusive inspection. Nevertheless, there are significant risks associated with confined spaces and managing the hazardous substances encountered e.g. naturally occurring radioactive materials (NORM), mercury, pyrophoric scale.

Avoiding the need to make and break joints also reduces the potential for hydrocarbon leakage.

Reference was also made to eliminating the need to manage and dispose of the residues from vessel cleaning.

6.5 Costs Savings from Deploying NII

The interviewees from the companies that had deployed NII were asked for data on the relative costs of intrusive examinations versus the use of NII.

When comparing costs, it should also be remembered that there is no such thing as a standard vessel and that each vessel has its own unique set of preparation and inspection requirements.

Costs for conducting intrusive examinations of a typical medium sized vessel quoted by interviewees from offshore Operators were an average of £236k. These costs include mechanical work and scaffolding for the vessel entry. The equivalent cost figures for NII were lower at an average of £44k. These costs include an adjustment for typical productivity factors in UKCS. The equivalent savings for large complex vessels and towers/columns, such as Glycol Contactors and DA Towers, are expected to be greater.

The interviewees were consistent in quoting cost savings of 50-60% for NII compared with intrusive examination for vessels on offshore installations.

Costs for cleaning vessels prior to entry and for leak testing and purging prior to restart are understood to vary considerably from vessel to vessel according to the process duty and levels of contaminants.

The benefits produced from not having to cease production are significant. This data was either not available to many of the participants in the survey or they were unable to share the information. The survey has nevertheless obtained data in relation to reduced TAR durations to allow this benefit to be estimated.

One of the biggest unknowns is how much the cost of a TAR could be reduced by; assuming that TARs could be shorter in duration with the wider use of NII (see section 6.8).

One interviewee mentioned that through using NII for intermediate examinations, they had shortened a TAR by four days. Another company had used NII to remove work scope from the TAR and, as a result, had reduced the cost of the event from £145m to £74m. This supports the view that NII offers the potential for substantial reductions in TAR costs and is consistent with the experience of onshore process facilities.

Appendix B contains cost data collected from a number of Operators.

6.6 Barriers to Deploying NII

Although the benefits derived from the greater use of NII are widely recognised among the participants in this survey there are perceived to be a number of barriers limiting the take up of NII within the offshore industry.

From the survey, the following are seen as the barriers to the greater use of NII within the industry:

- Engagement of Senior Management
- Inspection budgets
- Limited experience of NII within the industry
- The attitude of the Regulator (HSE)
- Capacity of the NDT Service Providers
- The competency of the NDT Technicians
- The use of DNV-RP-G103 Guidance for NII Assessment

These points were discussed during the survey interviews and the interviewees responses are summarised below.

Support from Senior Management

In the past when oil prices were higher, investment was mainly focussed on increased production and maintaining safety. Carrying out intrusive inspections was not really seen as an issue unless the work scope of TARs began to extend beyond the time allotted. When that had been the case there was pressure from Management to reduce the TAR duration and a number of the interviewees stated that NII had been used as a justification for deferring intrusive examinations. In general, senior management attention was focussed upon other things and there was little sustained drive for change.

The reduction in the price of oil resulted in Senior Managers being driven to find cost savings and maintenance costs are being challenged as part of the drive to increase production efficiency.

One interviewee stated that the use of NII was only allowed in his company (by Company Inspection Rule) for the deferment of inspections on a case by case basis. A change in Company policy would be necessary to allow NII to be used more widely.

None of the interviewees cited their Senior Management as a specific barrier to deploying NII. However, out of all those interviewed it was apparent that only one company's senior management is actively promoting the wider use of NII across their assets.

Therefore Senior Management are not perceived as a barrier to the greater use of NII, but are not seen to be actively encouraging its use. The prevailing view is that senior managers are largely unaware of the opportunity and potential benefits resulting from increased use of NII.

Inspection Budgets

The way in which inspection budgets are typically allocated means that it can be difficult to make meaningful cost comparisons between different inspection techniques. If the inspection budget is viewed in isolation NII can appear more expensive than undertaking intrusive inspection. In order to make a balanced comparison it is necessary to take a holistic approach to the asset OPEX budget and include all the costs associated with performing the inspection. If the potential benefits of increased production are then factored in, the financial case for greater deployment of NII becomes more compelling.

Limited Experience of NII within the industry

Inspection and/or Integrity Engineers tend to be conservative in their approach and the survey uncovered a resistance to change. A number of those interviewed expressed the view that any change to the established practice of conducting intrusive inspections was likely to be resisted at various levels within their company. Indeed, this was the prevailing view of those within the companies that have yet to implement or pilot NII. Conversely, the response from those in companies that were already making use of NII was more enthusiastic and this was not seen to be a barrier within their particular company.

Overall the take up of NII is still low amongst offshore Operators meaning that positive experience of implementing NII is in limited supply across the industry. The focus of

some engineers tends to be more on its perceived limitations rather than the potential benefits.

The Attitude of the Regulator

None of those interviewed in this survey were aware of regulatory pressures to either avoid the use of NII or challenge the greater use of NII strategies. Nevertheless, concerns were expressed that this might change should NII become more widely used. This was a concern for all participants in the survey regardless of the extent to which NII is currently used within their company.

Uncertainty as to the view of the HSE is perceived to be a barrier. It makes it harder to justify the use of NII to others within their company. Any clarification of HSE's position relating to the use of NII techniques by the offshore industry would, consequently, be welcomed.

A number of those interviewed suggested that any dialogue that the OGTC, or other industry bodies, has with HSE to establish their position on NII would be beneficial in this regard.

Capacity of the NDT Service Providers

All of the companies taking part in the survey use contractors to carry out the NDT inspections of their equipment. Some of the companies also use contractors to support the work of their Integrity Engineers. None of those interviewed stated that there were problems with their service suppliers' capability to deliver NII related services in the short term. However, it was noted that there are currently relatively few service providers in the market. There is a resulting concern that a significant increase in the uptake of NII could overstretch these providers. A number of the interviewees indicated that they would like to see more NDT service providers enter the market place whose services they could call upon.

Consequently the perceived barrier, in this instance, is the future capacity of the NDT service providers rather than an immediate problem.

This perception could be the result of the companies not appreciating the full suite of services their NDT providers are capable of offering. The issue may be that the service providers (with some notable exceptions) are not actively promoting their NII capabilities.

The Competency of the NDT Technicians

NII relies upon the use of a range of NDT techniques to detect and characterise defects in the vessel. Well established standard techniques are used for the bulk of the NDT work with the limited use of more specialised advanced NDT techniques in specific circumstances.

It is generally recognised that the probability of anomaly detection using NDT is less than 100%. However, it is important to understand that the probability of detection for internal examinations is also less than 100%. All techniques depend upon the competence and diligence of the technician/inspector performing the work and the working environment and conditions where the NII is carried out.

Confidence in the results of the NDT is important if NII is to be applied widely. Reservations within the industry about the competence of the NDT technicians would clearly have an adverse impact on the further application of NII.

The persons interviewed in the survey were clearly aware of this as a potential issue but were, nevertheless, consistent in expressing general satisfaction with the current performance of their NDT contractors. Where advanced techniques are required the usual practice is to bring in a specialist contractor, or to utilise the specialist teams available from their existing contractors.

A number of the interviewees referred to a PCN training and certification scheme in which ex-service corroded specimens are used to train NDT technicians in conditions representing those found in service. The use of real corrosion samples is seen to confer increased confidence in the technician's performance. However, the level of take up of this type of training was not immediately apparent to the interviewees. There is some confusion as to the certification and competency requirements for the technicians with consequent reliance upon the contractors ensuring that their NDT technicians are competent in each of the techniques.

The use of DNV-RP-G103 Guidance for NII Assessment

The companies who use contractors for integrity engineering typically place the requirement for preparing the NII work scope with one of these companies. In the main, these companies are also a specialist NDT supplier. Onshore the NII assessments are often carried out by the same company that carried out the RBI work.

Companies are not under the obligation to use DNV-RP-G103, nevertheless, all but one of those interviewed in the survey was familiar with this document. This person is from a company that had yet to undertake any NII work and was concerned that their lack of awareness of the guidance could affect their ability to procure a suitable service.

Some of the interviewees advised that their company used the screening and high level decision charts in DNV-RP-G103 alongside their normal Risk Based Inspection (RBI) process, whilst others stated that they use the guidance document throughout. Issues in applying DNV-RP-G103 are perceived to be another barrier to the increased use of NII.

All those using DNV-RP-G103 to its full extent reported that they found it difficult to use. The various comments noted on the guidance document are summarised as follows:

- The early stages are good, but the rest is heavy going and unreadable
- The guidance could be improved - the screening exercise is relatively easy to use whereas the more complex detailed part is difficult to apply
- It is convoluted to use and ultimately uses statistics to justify the outcomes

Given the difficulties experienced in using DNV-RP-G103, a number of those interviewed suggested that the OGTC facilitates guidance on using the standard and on the use of NII in general. It was felt that suitable guidance on how to use DNV-RP-G103 would make it easier to justify the use of NII to management in their company.

6.7 Limitations of NII

The stretch target proposed at the launch of this project is that there should be no vessel entry except for process reasons. There are a number of technical and practical hurdles to overcome before this can be fully achieved.

The interviewees were asked to identify the limitations they had experienced with NII. The limitations are listed below:

- Many vessels have insulation/passive fire protection (PFP), which can be difficult to remove and severely restricts external access for carrying out NDT. There are currently no NDT techniques that enable NDT to be undertaken through these systems. Removal for the purposes of inspection is therefore necessary. If the insulation/PFP is no longer required on some vessels in these cases it could be removed. Other options involve replacement with a removable insulation system that facilitates future access for NII. Removing the insulation/PFP and then replacing it with another solution requires a business case to be produced that evaluates costs of insulation/PFP removal versus potential OPEX benefits over the field life.
- Many vessels also have internal coatings. Whilst the onset of corrosion can be externally detected this occurs after the coating has failed. Therefore, a time-based reapplication policy may be more applicable for vessels with internal coatings as they generally have a useful life and internal inspection may not be that effective either, with the coating masking corrosion damage.
- Some vessels are clad with a corrosion resistant alloy. As with coatings, it can be difficult to detect damage using NII; especially if the defect is in the form of a pinhole or pit that does penetrate the thickness of the cladding. Newer assets tend to rely on corrosion resistant alloys for protection rather than internal coatings.
- Complex geometries prevent or limit NDT access to 100% of the inside of a vessel, especially in areas such as nozzle reinforcement plates and saddles. Whilst specialist NDT techniques are available that can provide some coverage, localised deterioration such as under deposit corrosion can be more difficult to detect.

- The external surface condition was mentioned by one interviewee and is a common issue affecting carbon steel vessels where their external protective coatings have broken down, leading to surface corrosion. This can limit the use of ultrasonic techniques, which tends to be the most prevalent NDT technique for NII.
- Flange faces were mentioned by two of those interviewed. Phased array NDT has some capability in this area but confidence is lacking in the technique.
- The tubeside of heat exchangers cannot be inspected when they are in operation. However NII may be possible for benign duties were the tubes are not subject to deterioration and the predicted damage mechanisms are confined to the shell. One of the interviewees noted they had experienced a fretting failure.
- Two of those interviewed mentioned that vessels constructed from high performance alloys (such as Duplex and Super Duplex) were a limitation. One interviewee was concerned about the performance of phased array NDT on these alloys and another stated that the failure mechanisms occurred more rapidly.
- Temperature limitations of NDT methods were mentioned by one operator (with respect to a hot glycol vessel). Although not a limit to NII, the vessel would have to be out of service to cool down.
- One interviewee noted that the record keeping of previous intrusive examinations was poor; which in turn could make NII difficult to enable and justify.
- One of those interviewed noted that non-entry examinations or minimum intrusive interventions (e.g. using an endoscope) should be considered along with NII as some of the benefits of a full vessel entry would still be realised.
- Several of those interviewed would welcome more guidance on the capability of each of the available NDT techniques. Given that DNV RP G103 gives information on NDT techniques in Appendix A and section 4.9 it may be that more publicity is required for this and other sources of information.

6.8 Impact on TARs

A significant driver for the deployment of NII is to shorten the duration of TARs by reducing the intrusive inspection work scope during the event. Where practicable the inspection work is removed from the TAR, to be completed at other times when the asset is online. All the interviewees were asked to elaborate on what effect NII might have on TARs and what the current strategy in their company is. Only the gas terminal can be regarded as having fully-embraced NII and is moving to an NII only strategy for circa 90% of vessels.

The responses, as illustrated in figure 3 below, show a variation in the interval between TARs for the companies operating offshore assets. The shortest interval is annually, two companies are on biannual intervals, three are on a triannual interval and one had moved to four-yearly. The gas terminal is in the process of moving from three yearly to a staggered nine year interval for their TARs.

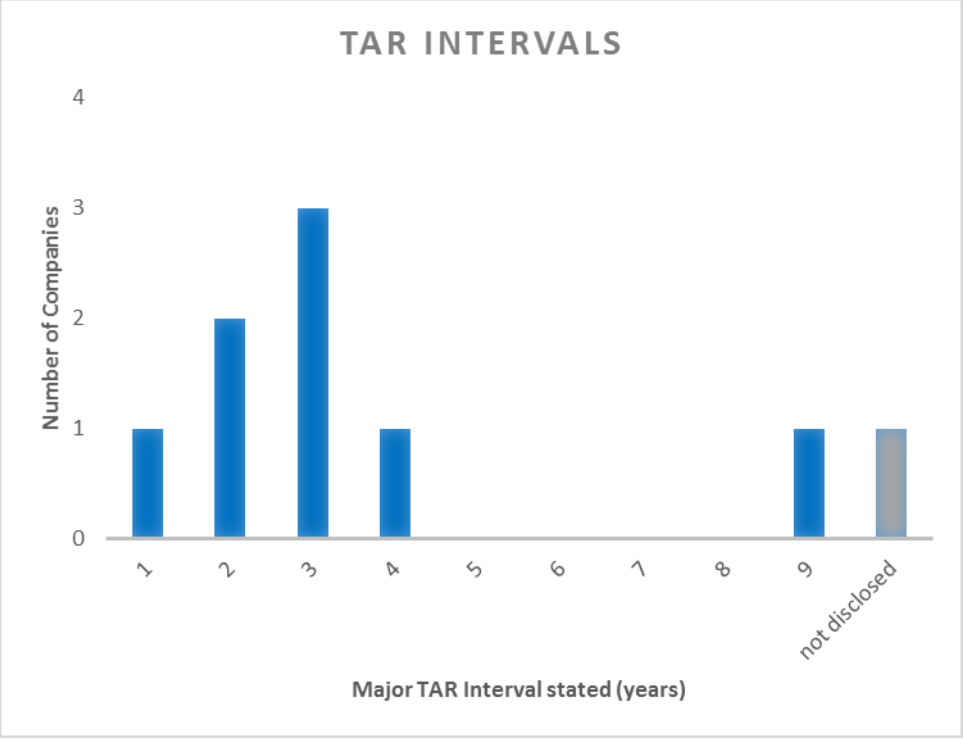

Figure 3: Interval between Major TARs

A number of the interviewees also made the point that not all the work scope in their TARs is completed during the event, even if it overruns.

While the intrusive inspection of vessels is a significant driver in determining the duration of TARs, it is not the only activity as the work scope includes maintenance, modification and repair tasks. One interviewee suggested that rather than shorten the duration of a TAR, any time freed up by reducing the inspection scope would be used to complete additional maintenance work (e.g. completion of equipment repair/replacement and critical/essential maintenance work).

A concern was raised that should NII identify the requirement for a repair, it may need to be planned to take place with the vessel offline and, therefore, this would be much easier when the vessel is intrusively examined as the necessary access would already be in place. Conscious of this requirement, it is established practice in one company to carry out their NII prior to a TAR in order to identify what repairs may be required, to assist in efficient planning for such repairs.

Conducting NII prior to a TAR is seen as useful in scoping the need to undertake repairs. In these circumstances the optimum timing would be to undertake NII as close to the TAR as possible; noting that the need for any repairs should be identified before the work scope freeze date, unless the vessel repairs can be treated as emergent work.

The above responses confirm that NII has the potential to reduce TAR duration (giving a cost saving and additional production) or to allow additional work to be completed. However, no linkage is made between the use of NII and extending the interval between TARs.

Data relating to the potential benefits to the industry from reducing TAR durations is contained in Appendix B.

6.9 OGTC Support to Facilitate the Deployment of NII

All of those interviewed were asked what support they would like to see from the OGTC for NII. There were many suggestions, most of which are listed below. Whilst the OGTC

is not able to commit to all of these, they indicated that they would consider how they could deliver those that could potentially yield the most benefit.

Three participants believed that there was a need to make the potential of NII more apparent to their senior management. There would usually be a cost associated with preparing a business case for NII and, therefore, management support is required. It is noted that no senior managers attended the OGTC NII breakfast briefing.

Building on the above, a number of the interviewees indicated that the production of an NII roadmap would be of use. One remarked that this needed to be suitable for use by smaller companies. Another suggested a benchmark of %NII completed by an operating company would be helpful and allow senior management to better understand the potential.

One participant believes that OGTC endorsement of the use of NII together with a simplified explanation of what it was and the benefits it could yield would be helpful. It was suggested that cost savings data should be included. (Getting this data will, however, be difficult without high level commitment within the operating companies). Another suggestion is a regular OGTC newsletter on progress made adopting NII on the UKCS.

An “NII for Dummies” publication was also suggested as a way of demonstrating what NII can and cannot do to a wider audience. Another interviewee requested a simplified screening tool to assess what would and would not be suitable for NII assessment. (This tool already exists in the form of the decision tree in DNV-RP-G103).

Although only one participant specifically suggested that OGTC liaise with the Regulator, a number of the participants in the survey clearly have concerns about the HSE’s position regarding the use of NII. It follows, that it is logical for the OGTC to perform this role on behalf of the UKCS as they were actively promoting the greater use of NII. The interviewees did not feel that they have a ready way of engaging with the HSE on this point.

Of those that chose to use the detailed part of DNV-RP-G103, the feedback is that it is too complex. OGTC are now members of the HOIS JIP, and are in a position to feed this observation back. In addition, it was suggested that the OGTC could provide guidance to help the industry use the document.

A number of the participants suggested that more information on the capability and limitations of available NDT techniques would be beneficial. There is already information in circulation but some of the data is out-of-step with the pace that NDT technology is advancing. Again the OGTC's connection to HOIS could be exploited as it offers a route to raise this matter to assist industry.

It was also suggested that the OGTC could facilitate the creation of worked examples on typical problem areas such as CUI, flange faces and wrapped joints.

The availability of improved NDT training courses, using ex-service corroded specimens, to potentially improve the capability and repeatability of NDT operators was also mentioned. Take up by service companies has been disappointing to date, despite the encouragement of industry.

7 Conclusions

This survey has provided information about the current status of the application of NII in the UKCS and the potential for its wider application.

Currently take up of NII for the inspection of vessels is low across the UKCS. Indeed, there are some Operators of offshore installations who have yet to use the methodology at all. In contrast, the survey revealed that some operating companies have started to use NII in a fully non-intrusive inspection strategy for vessels, or as a means to either increase or defer the intervals between the intrusive inspections.

The survey clearly indicates that there is considerable potential to increase the amount of NII undertaken on offshore installations. Whilst limitations in the current capability of NDT technology suggest that 100% NII coverage is unlikely to be achieved in the short to medium term, a target of 80% seems reasonable at this time. Further advances in the capability of NDT through development of sensor technology may be able to improve the coverage of the difficult to examine areas and hence increase the percentage of NII coverage.

As well as improved safety, a greater use of NII offers significant savings in terms of the cost of performing the inspections. The survey has identified that the potential for savings in the direct costs associated with the inspections can be up to 80% and has pointed to the potential for significant savings in the cost of delivering TARs. While specialist advanced NDT has a cost, the costs associated with enabling a vessel to be inspected internally are normally much greater.

The survey has also provided data to quantify the potential benefit to the industry from fewer days of lost production, from reduced TAR durations.

The overall benefit to the industry from deploying NII is estimated to be £242 million per annum.

Increased use of NII will require management drive and support and acknowledgement by the Regulator. It is anticipated that as more operating companies are seen to realise the benefits from deploying NII, the momentum for increasing use NII will build and it will gradually become accepted practice.

Those who are using NII are all aware of the DNV-RP-G103 guidance document. The initial screening tool is seen to be straightforward, but those using the detailed guidance to identify the examination plans for vessels find the process to be complex and difficult to apply. There appears to be a need for a roadmap to make it easier for the Integrity Engineers and others to navigate their way through the guidance.

With respect to the UKCS MER strategy, overall the survey indicates that the OGTC is justified in promoting the greater use of NII in the UKCS.

The next phase of the project will be to work with a small number of companies with limited experience of NII, to undertake a number of pilot studies.

8 References - Applicable Regulations & Guidance Documents

1. Safety Case Regulations, 2005 (SCR)
2. Prevention of Fire and Explosion and Emergency Response Regulations, 1995 (PFEER)
3. Provision and Use of Work Equipment Regulations, 1998 (PUWER)
4. Pressure Systems Safety Regulations, 2000 (PSSR) *
5. API RP 580 Risk-Based Inspection, 3rd Edition 2016.
6. Recommended Practice for Non-Intrusive Inspection, DNV-RP-G103, January 2011.
7. Table of UKCS Installations, Oil & Gas Authority
8. Business Outlook 2017, Oil & Gas UK publication

* Note: PSSR applies to onshore facilities and is more prescriptive that the offshore regulations.

Agenda		
08:30	Registration, tea / coffee and bacon rolls	
08:45	Welcome and introduction	Rebecca Allison, Asset Integrity Solution Centre Manager, OGTC
09:00	NII and its application to Upstream Oil and Gas Operations	Paul Jackson Functional Leader, ABB Consulting
09:15	Panel discussion, 3 industry partners NII in practice, to reduce OPEX and turnaround complexity and duration	Paul Jackson, Billy Mackay & Industry Partners
10:15	NII Survey - Next steps, support required	Paul Jackson
10:30	Tea / coffee, networking and close	

Figure 4: Breakfast Briefing Agenda

Non-Intrusive Inspection Survey

Pre-interview questions

This questionnaire aims to gather some initial information from operating companies in the UKCS in advance of a face-to-face interview about Non-Intrusive Inspection (NII). It should also help ensure that companies have relevant data to hand by ready for the face to face interviews. Please provide responses to the questions to the best of your ability, but do not worry if you cannot answer every question; this may indicate what some of the barriers to greater adoption of NII are.

1) What parts of integrity assurance does your organisation delegate to a supplier and which are retained in-house?
   Aspects could include: inspection management, inspection, Non-destructive Testing (NDT).
2) How many vessels are including in the scope of the asset inspection programme?
   If possible give a breakdown by size and type of vessel.
3) What proportion of vessels are currently covered by non-intrusive inspection methods?
4) Of the above non-intrusive inspections what proportion of vessels are?
   a) Wholly covered by non-intrusive inspection?
   b) Inspected by a combination of intrusive and non-intrusive inspection to increase the time between intrusive inspections?
   c) Inspected non-intrusively to defer or postpone intrusive inspections?
5) What would you estimate the typical cost to be of performing one intrusive inspection on a typical medium sized vessel (excluding deferred and lost production)?
   If possible give a breakdown if the cost build up, e.g. vessel preparation, scaffolding and access, inspection and re-instatement costs.
6) What would you estimate the typical cost to be of performing the equivalent inspection non-intrusively?
   If possible give a breakdown if the cost build up, e.g. vessel preparation, scaffolding and access, inspection and re-instatement costs.
7) Has your organisation gone through an exercise to increase the proportion of NII?
   a) If so how has this been done (e.g. RBI)?
   b) If not, what if anything are you planning to do?
8) Does your organisation have a consensus view as to the potential increase in the percentage of non-intrusive inspections as a total proportion of inspections within the inspection programme?
   If desired, quality you answer by stating the conditions or requirements that have to be met in order for this percentage increase to be achieved or achievable.
9) What is the current frequency of TARs?
   If desired, provide a breakdown across the asset base.
10) What are typical TAR durations?
    If desired, provide a breakdown across the asset base.

Non-Intrusive Inspection Survey

Interview questions

This face-to-face interview is part of a survey to gather information from operating companies in the UKCS about Non-Intrusive Inspection (NII). The results of this survey will be used by the OGTC to understand the size of the potential opportunity for greater use of NII in the UKCS, and the barriers to exploiting this opportunity that operators currently face. To help ensure that the industry gets the most out of the survey please do the following.

- *Release appropriate people to be interviewed. Ask us if you are not sure which people to put nominate.*
- *Provide data and prepare responses to pre-questions (on a separate document) to the best of your ability. Have a copy of your responses and any supporting data to hand on during the interview session.*
- *Allow publication of anonymised results. Please discuss any issues with confidentiality in advance.*

NII Capability

1) What NII capability do you have in house?
2) What NII capability do your current or potential suppliers have?
3) Do you regard NII capability as a core service of your current / potential suppliers or do you regard it as a specialist activity?
4) How confident are you in the results of non-intrusive inspections, compared to intrusive ones?
5) What capacity do you have to perform non-intrusive inspections outside of shutdowns?
6) What operational (e.g. access) or external (e.g. corporate policies, regulator pressure) constraints do you face to doing non-intrusive inspection?

Key barriers to greater substitution of intrusive inspection by non-intrusive methods

7) What technical NDT challenges do you face? E.g.
   - Organic coatings
   - PFP – Passive Fire Protection
   - Complex geometry e.g. saddles and reinforced nozzles
8) How useful are currently standards and guidelines and what parts of them have you adopted?
   a) Do you have issues with:
      i) Complexity of the DNV DNV-RP-G103 Recommended Practice guide?
      ii) Translating the guidelines into a step-by-step process that can be implemented with confidence?
      iii) Do you perceive any gaps in the current version of DNV RP G103?
9) In the context of NII, what challenges around competence do you face? E.g. in-house and supplier experience, skills, training and training courses.

10) What corporate and management cultural challenges do you face?
11) What engineering and operations challenges do you face?
12) Are there any key economic / cost challenges?
13) What supply chain challenges do you see?

Opportunities presented by substitution of intrusive inspections by non-intrusive methods

14) What proportion of vessels could be 100% NII if barriers were overcome?
15) What proportion of vessels could have intermediate inspections or extended intrusive inspection intervals if NII barriers were overcome?
16) What is the potential for reduction of TAR duration & frequency if intrusive inspections are reduced?
17) What would the benefits be?
    b) Financial benefits
    c) Operational benefits
    d) Asset integrity benefits
18) What proportion of TAR scope is typically completed?
19) How strongly is the TAR programme driven by the inspection programme?
20) What proportion of personal safety near misses and hazard observations reported on assets are related to vessel entry or confined space entry (inclusive of preparation and reinstatement activities)?

As this could be a sensitive question or a question the company may not wish to answer, it was not asked in the pre-interview questions. An estimated or anecdotal answer is sufficient.

Support to industry

21) What support do you think The OGTC and other bodies need to provide to support the transition to greater use of NII?
22) What if any support for NII are you currently looking for? If so, are you getting the support you need?
23) Are you efforts to transition to NII being supported by stakeholders? E.g. workforce, management, Health and Safety Executive?
24) Where do you think that industry bodies such as the OGTC need to focus resources in order to best support operators with the transition to greater use of NII?

Other issues

25) Is there anything from your answers to the pre-questionnaire that you would like to explain or discuss?
26) Is there anything that we've not discussed so far that you'd like to mention about NII or wider integrity management issues in the Oil and Gas industry?

Appendix B Cost Data and Estimation of Benefit to UKCS

There are two factors contributing to the financial benefit to be derived from the extensive use of NII for the inspection of pressure vessels. One is the direct saving in the overall cost of undertaking the inspection work. The second factor is the additional production resulting from the increased availability of the equipment. In some instances NII enables the inspection to be undertaken without interruption to production.

Some of the participants in the survey were able to provide information relating to the relative cost of NII versus the cost of undertaking intrusive inspection of the same vessel.

Data was also obtained in relation to the reduction in turnaround duration resulting from the application of NII.

This information has been used to estimate the potential benefit to the UKCS as a whole.

B1. Information provided by Operators

The following data in relation to the costs of inspecting process vessels was obtained by OGTC and ABB during the NII survey in discussion with the survey participants. These are average costs for offshore inspections of process vessels and include an allowance for UKCS productivity rates. Savings from using NII are likely to be significantly greater for large vessels and towers/ columns, such as Glycol Contactors and DA Towers.

Average cost per vessel of inspection	£K
Intrusive inspection	236
NII	44
Saving	192

Table 1: Vessel inspection cost data

The figures quoted in Table 1 include the mechanical and process preparation and return to service costs.

The following productivity factors have been assumed for UKCS:

- Intrusive inspection -10 hour day (2 hours for lunch and breaks) productive hrs of 7 per day.
- NII- 10 hour day (2 hours for lunch and breaks). Efficiency for NII is greater (single trade) productive hours of 8.5 per day, with the bulk of reporting completed onshore.

The experience of one UKCS Operator with a requirement to intrusively inspect 28 process vessels during a planned shutdown was recorded during the survey.

The estimated time required to inspect these vessels intrusively was 100 days.

The Operator undertook a structured detailed NII assessment. This determined that 27 vessels could be inspected using NII techniques. Only 1 vessel still required intrusive inspection.

The Operator noted that the use of NII on this shutdown had the following benefits:

- A significant reduction in the number of confined space entries and the associated risks to personnel.
- Reduced preparation of process plant for inspection and associated reinstatement activities including leak testing.
- A reduction in the number of break ins/disturbance to process plant containing hazardous substances.
- The results obtained from the NII provided an improved quality of inspection data
- The duration of the planned shutdown was reduced from 21 days to 14 days, giving a significant reduction in production losses.

B2. Estimation of savings in inspection costs

In order to estimate the potential savings in inspection costs across the UKCS it is necessary to have a figure for the population of vessels on the offshore installations. An estimate of the numbers of process vessels in the UKCs is shown in Table 2.

Offshore Installations in UKCS	Number of installations*	Average number of process vessels on installation **	Number of process vessels in UKCS
Manned Installations	143	28	4004
Unmanned Installations	118	5	590
Total	261		4594

Table 2: Estimate of the population of process vessels in UKCS

*Source: Table of UKCS Installations (reference 7).

**Source: Data provided by OGTC from discussions with industry for process vessels (excluding utilities) of sufficient size on an installation to potentially require intrusive inspection.

Assumptions:

1). On average, vessels are subject to inspection once every 5 years. (OGTC data).

2). 80% of vessels are suitable for inspection using NII. (A finding of the Phase 1 survey).

Estimate:

The average number of inspections of vessels per year = 4594 / 5 = 919

The potential number of NII inspections per year = 919 x 0.8 = 735

Using the cost data in Table 1 above, the potential savings in inspection costs resulting from full roll-out of NII across UKCS
= 735 x £192,000 = **£141 million per annum** (US$183 million per annum)

B3. Estimation of value to UKCS of the potential reduction in lost and deferred production

The reduction in turnaround duration of 7 days, recorded in B1, is equivalent to an increase in production of 7 / 365 = 1.9%.

If the vessels are inspected every 5 years the average production increase is 1.9% / 5 = 0.38% per year.

Assumptions:

1). Implementation of NII across UKCS results in an average annual increase of 0.38% in production for all producing assets.

2). Average oil price of US$55 per barrel. (2017 average price of Brent Crude).

Estimate:

In 2016 the UKCS produced 630 million boe. Source:- Oil & Gas UK Business Outlook (reference 8).

Estimated value of UKCS production = 630 million x 55 = US$34.7 billion. **(£26.7 billion)**.

An annual 0.38% increase in production is therefore potentially worth US$34.7 billion x 0.38% = US$132 million **(£ 101million) per year**

B4. Potential benefit to UKCS of NII implementation

By combining the figures estimated in B2 and B3, the potential benefit from the roll-out of NII across all producing assets in UKCS can be estimated. As shown in Table 3.

	£ million per annum
Savings in inspection costs	141
Reduction in deferred/lost production	101
Total benefit to UKCS	242 *

Table 3: Estimate of potential benefit to UKCS

*Equivalent to US$315 million per annum.

