



## **OGTC - ABB NII Initiative**

### ***Phase 2 Summary Report***



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OGTC and ABB are progressing an opportunity for Operators in the UKCS to benefit from recent advances in non-intrusive inspection (NII) technology. The benefits to UKCS are projected to be of the order of £240 million per annum in reduced maintenance costs associated with preparing vessels for inspection and increased production due to higher equipment availability. The initiative has been progressed in two phases.

Phase 1 of the study was a survey in which interviews were conducted with Technical Authorities from nine major UKCS Operators about their current inspection methodology to establish the current status and potential for application of the NII methodology and technology. The findings of these interviews are summarised in the Non-Intrusive Inspection Survey Report produced by ABB for OGTC and issued to the UKCS in 2017.

Phase 2 involved four pilot studies with selected Operators to further demonstrate the potential to deploy NII technology. This report summarises the outcome of the pilot NII reviews of 79 representative vessels subject to internal inspections on the assets of four Operators. The pilot studies considered a range of vessel types and materials located on both fixed installations and FPSOs.

The headline outcomes of the Phase 2 pilot studies which took place between October 2017 and February 2018 are as follows:

- The requirement for intrusive inspections across the four Operators could be reduced by 47%.
- Some 44% of the vessels were found to require vessel entries for process cleaning, the inspection of internal fittings or linings, or for periodic repairs / item replacement.
- If we set aside the 44% of vessels requiring entry for other reasons and a vessel due replacement, 84% of the remaining vessels are potential candidates for NII.
- The cost of inspection for the 37 vessels identified as suitable for NII could be reduced by an estimated £ 1.5 million per annum.



- Exposure of individuals to the risks of entry to confined spaces could be significantly reduced as a result of the 47% reduction in the number of internal inspections requiring man entry.
- The corresponding reduction in the number of flanged joints to be broken and then re-made would reduce the likelihood of loss of containment and would contribute to improved safety and environmental performance.
- The reduction in vessel cleaning and purging requirements would further improve safety and environmental performance.

These outcomes assume that findings of the pilot studies are implemented.



## 2 Background

In line with the UK Continental Shelf (UKCS) Maximising Economic Recovery (MER) strategy, the Oil and 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. This initiative has been progressed in a number of phases.

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.

In Phase 1 a survey of nine Operators established the current use of NII technology across the UKCS and the potential for its wider application. 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 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
- A lack of management engagement
- A lack of transparency of the overall cost of inspection.
- Availability of data within the UKCS

A second phase has now been completed. Phase 2 was intended to help the industry overcome the barriers outlined above and gain the benefits from deploying NII technology across the UKCS.

Phase 2 comprised pilot studies with four Operators that were making no use of NII as a substitute for major intrusive inspection. Some 20 vessels were assessed for each Operator to identify those which could be inspected effectively using NII. All of these vessels were subject to schemes of examination based upon internal inspection. The purpose of Phase 2 was to demonstrate the scope for the application of NII with these Operators.



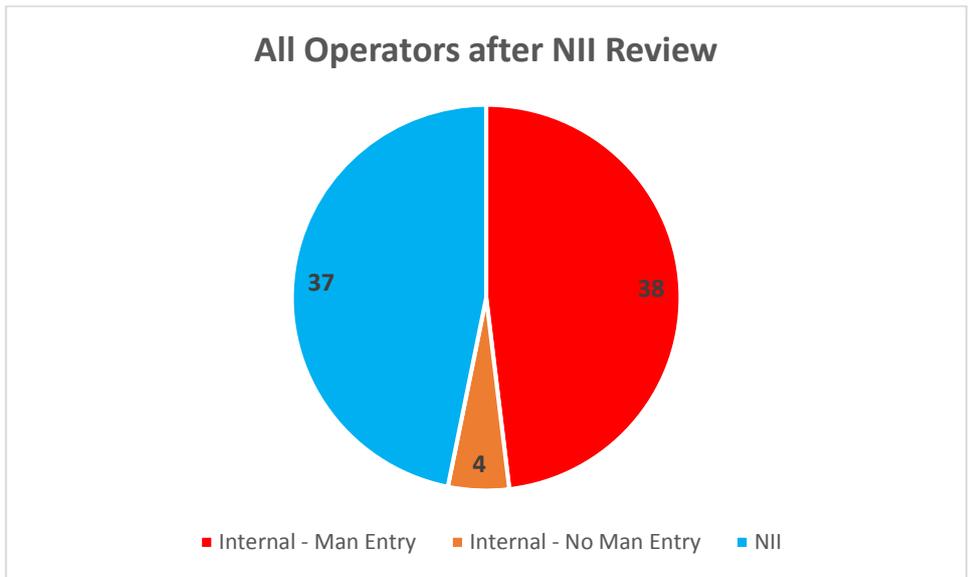
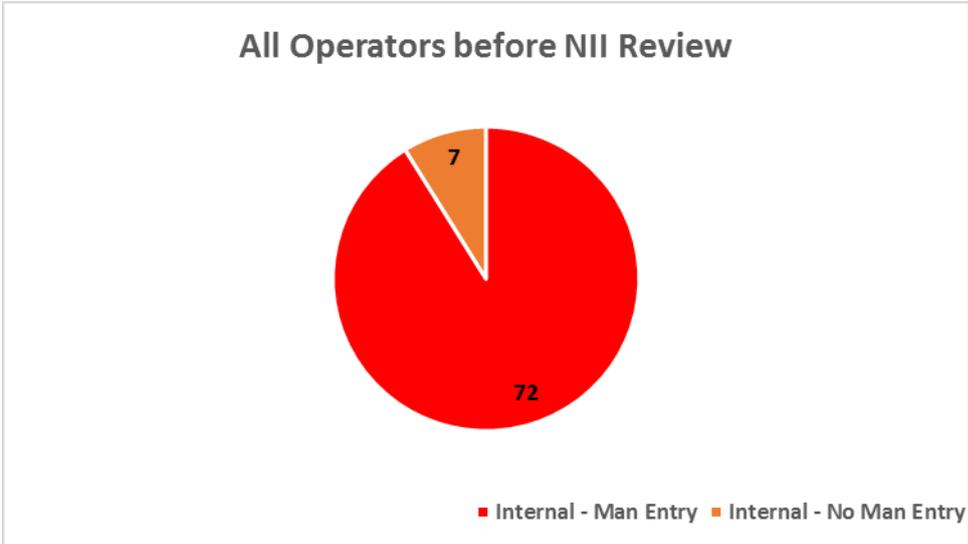
### 3 Summary of Changes to the Inspection Requirements

The changes to the inspection requirements determined as a result of the Phase 2 pilot studies are summarised in Table 1 below, and are illustrated in more detail in Figures 1 and 2. The resulting reduction in inspection costs is shown in Table 2 on page 11. The inspection costs used in this estimation are based upon the findings of the NII survey in Phase 1.

	Operator A	Operator B	Operator C	Operator D	Overall
<b>Vessels in Study</b>	20	20	19	20	<b>79</b>
<b>Before NII Study</b>					
<b>Internal – Man Entry</b>	20	17	19	16	<b>72</b>
<b>Internal – No Man Entry</b>	0	3	0	4	<b>7</b>
<b>After NII Study</b>					
<b>Internal – Man Entry</b>	6	9	11	12	<b>38</b>
<b>Internal – No Man Entry</b>	0	0	0	4	<b>4</b>
<b>NII</b>	14	11	8	4	<b>37</b>
<b>% NII</b>	70%	55%	42%	20%	<b>47%</b>

Table 1: Summary of Changes to Inspection Requirements





**Figure 1: Inspection splits before and after NII Review**



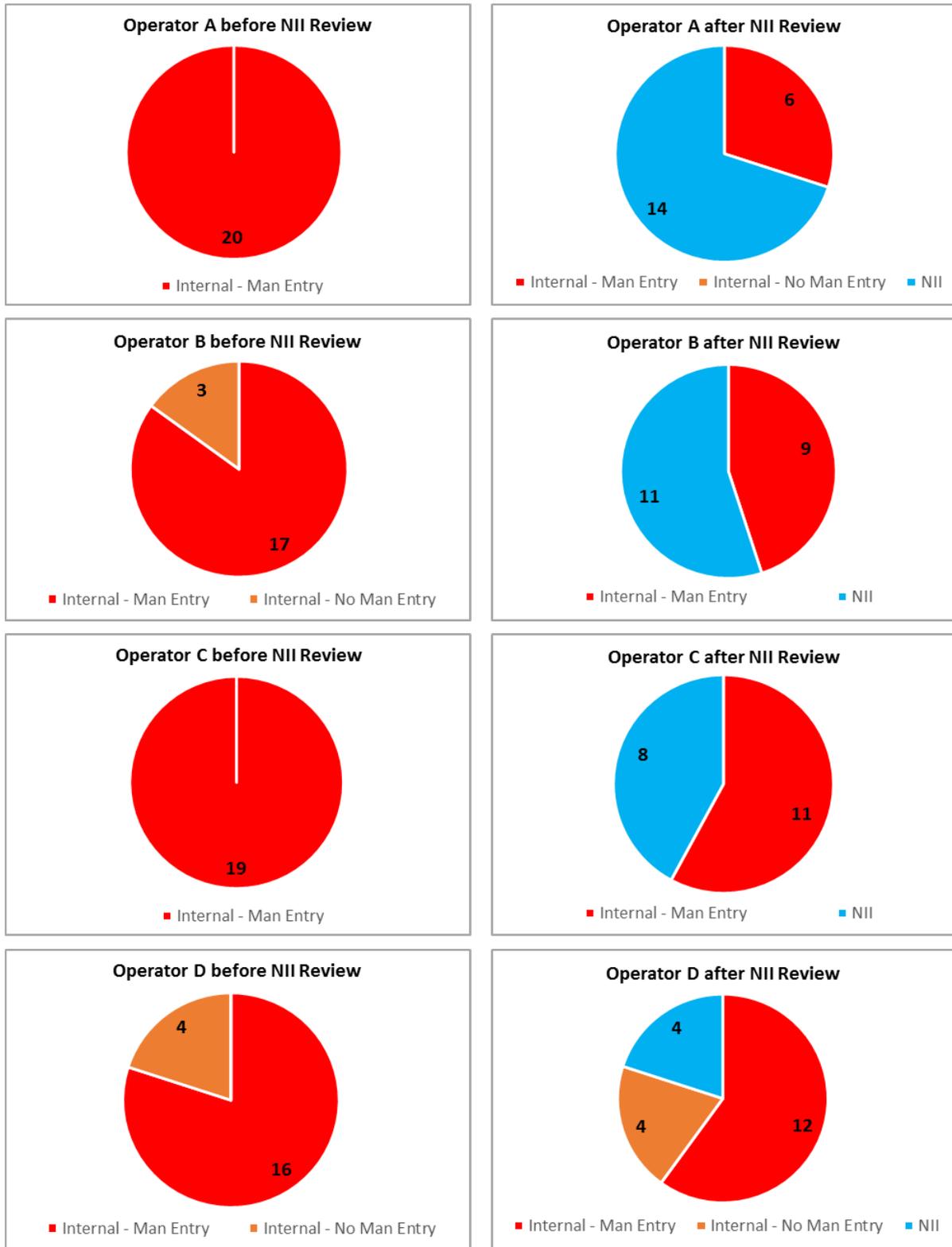


Figure 2: Inspection Splits before and after NII Review for each Operator



	<b>Operator A</b>	<b>Operator B</b>	<b>Operator C</b>	<b>Operator D</b>	<b>Overall</b>
<b>Vessels in Study</b>	20	20	19	20	79
<b>Before NII Study</b>					
<b>Annualised Inspection Cost (£k)</b>	550	1,259	1,455	673	3,937
<b>After NII Study</b>					
<b>Annualised Inspection Cost (£k)</b>	239	608	1,032	603	2,482
<b>Cost Saving (£k)</b>	311	651	423	70	1,455
<b>Cost Saving (%)</b>	57%	42%	29%	10%	37%

**Table 2: Summary of Changes to Annual Inspection Costs**

The cost estimations are recorded in Table 5 in Appendix A.



## 4 Assessment Methodology

The NII assessments were undertaken using a screening methodology based on the DNV Recommended Practice on Non-Intrusive Inspection (DNV-RP-G103). The same methodology was followed for each of the pilot studies. Figure 3 outlines the methodology, which has five stages:

1. Review the item's deterioration mechanism and likelihoods based on:
  - Inspection history, including the type and effectiveness of inspection methods;
  - Operational information such as operating temperatures, fluid composition; and
  - Design and construction specification, including Materials of Construction and internal and external coatings.
2. Carry out NII screening procedure following the DNV RP guidance to reach a high level decision about the suitability of NII based on:
  - The review of deterioration mechanisms and likelihoods;
  - Inspection history, including the type and effectiveness of inspection methods; and
  - Learning from other equipment on that asset, or similar equipment on other assets.
3. (If NII is possible). Produce a detailed technical assessment and justification. Review with the in-house team including the materials Technical Authority (TA) and inspection. (If NII is not possible go to Step 5.)
4. Update the CMMS and set the new strategy with the new inspection scope and interval.
5. Execute inspections. Periodically Step 1 of the process will be revisited.

The results of steps 1 to 3 of the methodology were recorded in an Excel spreadsheet provided to each of the Operators.



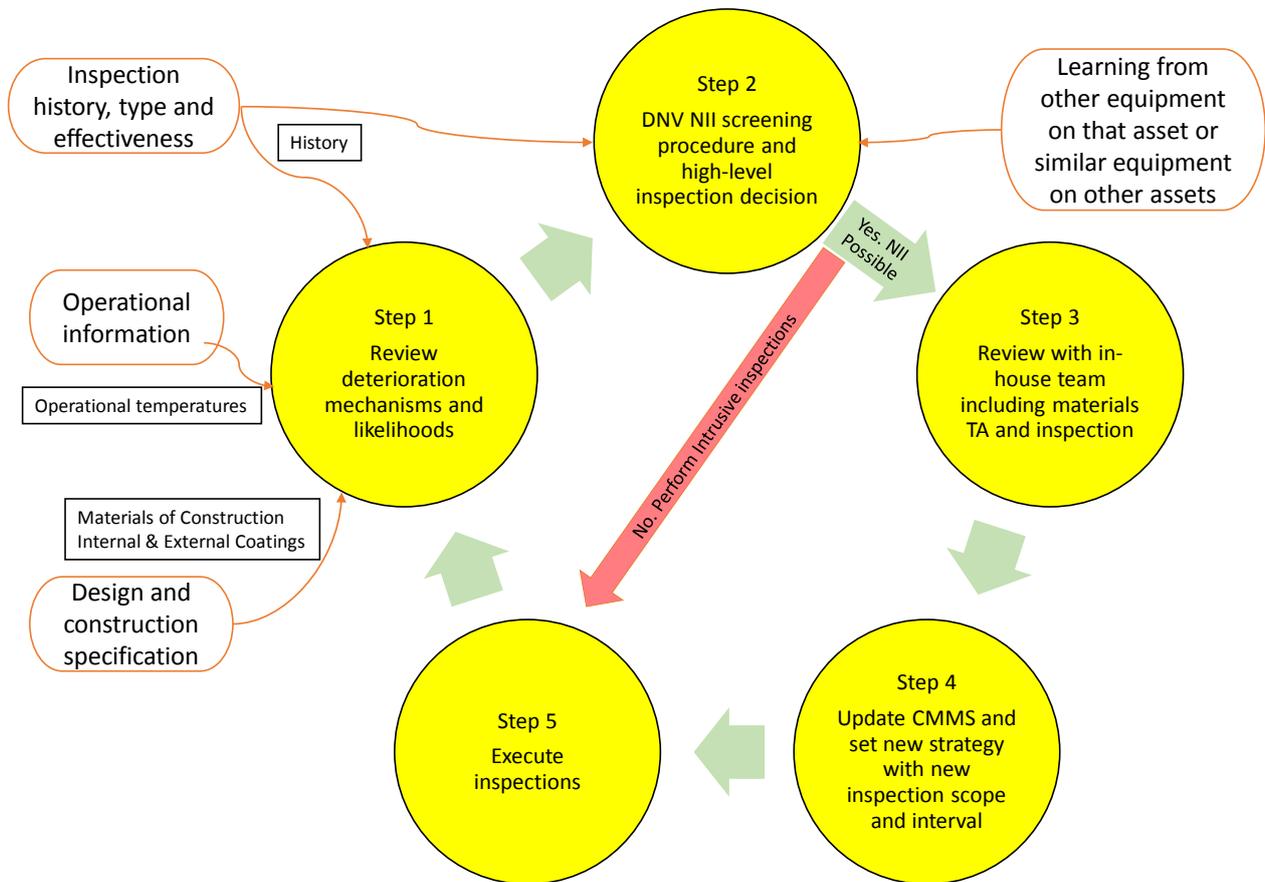


Figure 3: NII review methodology

## 5 Phase 2 Pilot Study Findings

### 5.1 Study scope

Four Operators participated in the pilot studies. The studies covered 79 vessels located on three fixed installations and four FPSOs. These installations are located on the UKCS, or, as is the case for one of the FPSOs, shortly to be relocated to the UKCS. All of the vessels were subject to intrusive inspection. In the majority of cases this inspection required man-entry into the vessel.

The pilot studies considered a range of representative vessel types including scrubbers, separators, drums and heat exchangers. Materials were mainly carbon steel (75%) with some duplex (20%) and stainless steel (5%). 55% of the vessels had a lining.

### 5.2 Type of inspection

The absence of internal degradation mechanisms in many of the vessels enabled the requirement for intrusive inspection to be reduced or eliminated. This was the situation for Operators A, B & C. For Operator D it was determined that there was little scope for a reduction in intrusive inspection.

Prior to the study all operators had 100% intrusive inspection. Following the study the requirement for intrusive inspection was reduced to:

- 30% of the vessels for Operator A
- 45% of the vessels for Operator B
- 58% of the vessels for Operator C
- Only 80% of the vessels for Operator D

The pilot study found that the majority of Operator D's vessels require an entry for operational and maintenance reasons and hence no advantage would be gained in moving to an NII strategy. A significant number of the 20 vessels in the sample require periodic entry for cleaning and/or for inspection and repair of the internal fittings. Eight of



these vessels have internal heating elements that require inspection. One vessel has not been internally inspected since installation and no inspection history was available for another vessel.

The variation in the results between the Operators is also due to the number of vessels with internal linings and the need, based upon operating experience and the materials of construction, to enter the vessel on a periodic basis to inspect and where necessary repair or replace the lining. The materials of construction specified for the vessel shell and the lining are important factors, especially where linings with a limited life have been applied. For example, there is more opportunity to move to NII where the shell is made from carbon steel or duplex with an internal metallic overlay than vessels coated with some of the non-metallic linings.

A significant outcome of these pilot studies is that for the vessels that are deemed to be suitable for NII the inspection can potentially be undertaken with the equipment online.

The range of inspection intervals for each Operators are listed below:

- Operator A - 60 to 144 months.
- Operator B - 18 to 72 months.
- Operator C - 12 and 72 months.
- Operator D - 12 and 144 months (with more than half of the vessels on a 144 month interval).

The reasons for the significant variation in periodicity from Operator to Operator are not clear and investigation of this was not within the scope of the pilot studies. Operator A has the fixed installations and Operators B, C & D have FPSOs, but this may not be a relevant factor.

The fact that Operator A's vessels are inspected much less frequently is the reason why the estimated cost savings for this Operator are substantially lower than those for Operators B and C when the figures are calculated on an annual basis. This is despite the fact that Operator A has the largest percentage of vessels that are suitable for NII (70% in comparison with 55%, and 42% for Operators B & C respectively). Operator D has the lowest annualised cost saving by a wide margin. Only a few of Operator D's



vessels are suitable for NII, because entry is undertaken for the reasons discussed on the previous page, and the inspection intervals are longer.

See Section 5 and Table 5 in Appendix A.

### 5.3 Discussion of findings

One of the criteria in DNV-RP-G103 for moving to an NII strategy is that vessel entry is not programmed for other reasons. As can be seen in Table 3, below, vessel entries are required for reasons other than inspection for 17 of the vessels, some 22% of the vessels assessed during the pilot studies.

The need to remove sand is one of the main requirements for a vessel entry. On-line sand removal technology can be installed but it is not clear to what extent this capability has been installed on the vessels in these assets. Other vessels were found to be in need of internal repairs, for instance to areas of pitting or to internal fittings (i.e. grids). Two vessels were found to require periodic replacement of sacrificial anodes. Some vessels require both the removal of sand and internal repairs. Overall 25 vessels, were deemed to be not suitable for NII. This is 32% of the vessels covered by the four pilot studies.

Deemed suitable for NII	37
Determined to be not suitable for NII	25
Vessel entry required for reasons other than inspection	17
Total	79

**Table 3: Outcome of NII assessment**

Table 4, on the next page, records the reasons why NII cannot be applied to the vessels. It is notable that reservations about the capability of NII to detect the anticipated defects



applies to only 3 of the vessels, 4% of the vessels covered in the pilot studies. Another 3 vessels will be processing hydrocarbons from new fields and uncertainty about the fluid composition means that the presence and rate of progression of internal deterioration cannot be predicted with sufficient confidence. A lack of inspection history meant that another vessel had to be excluded. All together this means that only 9% of the vessels cannot be inspected using NII for technical reasons.

Low confidence in ability of NII to detect the predicted defects	3
Uncertainty about the fluid composition from new field(s)	3
Inspection of vessel lining	7
Inspection of heat exchanger tubes	9
Inspection of heating element	1
Limited remaining life of vessel	1
No inspection history – vessel not inspected since installation in 2012	1
Total	25

**Table 4: Vessels not suitable for NII**

17 vessels require internal inspections to internal fittings (i.e. the lining, heat exchanger tubes or heating element). It was established that for these vessels the inspection had to be done internally. For the remaining vessel it was decided that NII was not worth undertaking for reasons of limited vessel life.

If we exclude the vessels requiring entry for the reasons outlined above, i.e.

- 17 vessels for which entry is required for reasons other than inspection
- 17 vessels with internal fittings requiring an internal inspection to be undertaken



plus the vessel with limited operational life, the vessels deemed suitable for NII represent 37 out of the remaining 44 vessels. This is 84% of the vessels that are potential candidates for NII.

## 6 Estimation of resulting savings in inspection costs

The savings that would result from substituting NII for internal Inspections have been estimated for each Operator based on an average cost for each type of inspection. These figures have been annualised by dividing the costs by the inspection interval.

The estimated cost for an internal inspection includes the costs of the vessel's mechanical preparation for internal inspection, scaffolding, undertaking the inspection and reinstating the vessel. Based upon the findings of the NII survey (Phase 1), a figure of £236k has been used for the average cost of undertaking an internal inspection.

A figure of £44k is used for the average cost of undertaking the NII inspections. This estimate is also based upon the findings of the NII survey. Any availability cost impact on the operation of the asset resulting from a vessel needing to be offline for non-intrusive inspection to be undertaken has likewise been excluded.

ABB accepts that this approach has only produced a very approximate estimate for the cost reduction, as highly detailed cost information would be required and a much more in depth analysis needed in order to produce a more accurate estimate. The actual savings will vary according to the operational circumstances relating to each Operator, whereas the estimated savings assume that the average figures apply to each Operator.

The estimation of the annualised costs for each of the four Operators before and after the reviews are provided in Table 5 in Appendix A. The change in costs for each of the operators is shown in Table 2 and is illustrated in Figure 4, on the next page. This demonstrates the magnitude of the potential savings resulting from the application of NII. As noted in Section 4 the annual inspection costs for Operator A are lower than Operators B and C because the interval between the inspections is longer for Operator A, thereby reducing the cost on an annualised basis.



The total cost saving across the four operators is estimated to be almost £1.5 million per annum, representing a 37% overall saving in inspection costs. This is illustrated in Figure 5 on the next page. The cost of intrusive inspections remains the major contributor to the overall cost of inspection.

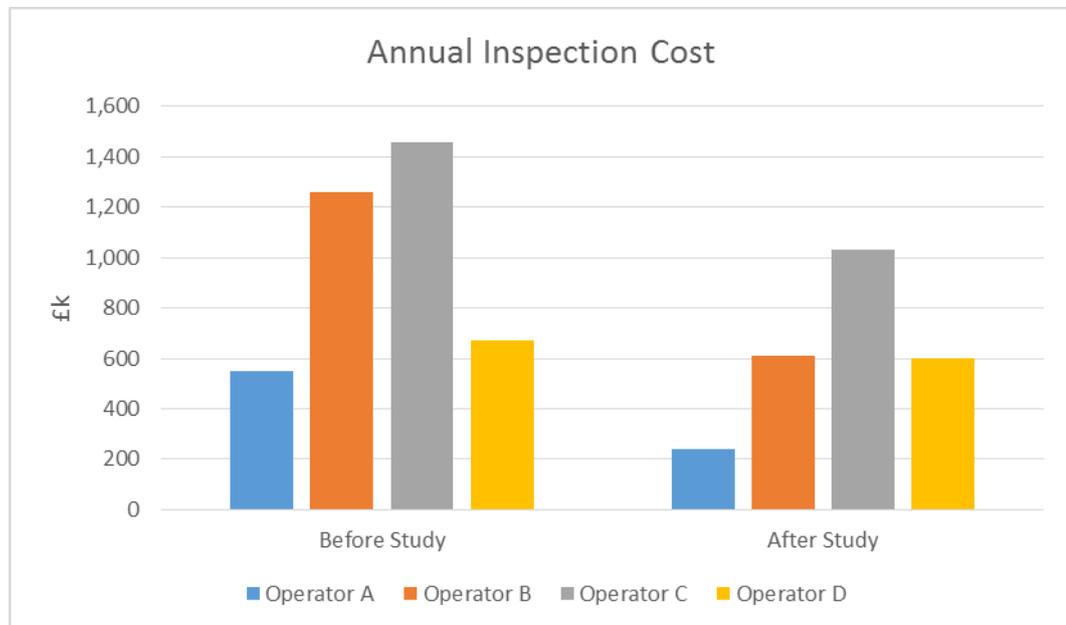
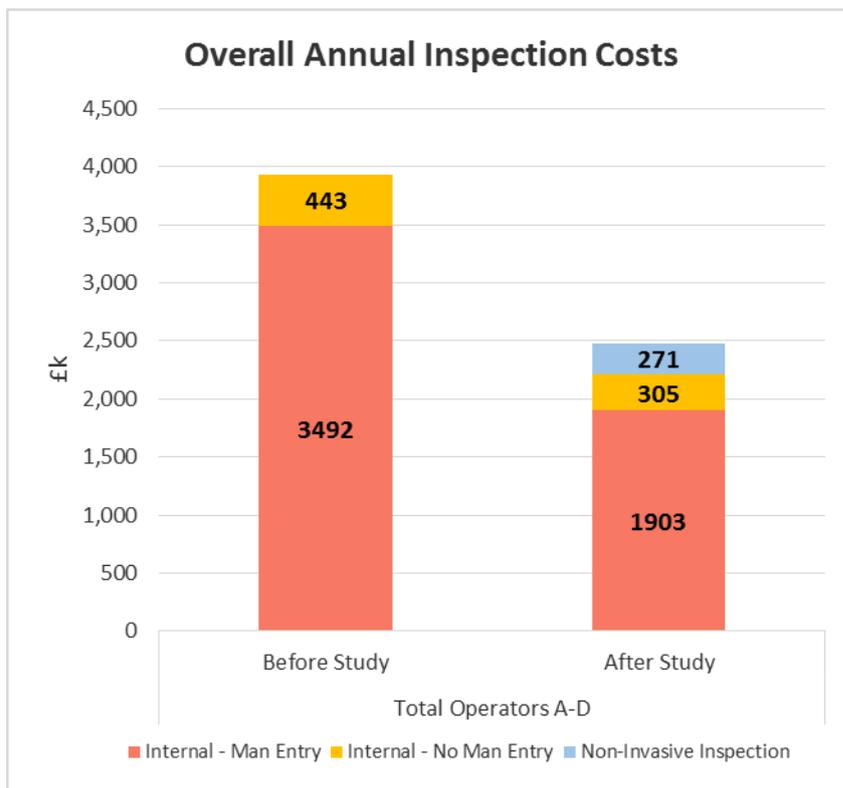


Figure 4: Change in Inspection Costs for Operators A-D





**Figure 5: Overall Change in Annual Inspection Costs**

The estimated costs for intrusive inspections and NIIs for each Operator are shown in Figure 6, on the next page. This clearly illustrates the differences in the potential cost savings for each Operator.

The cost savings estimated in Table 5 are, however, likely to be an underestimation of the savings in the total cost of inspecting the vessels. ABB does not have the data needed to estimate the production costs associated with undertaking the inspections on the vessels covered by these pilot studies.





**Figure 6: Inspection Costs for Operators A-D**



These NII pilot studies have identified a significant reduction in the number of intrusive inspections for the 79 vessels considered, at an acceptable level of risk, together with a corresponding direct saving in inspection costs of approximately £1.5 million per year, equivalent to a saving of approximately 37%.

The potential for the application of NII varies significantly from one Operator to another. Nevertheless, the estimated cost savings are worthwhile in each case.

The £1.5 million inspection cost saving equates to an annual saving of circa £20k per vessel. In Phase 1 the potential savings in inspection costs for the vessels across the UKCS was estimated to be £141 million per year. This is equivalent to circa £30K per vessel per year based upon an average inspection frequency of 60 months.

In Phase 1 the potential value of the increased production to the UKCS that would result from implementation of NII was estimated to be of the order of £100 million per year.

44% of the vessels assessed in the pilot studies were found to require vessel entries for cleaning, periodic repairs and replacements, and for the inspection of internal fittings or the vessel lining. If these vessels are excluded NII can be used to inspect 84% of the remaining vessels.

7 out the 79 vessels were found to be unsuitable for NII due to uncertainty in the ability of NII to detect the predicted defects (3), uncertainty about the fluid composition (3) and no inspection history (1).

By adopting NII it has been demonstrated that 37 vessels would not require man entry for the vessel to be inspected. This represents a significant safety improvement as the individual exposure of persons to the risks associated with a confined space entry is correspondingly reduced.

The associated reduction in the number of joints to be broken and then re-made directly reduces the likelihood of loss of containment contributing to improved safety and environmental performance. The reduction in cleaning and purging requirements will also contribute to improved safety and environmental performance.



Appendix A Table 5 – Estimated Annual Inspection Costs Before and After NII Pilot Study

Vessels in study	Operator A					Operator B					
	Inspection interval (months)	Number of vessels	Annualised number of inspections	Cost per inspection (£k)	Annualised inspection cost (£k)	Inspection interval (months)	Number of vessels	Annualised number of inspections	Cost per inspection (£k)	Annualised inspection cost (£k)	
Before Study						Before Study					
Internal - Man Entry	144	4	0.33	236	78.67	Internal - Man Entry	60	10	2.00	236	472.00
Internal - Man Entry	120	6	0.60	236	141.60	Internal - Man Entry	48	1	0.25	236	59.00
Internal - Man Entry	108	2	0.22	236	52.44	Internal - Man Entry	36	4	1.33	236	314.67
Internal - Man Entry	84	1	0.14	236	33.71	Internal - Man Entry	24	1	0.50	236	118.00
Internal - Man Entry	72	5	0.83	236	196.67	Internal - Man Entry	18	1	0.67	236	157.33
Internal - Man Entry	60	1	0.20	236	47.20	Internal - No Man Entry	72	2	0.33	236	78.67
Internal - Man Entry	To be reassessed	1	-	236	0.00	Internal - No Man Entry	48	1	0.25	236	59.00
<b>Totals</b>		<b>20</b>			<b>550.29</b>	<b>Totals</b>		<b>20</b>			<b>1,258.67</b>
After Study						After Study					
Internal - Man Entry	120	1	0.10	236	23.60	Internal - Man Entry	72	1	0.17	236	39.33
Internal - Man Entry	108	1	0.11	236	26.22	Internal - Man Entry	60	5	1.00	236	236.00
Internal - Man Entry	72	3	0.50	236	118.00	Internal - Man Entry	36	3	1.00	236	236.00
Internal - Man Entry	To be reassessed	1	-	236	0.00	NII	60	11	2.20	44	96.80
NII	144	4	0.33	44	14.67						
NII	120	5	0.50	44	22.00						
NII	108	1	0.11	44	4.89						
NII	84	1	0.14	44	6.29						
NII	72	2	0.33	44	14.67						
NII	60	1	0.20	44	8.80						
<b>Totals</b>		<b>20</b>			<b>239.13</b>	<b>Totals</b>		<b>20</b>			<b>608.13</b>
				<b>Annual Cost Saving (£k) Operator A</b>	<b>311</b>					<b>Annual Cost Saving (£k) Operator B</b>	<b>651</b>
				<b>Annual Cost Saving (%) Operator A</b>	<b>57%</b>					<b>Annual Cost Saving (%) Operator B</b>	<b>52%</b>

Vessels in study	Operator C					Operator D					Overall	
	Inspection interval (months)	Number of vessels	Annualised number of inspections	Cost per inspection (£k)	Annualised inspection cost (£k)	Inspection interval (months)	Number of vessels	Annualised number of inspections	Cost per inspection (£k)	Annualised inspection cost (£k)		
Before Study						Before Study						
Internal - Man Entry	72	1	0.17	236	39.33	Internal - Man Entry	144	12	1.00	236	236.00	
Internal - Man Entry	60	1	0.20	236	47.20	Internal - Man Entry	108	2	0.22	236	52.44	
Internal - Man Entry	48	8	2.00	236	472.00	Internal - Man Entry	96	1	0.13	236	29.50	
Internal - Man Entry	36	6	2.00	236	472.00	Internal - Man Entry	60	1	0.20	236	47.20	
Internal - Man Entry	30	2	0.80	236	188.80	Internal - No Man Entry	144	2	0.17	236	39.33	
Internal - Man Entry	12	1	1.00	236	236.00	Internal - No Man Entry	96	1	0.13	236	29.50	
						Internal - No Man Entry	12	1	1.00	236	236.00	
<b>Totals</b>		<b>19</b>			<b>1,455.33</b>	<b>Totals</b>		<b>20</b>			<b>669.98</b>	<b>Before Study</b>
												<b>Overall Total Annual Cost (£k)</b>
												<b>3,934.27</b>
After Study						After Study						
Internal - Man Entry	72	1	0.17	236	39.33	Internal - Man Entry	144	9	0.75	236	177.00	
Internal - Man Entry	60	1	0.20	236	47.20	Internal - Man Entry	108	1	0.11	236	26.22	
Internal - Man Entry	48	2	0.50	236	118.00	Internal - Man Entry	96	1	0.13	236	29.50	
Internal - Man Entry	36	4	1.33	236	314.67	Internal - Man Entry	60	1	0.20	236	47.20	
Internal - Man Entry	30	2	0.80	236	188.80	Internal - No Man Entry	144	2	0.17	236	39.33	
Internal - Man Entry	12	1	1.00	236	236.00	Internal - No Man Entry	96	1	0.13	236	29.50	
NII	48	6	1.50	44	66.00	Internal - No Man Entry	12	1	1.00	236	236.00	
NII	48	2	0.50	44	22.00	NII	144	4	0.33	44	14.67	
<b>Totals</b>		<b>19</b>			<b>1,032.00</b>	<b>Totals</b>		<b>20</b>			<b>599.42</b>	<b>After Study</b>
												<b>Overall Total Annual Cost (£k)</b>
												<b>2,478.69</b>
				<b>Annual Cost Saving (£k) Operator C</b>	<b>423</b>					<b>Annual Cost Saving (£k) Operator D</b>	<b>71</b>	<b>Overall Annual Cost Saving (£k)</b>
				<b>Annual Cost Saving (%) Operator C</b>	<b>29%</b>					<b>Annual Cost Saving (%) Operator D</b>	<b>11%</b>	<b>Overall Annual Cost Saving (%)</b>
												<b>37%</b>

