national gas transmission

ENGINEERING JUSTIFICATION PAPER (EJP)

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AC Inspection and Remediation

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Version: 1.0

Issue: Final

December 2024

RIIO-GT3 NGT_EJP08

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1 Summary Table

Table 1: AC Inspection and Remediation EJP Executive Summary Table

Name of Project	*AC Inspection and Remediation*		
Scheme Reference	*NGT_EJP008_AC Inspection and Remediation_RIIO-GT3*		
Primary Investment Driver	*Asset Health*		
Project Initiation Year	*FY27*		
Project Close Out Year	*FY31*		
Total Installed Cost Estimate (£)	£5.3m		
Cost Estimate Accuracy (%)	+/- 10%		
Project Spend to date (£)	0		
Current Project Stage Gate	ND500 Stage 4.0		
Reporting Table Ref	6.4		
Outputs included in RIIO-T2 Business Plan	Yes		
Spend Apportionment (£m)	**RIIO-T2**	**RIIO-GT3**	**RIIO-GT4**
	0.3	5.0	0

2 Executive Summary

2.1.1 We propose to invest £5.3m of baseline allowances to address the emerging threat of Alternating Current (AC) induced corrosion, to 24% of National Gas Transmission (NGT) buried pipeline assets in RIIO-GT3. AC induced corrosion is the degradation of a pipeline which is solely caused by the presence of AC from a high voltage overhead power line.

2.1.2 The primary driver for this investment is to achieve compliance with International Standards ISO 18086 requirements managing AC risk. This investment is required to continue to comply with statutory legislation, industry best practise, and to meet with HSE expectations from ongoing industry workshops.

2.1.3 51 interventions are required to maintain the current level of risk. This level of risk is the same seen at the start of RIIO-T2 for this asset category.

2.1.4 The assets in this investment are pipelines. We have considered six options across the pipelines portfolio to address AC risk, to establish an optimal programme that would deliver desired regulatory outputs. In summary we are proposing the following intervention mix:

Table 2: RIIO-GT3 volumes proposed in this EJP.

	AC Enhanced In-Line Inspection	AC Survey and Mitigation Design	AC Mitigation	Total
RIIO-GT3 volumes	[redacted]	[redacted]	[redacted]	51

2.1.5 In RIIO-T2 we will have delivered 11 inspection interventions in-line with our allowance of 11. The growth in RIIO-GT3 proposed intervention volumes is from the need to assess 25 pipeline sections in RIIO-GT3, an increase over the 11 in RIIO-T2. Additionally, we need to commence with installation of physical mitigation measures to protect our pipelines, and a programme of enhanced in-line inspections.

Table 3: RIIO-T2 vs RIIO-GT3

	RIIO-T2 Business Plan	RIIO-T2 Forecast Delivery	RIIO-GT3 Business Plan
Interventions	11	11	51
Investment	£1.4m	£1.4m	£5.3m
Pipeline population	7%	7%	24%

2.1.6 Due to rapid expansion of Overhead Power Line capacity, it is important we deliver a stepped increase in AC corrosion assessment and mitigation during RIIO-GT3 and on an ongoing basis to comply with industry standards and to ensure future network risk levels are not compromised.

2.1.7 This work is deliverable as the AC Enhanced In-Line Inspection is linked to an existing statutory inspection and the Survey and Mitigation can be delivered without a pipeline outage.

2.1.8 The profile of investment for RIIO-GT3 is shown in the below table:

Table 4: RIIO-GT3 funding request for AC Corrosion (£m, 2023/24)

Financial Year	2026	2027	2028	2029	2030	2031	Total
AC enhanced In-line Inspection	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
AC Mitigation	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
AC Survey and Mitigation design	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

3 Introduction

3.1.1 This report covers Alternating Current (AC) induced corrosion to our National Transmission System (NTS) pipeline assets. Sources of AC current include the electricity transmission system, which transports AC via its Overhead Power Line (OHPL) systems and electrified railway lines. When these are in close vicinity to buried pipelines, the transfer of AC current to the pipeline can cause corrosion to occur via coupling. This EJP considers all the NTS pipeline assets.

3.1.2 In some instances, the OHPL run parallel to our NTS pipelines, exposing them to risk of AC-induced corrosion. AC corrosion features are generally identifiable as shallow circular pits with small circular dimples within the pit as shown in Figure 1 below.

Figure 1: Typical AC Corrosion Feature

3.1.3 This paper sets out our approach to how we propose to find, monitor, and mitigate the effects of AC exposure and induced AC Corrosion in RIIO-GT3. The interventions in this document have been generated by the known issues we have experienced along with achieving compliance with International Standards ISO18086 and BS EN 12954.

3.1.4 One example of AC interference on the NTS is [redacted] which had a recorded AC density of [redacted]. This value is above the threshold for 'very high likelihood of AC induced corrosion' set in BS EN 12954.

Figure 2: High Tension Cables [redacted].

3.1.5 This location has been subject to assessment during RIIO-T2 in which damage was found caused by AC induced corrosion. A feature from the investigation is circled in the image below. This assessment has concluded and resulted in the requirement to mitigate to protect from further AC induced corrosion damage.

Figure 3: [redacted]

3.1.6 AC corrosion is a significant risk to our pipeline integrity and levels of AC above certain levels set in BS EN 12954 can result in accelerated corrosion. Corrosion rates of 1mm per year have been experienced within the UK. Sustained accelerated corrosion left undetected, could cause a standard wall thickness pipeline on the NTS to rupture within a few years.

3.1.7 In RIIO-T2, we commenced a regime of surveying a sample of pipelines to understand whether AC risk was being experienced on our pipeline sections and whether we need to take action to protect our pipelines. This followed the criteria in ISO 18086 – AC Corrosion risk of cathodically protected pipelines.

3.1.8 The 11 locations assessed in RIIO-T2 have identified a need for mitigation, resulting in the expansion of this activity to understand our AC induced corrosion risk. In RIIO-GT3, we are expanding this to mitigate the sections surveyed within RIIO-T2 to prevent AC induced corrosion growth and survey the remainder of our highest risk sections within England and Wales. The purpose of this is to understand whether we need to mitigate more sections and commence a proactive inspection regime to ensure that any AC corrosion features are swiftly addressed to ensure integrity of our pipeline assets.

3.1.9 The scope of this document is aligned with our Asset Management System (AMS) and relates to our Business Plan Commitments (BPCs) for Meeting our critical obligations every hour of every day. More information on our AMS and a description of our commitments is provided in our NGT_A08_Network Asset Management Strategy_RIIO_GT3 annex and our BPCs are detailed within our NGT_Main_Business_Plan_RIIO_GT3.

3.1.10 This EJP interacts with NGT_EJP17_Pipeline_RIIO-GT3 document submitted by NGT. This delivery of this investment proposal is linked with In-Line inspection investments to examine pipeline condition.

4 Equipment Summary

4.1.1 Pipelines are the primary asset within the NTS that enables transportation of gas around the network.

4.1.2 Prior to RIIO-T2 we commissioned external supplier [redacted] to analyse our pipeline data and create an AC influence risk score for our pipeline sections within England and Wales. This analysis was undertaken at Pressure Systems Safety Regulations (PSSR) section level to ensure a localised view of AC risk and to not dilute the risk score over a longer section of pipeline. We were unable to complete this analysis for Scotland due to not receiving data from the OHPL operators. This issue has been raised to the industry and conversations are ongoing between NGT, Health and Safety Executive (HSE) and United Kingdom Onshore Pipeline Operators' Association (UKOPA), along with the OHPL operators, to obtain the data.

4.1.3 The Cathodic Protection (CP) system for the pipeline does not have a significant influence on rates of AC induced corrosion so the associated equipment is not considered within this paper.

4.1.4 Power ratings of OHPL could have an impact on the levels of induced current but is not significant so was not included within the assessment.

4.1.5 The assessment looked at the main factors that determine AC influence on pipelines which are listed below.

- The separation distance between pipeline and OHPL and the lengths of these parallel occurrences
- Angles of crossings between pipeline and OHPL
- Soil corrosivity
- Presence of a Bentonite Sleeve
- Coating system of the pipeline and its electrical characteristics.

4.1.6 Pipeline characteristics such as grade of steel, pipeline diameter and operating pressure do not have an impact on AC corrosion.

4.1.7 The purpose of the analysis was to understand the interaction between OHPL and our NTS to make an assessment on the level of risk our NTS is exposed to. This assessment was undertaken in accordance with British Standard- BS EN ISO 18086 and following recommended industry guidance provided by UKOPA. It is intended to update this analysis on an iterative basis.

4.1.8 The result of this analysis results in the below numbers of pipeline sections:

- P1 – High risk of AC influence – 36 sections
- P2 – Medium risk of AC influence – 72 sections
- P3 – Low risk of AC influence – 21 sections

4.1.9 These sections are listed by PSSR sections, so we carry out additional desktop analysis when reviewing ILI information. The definitions of P1-P3 relates to levels of risk of AC Induced corrosion occurring across the section and are aligned to BS EN 12954.

4.1.10 The focus of this EJP is tailored towards the P1 sections which are listed in the table below which are currently our highest risk sections on the NTS. This is the pipeline population deemed at high risk of AC influence. This volume in [redacted].

Table 5: P1 Pipeline Sections- High risk of AC-induced corrosion

Section	Pressure Rating (Bar)	Diameter (mm)	RIIO-T2 Surveys	RIIO-GT3 Survey	RIIO-GT3 Mitigate
[redacted]	70	900	Yes		Yes
[redacted]	70	450	Yes		Yes
[redacted]	70	1050	Yes		Yes
[redacted]	70	600	Yes		Yes
[redacted]	70	450	Yes		Yes
[redacted]	94	1200		Yes	
[redacted]	70	1050		Yes	

[redacted]	75	900	Yes		Yes
[redacted]	75	900	Yes		Yes
[redacted]	70	900		Yes	
[redacted]	70	1050		Yes	
[redacted]	70	300	Yes		Yes
[redacted]	75	750		Yes	
[redacted]	70	1200		Yes	
[redacted]	70	1050	Yes		Yes
[redacted]	70	1200			
[redacted]	75	1050	Yes		Yes
[redacted]	85	600	Yes		Yes
[redacted]	70	1050		Yes	
[redacted]	70	900		Yes	
[redacted]	70	900		Yes	
[redacted]	70	900		Yes	
[redacted]	70	300		Yes	
[redacted]	75	1200		Yes	
[redacted]	75	600		Yes	
[redacted]	75	900		Yes	
[redacted]	75	900		Yes	
[redacted]	70	300		Yes	
[redacted]	70	900		Yes	
[redacted]	84	900		Yes	
[redacted]	70	900		Yes	
[redacted]	70	600		Yes	
[redacted]	70	1050		Yes	
[redacted]	85	900		Yes	
[redacted]	85	900		Yes	
[redacted]	70	750		Yes	

4.1.11 Additional information on this equipment group such as the health score at the beginning and end of the price control and monetised risk are provided in the accompanying Excel EJP.

5 Problem/Opportunity Statement

5.1 Why are we doing this work and what happens if we do nothing?

5.1.1 AC Interference from parallelisms or crossings with overhead or buried powerlines, expose pipeline assets to a risk of accelerated corrosion growth and damage to the integrity of the pipeline. When AC current is present on a pipeline, even with adequate cathodic protection levels, ongoing corrosion can occur.

5.1.2 AC induced corrosion is a known problem which has damaged pipelines and will worsen over time, accelerated by the push for electrification in the UK to meet Net-Zero targets. The increasing uptake of renewable technology such as solar/wind will require the existing OHPL network to increase in capacity to carry the additional load. This rapid expansion of the electricity network increases the transfer of current to our buried pipeline assets. Therefore, the risk of AC induced corrosion to buried transmission pipelines is rapidly increasing and hence we need to undertake the increased work proposed in this EJP.

5.1.3 Up to now the electricity networks have remained relatively static with the occasional scheme or modification to an existing OHL circuit being managed on a case-by-case basis. This is due to significant change with the increasing shift to electrification. Ongoing projects are increasing capacity in the existing network by as much as 40-50% (this is through initiatives such as Line Vision, Dynamic Line Rating, Smart Wires, and their ongoing initiative The Great Grid Upgrade.

5.1.4 There will be a substantial increase in onboarding of local power generation schemes such as wind farms, solar arrays and Battery Storage on a local scale which will alter the historical power flows as it is transformed to AC for transmission. The electricity network in the UK is going to see significant structural and operational changes in the next 4 -6 years with this continuing to 2035 and we need to respond to this to ensure that we can protect our assets.

5.1.5 The UK relies on many Combined Cycle Gas Turbines to generate power. To export the electricity, High Voltage Alternating Current lines (HVAC) from the power station will cross the gas supply pipelines. This network configuration and reliance on gas to generate power means that there are a high number of HVAC lines crossing or running parallel to NGT pipelines.

5.1.6 NGT has engaged with consumers on the topic of AC corrosion. This suggested that consumers feel that the electricity industry has a role to play in prevention of AC induced corrosion to gas pipelines.

5.1.7 Given that AC corrosion features have the potential to grow quickly, they are a significant threat to the integrity of our pipelines. Within the UK, the impact of AC induced corrosion on [redacted] ethylene pipeline shows that AC induced corrosion can result in metal loss of more than 1mm per year.

5.1.8 Currently our methods for managing AC risk are to conduct In-line Inspection (ILI) runs in accordance with Intervals 2 methodology, and where the model highlights an AC risk, enhanced desktop analysis is carried out. Intervals 2 looks at pipeline characteristics and historic condition data to identify future inspection requirements. This identifies the features on the pipeline section and examines the corrosion growth rate of features present to check for active corrosion.

5.1.9 However, the current ILI tools used are unable to accurately identify micro and deep features which could grow via AC induced corrosion to a through-wall event in between ILI runs. This leaves us in a position of unacceptable risk to our asset base.

5.1.10 The production of the AC risk model has identified pipeline sections that are at high risk of AC induced corrosion, and our work to obtain data to understand this further during RIIO-T2 has validated our model and identified a need to protect our pipelines. This increase in understanding along with the growth in capacity of the electricity grid utilising technologies such as Line Vision[1] means that we must change our management practices to survey and mitigate at risk sections to pro-actively protect our pipelines from AC induced corrosion, rather than current re-active practises of catching corrosion features before they are able to grow.

[1] https://www.nationalgrid.com/national-grid-trials-new-technology-which-allows-more-renewable-power-flow-through-existing-power

5.1.11 Due to the rapid growth rate associated with AC induced corrosion, re-active practices result in an unacceptable risk and a failure in our statutory duties. The PSSR 2000 Part III section 8 states that for the system to be operated the written scheme of periodic examination is suitable and considers every pipeline in which a defect may give rise to danger. Due to the changing electricity network landscape and wider industry awareness of the emerging AC induced corrosion threat to buried pipeline assets, we need to adapt our existing asset management practises. This will ensure that we examine this risk and remediate where required so that our pipeline assets operate safely.

5.1.12 The drivers for this investment are summarised in the below table:

Table 6: Categories of Driver for AC Induced Corrosion

Driver Category	Description
Legislation	Compliance with Pressure System Safety Regulations 2000 (PSSR). General legislation for all pressure vessels and mandates the requirement for a regime of inspection and subsequent remediation of defects.
Legislation	Compliance with The Pipeline Safety Regulations 1996 (PSR). Specific legislation for those operating pipelines and places the obligation to manage the safety risks that they present to members of public and NGT staff.
Industry Standards	The internal/external inspection and subsequent remediation of pipeline defects or "features" to industry standards (IGEM TD/1), supplemented by NGT policies and procedures and is accepted by the Health and Safety Executive (HSE) as an appropriate way of operating a safe pipeline network and complying with all relevant legislation.
Industry Standards	International Standards for protecting assets from AC corrosion (ISO 18086). These standards have been adopted by operators worldwide and provide guidance on evaluation and assessment methods that NGT has adopted into its management practises.
Risk Management	AC-induced corrosion is an ongoing threat to the integrity of our pipelines. With the change in energy outlook in the UK we need to challenge existing Business As Usual (BAU) inspection and monitoring techniques. By collecting enhanced data, we can proactively monitor the impacts of AC current on the NTS pipeline assets today and over time to monitor the effects of increased electrification. This will enable pro-active decision making to respond to AC current levels before they are able to create an integrity problem.
Asset Deterioration	Pipeline assets are subject to corrosion, the associated metal loss and reduction in wall thickness where the coating has failed results in deterioration over time. The ongoing management of pipelines involves inspection and remediation of defects in-line with internal policy. AC induced corrosion will result in the deterioration of our pipeline asset and result in corrosion feature growth and damage to our coating systems.

5.2 What is the outcome that we want to achieve?

5.2.1 This EJP seeks to acquire funding so that we can commence with the below actions to proactively monitor and manage AC induced corrosion:

- Undertake surveys to gather data and record long-term AC exposure to make assessments on induced AC risk. This will be a one-off data gathering exercise and will occur over two 7-day periods in the summer and winter. This data will be used to understand if a pipeline we deem to be theoretically 'at high risk' is at risk in the field to validate our initial analysis for the NTS.
- Commencement of a programme of ILI inspections using a circumferential Magnetic Flux Leakage (MFL) tool to proactively check for AC corrosion features and monitor them over time so that we can identify AC corrosion features and act when needed to remediate defects found before they develop to a point in which pipeline integrity is compromised.
- As we gather data and continue to understand the impact of AC on our NTS pipelines we are recommending that we commence with installing mitigation systems to shield and protect our pipelines from AC current with the aim of not allowing AC features to develop.

5.2.2 If we do not commence with a programme of proactive monitoring and mitigation, then AC induced corrosion features could be present on our pipelines. Left untreated, they can result in a loss of containment of gas and the disruption and safety risks that brings with it. The HSE are aware of AC induced corrosion and expect NGT to understand and manage the risk posed to the assets. This is reported back to the HSE as part of the bi-lateral corrosion intervention meetings held twice yearly.

5.3 How will we understand if the spend has been successful?

5.3.1 We will evaluate the impact of mitigation works via our proposed assessments and enhanced ILI programme. We will understand whether the spend has been successful by reduced AC levels experienced on pipelines, along with the prevention of AC corrosion features developing on mitigated sections.

5.4 Narrative Real-Life Example of Problem

5.4.1 AC induced corrosion has been the subject of laboratory studies and seen in real-world cases of pipeline corrosion.

5.4.2 [redacted]

5.4.3 In 1986, a high-pressure gas pipeline accident occurred in Germany[2] which resulted in AC corrosion becoming a widespread industry topic and safety concern. This pipeline was a well-managed pipeline. It ran parallel to an AC powered railway line, which had a Cathodic Protection system installed and operating effectively. The pipeline suffered from corrosion failure. An investigation indicated that the sole cause of the failure was AC corrosion.

5.4.4 This failure resulted in numerous studies which showed that cathodic protection does not provide effective protection against AC Corrosion. It does not have a significant impact on AC induced corrosion rates and that AC mitigation is required to prevent serious corrosion.

Figure 4: AC Corrosion Feature at [redacted]

5.5 Project Boundaries

5.5.1 The spend in this EJP will cover assessments of the pipeline focussed on AC corrosion risk, and installation of mitigations to protect pipelines against AC corrosion.

5.5.2 The tool used to carry out the enhanced ILI runs is the same tool that will be used prior to any pipeline hydrogen repurposing decisions so will possibly be able to be combined. If a run has already taken place by the time this work is delivered, we will seek to use the results from the previous inspection rather than re-inspecting. We will combine ILI runs with hydrogen where able to, avoiding duplication of the same in-line inspection.

5.5.3 Not in scope for this investment:

- Pipeline integrity remediation.
- Performance or remediation of CP systems.

[2] [AC CORROSION - A NEW CHALLENGE TO PIPELINE INTEGRITY (corrosionservice.com)]

6 Probability of Failure

6.1 Probability of Failure

6.1.1 NGT has used a combination of industry wide data and academic research to inform this section of the EJP. This shows a theoretical high probability of failure for our pipeline asset base from the risk of AC corrosion. It should be noted that history may not be a reliable guide.

6.1.2 Therefore, given the potential consequences of being inaccurate, we want to do this work as a priority to establish the probability of NGT failure and will report findings back to other UK pipeline operators and the HSE/ Ofgem via UKOPA AC corrosion working groups.

6.1.3 There are numerous examples of AC corrosion features affecting buried steel pipelines worldwide. A few of examples of these include:

- 1986 - Pipeline in Germany[3] - Two corrosion perforations on a gas pipeline. Sole cause of failure was AC Corrosion.
- 2015 - Coal tar enamel pipeline, UK - Through wall corrosion on a 7.7mm thick aviation fuel line.
- 2006 - Intermediate pressure gas pipeline in the South of England - Through wall corrosion with a rate of 2.4mm per year, shown in Figure 5.

Figure 5: IP Gas Pipeline Through Wall Corrosion

6.1.4 The phenomenon of AC induced corrosion is a well understood threat in the pipeline industry. Pipelines unprotected from high levels of AC, or that experience AC corrosion undetected, have a high chance of significant damage.

6.1.5 Current densities above 20 A/M² can indicate active AC corrosion. The interventions proposed in this EJP will enable NGT to measure the current density for the identified sections.

6.1.6 The failure mode is the development of a corrosion feature which can grow rapidly as AC corrosion is faster acting than normal corrosive action. This event, left undetected, would result in through wall corrosion damage and lead to loss of containment. Using a pipeline wall thickness of 12mm and an AC corrosion growth rate of 1mm per year (as experienced in the [redacted] ethylene pipeline case) could result in an integrity failure within 12 years. The period between In-Line Inspections varies depending upon condition of pipeline and performance of Cathodic Protection systems but is usually between every 3 to 15 years. This means that for a higher risk pipeline section with significant levels of AC current, a corrosion feature could develop and grow between ILI inspections to a point which compromises the integrity of the pipeline.

[3] AC CORROSION - A NEW CHALLENGE TO PIPELINE INTEGRITY (corrosionservice.com)

6.1.7 Our risk analysis has identified 36 pipeline sections that are deemed as being at high risk of AC induced corrosion. A copy of this analysis is available in Appendix: AC Risk Model.

6.1.8 In RIIO-T2 we surveyed 11 of the P1 sections. From this 11, we have identified a problem with AC current and a requirement to mitigate all sections to protect them. A copy of the survey information is available in the Appendix: Survey results

6.1.9 For RIIO-T2, [redacted] of our theoretical high-risk sections have had their risk validated with a requirement to physically mitigate identified. If we apply this figure to the remaining [redacted] we are assessing during RIIO-GT3, we could reasonably expect a further [redacted] requiring future physical mitigation in the next price control.

Probability of Failure Data Assurance

6.1.10 The data from the above section has been taken from a combination of sources both internally and externally. Internal operational data was used to undertake analysis of the NTS and risk score sections. This model was produced by [redacted].

6.1.11 The theoretical conversion from 'at risk' to requiring mitigation figure of [redacted] has been calculated based on surveys undertaken within RIIO-T2 by [redacted] to understand the actual AC risk and identify whether a need to mitigate exists.

6.1.12 The AC corrosion growth rate of 1mm per year has been taken from historical industry investigations and reflects numerous academic conclusions on growth rate. A technical document available from the National Association of Corrosion Engineers (NACE) international shows in short term field testing a recorded peak AC corrosion rate as high as 10mm per year[4]. It is felt that the usage of an assumed rate of 1mm per year is valid given the numerous laboratory and field studies which support this.

[4] NACE 35110-2010.pdf (antpedia.com)

7 Consequence of Failure

7.1 Consequence of Failure

7.1.1 In the event of a pipeline failure, this would be a significant emergency event to isolate the pipeline and resolve the immediate event. The pipeline would need to be isolated whilst an investigation occurs, impacting on the ability to operate the NTS. At locations which are fed by a single pipeline, there could be a loss of gas supply whilst service is restored.

7.1.2 The table below indicates the expected impacts should any failures occur on a buried transmission pipeline.

Table 7: Consequence of Failure Summary

Asset	Environment	Financial	Availability	Safety
Pipeline	The release of gas arising from a leak or rupture of the pipeline, caused by external interference, corrosion or other failure modes would have a negative impact on the environment with Methane being 28 times more harmful than Carbon dioxide to the contribution of climate change. This is further discussed in the Network Decarbonisation EJP.	There would be a significant financial impact of a large-scale failure or loss of service event. This could include loss of revenue, compensation, cost to repair the asset and fines.	The shut-down of a pipeline to repair a leak or rupture caused by corrosion requires outages which can result in loss of supply to customers. Dependant on the scale of loss of supply, this can have a knock-on impact on the wider economy such as industrial clusters being unable to manufacture and health impacts for people in high-risk groups.	A pipeline leak or rupture caused by corrosion is a significant safety concern. Where the pipeline passes near centres of population risk of ignition of the leak or rupture is relatively large.

8 Interventions Considered

8.1 Interventions

8.1.1 This section summarises the options available to manage AC induced corrosion and provides a high-level overview of options we have considered.

8.1.2 It is worth noting that all options discussed in this EJP apply to England and Wales only. We do not have data for Scotland as we have not been provided this by the Electricity Grid Operators. Once we have this data, we will undertake analysis in-line with ISO18086 to establish the AC interference risk and will risk trade to mitigate sections that are of higher risk and re-engage with Ofgem on progress in this area.

8.1.3 We have consulted with other UK Pipeline Operators and continue to share our methodology as industry best practise.

Counterfactual (Do Nothing)

8.1.4 The counterfactual is to continue with existing pipeline inspection and remediation practices. The ILI tools currently used do not have the resolution to accurately pick up all AC corrosion features.

8.1.5 This option has been ruled out as it is not a tolerable level of risk to carry, and we would not be fulfilling our statutory responsibilities as a responsible operator.

AC Mitigation – Enhanced ILI – Enhanced inspection using Circumferential MFL tool.

8.1.6 The AC enhanced in-line inspection is the addition of a circumferential MFL tool to assist the identification of AC corrosion features.

8.1.7 This option will support the enhanced desktop analysis we currently undertake on AC high risk sections and expand on the knowledge we have obtained in RIIO-T2.

8.1.8 This option cannot be relied on in isolation to manage AC risk and so we must also carry out additional data collection to validate the AC corrosion risk. Due to the rapid growth of AC corrosion features, these can grow to through wall between ILI inspections.

AC Mitigation – Survey

8.1.9 AC Mitigation Survey is the installation of monitoring equipment such as ER probes to a pipeline section to monitor levels of AC current present on the pipeline over a period to understand levels of exposure and fluctuations over time (such as peak energy demand, seasonal variations).

8.1.10 Following this monitoring exercise, an assessment will be undertaken in accordance with ISO 18086 to determine whether the pipeline section carries an unacceptable risk. The outcome of this will either show a clear problem which needs to be mitigated and managed or confirm that the section is not currently at risk of AC corrosion.

8.1.11 If a problem is found, this option includes the design of mitigation solution to protect the pipeline from AC.

8.1.12 This option does not require an outage to deliver and will not result in any constraints or supply restrictions.

AC Mitigation Installation

8.1.13 Mitigation options vary dependant on the circumstances surrounding the pipeline. These include a range of interventions, such as the installation of ER probes to monitor corrosion rates, installation of a sacrificial anode such as zinc ribbons to the installation of a protective slab over the pipeline. Mitigation solutions generally take the form of the installation of Zinc ribbons running parallel to the pipeline section. These act as a sacrificial anode, in-turn protecting the pipeline from AC. To prevent third party damage, they are installed at a depth like the pipeline section it runs parallel to. The sacrificial anodes have a lifespan of approximately 20 years from date of installation.

8.1.14 Mitigations are bespoke dependant on soil composition and amount of AC current amongst other factors. This option acts as a defence for the pipeline and has the benefit of reducing the risk of AC corrosion features occurring on the pipeline section.

8.1.15 This option will occur following the above option survey and mitigation design to address a validated AC corrosion risk.

8.1.16 For RIIO-GT3, we are proposing the installation of zinc ribbons, test posts and ER probes to the sections based on the assessment and design work carried out during RIIO-T2.

8.1.17 These works would not require a planned outage to deliver.

OHPL agreements

8.1.18 The opportunity between electricity operators and National Gas to explore options for OHPL/pipeline high risk sections could result in alternative solutions such as change in network operation or retrofitting of protective equipment to prevent AC current leakage.

8.1.19 Discussions relating to operator collaboration on this issue are being explored via a working group hosted by UKOPA and led by the HSE.

8.1.20 NGT attend these on a quarterly basis to share best practise with the UK pipeline industry. and discuss this issue and collaboratively discuss challenges faced by the various industries.

8.1.21 We have historically had two mandated attendance AC Risk Workshops chaired by UKOPA and supported by the HSE and Ofgem. This highlighted the responsibilities of the Electricity industry as our existing pipeline assets may already have been put at risk because of changes to OHL systems that have already been undertaken without consultation.

8.1.22 Through this group we have been requesting that there is a mandatory requirement to provide evidence that electricity companies have considered the risk of harm of our assets and mitigation where required as part of their project development.

Pipeline Diversion

8.1.23 Diversion of sections that are experiencing AC current due to being situated parallel to the OHPL or crossing it could be explored to provide separation distance from the AC source. The advantage of this option is that it has the potential to eliminate AC Corrosion risk.

8.1.24 However, the cost of this does not offer value to the consumer. Over time, electrical network growth could result in AC lines being installed in proximity thereby rendering the original diversion wasted.

8.1.25 It is not practicable to conduct numerous diversions and given the requirement to supply power stations with gas and the electrical power coming out of it this option does not physically work without significant configuration of power stations and the gas and electrical networks.

8.2 Interventions Summary

8.2.1 The below table shows a summary of the options considered.

Table 8: Options summary table

Intervention	Positive	Negative	Taken Forward	Reasons
Do Nothing (Counterfactual)	Low-cost option in the short term with no change to current working practices.	At risk of threat of AC induced corrosion and the impact on network integrity along with the safety risk of loss of containment and loss of supply to consumers.	No	Unacceptable to ignore threat, resulting in lack of compliance with statutory obligations.
AC Mitigation-Enhanced ILI	Gain data/ understanding of our high-risk AC sections. Targeted approach validates our model and verifies our approach was correct.	Possible to miss sections which are 'real-world' at risk of AC corrosion. Changes to risk during the price control between ILI runs means that ILI cannot be relied on in isolation.	Yes	Offers a balance between cost vs risk to NGT and consumer. Maintains a suitable network to ensure security of supply. Included within Option 1 on the CBA showing a positive return.

Intervention	Positive	Negative	Taken Forward	Reasons
AC Mitigation - Survey	Understand the longer-term impact to pipeline section and gain clarity over whether situational or daily influence. Validates whether acceptable levels of AC influence or provides evidence for requirement to remediate.	Possible abortive costs if survey determines acceptable level of AC.	Yes	Offers understanding/evidence to enable effective mitigation or confidence in the section if not adversely at risk of AC induced corrosion. Achieves compliance with ISO 18086 to ensure that we mitigate where appropriate, delivering maximum value for the consumer. Included within Option 1 on the CBA showing a positive return.
AC Mitigation Installation	Protects pipeline section from threat of AC resulting in fewer AC corrosion features.	Cost of installation and additional assets to existing CP system.	Yes	The threat of AC on our pipeline integrity is not going to go away so mitigation offers a reduced risk of pipeline deterioration with lower AC corrosion defects received over time. Without mitigation we will require significant repairs/replacement of our pipelines which is not of value or an acceptable position long term. CBA shows a positive return for the investment.
OHPL Operator agreements	Low-cost option to explore which could provide solutions in some instances.	Possible limited solutions if relationship strained/reluctance to accept problem or retrofit solutions unavailable.	Yes	This is currently being explored via UKOPA.
Diversion of pipeline	Moves the pipeline away to clear separation distance, possibly removing all risk.	High cost, resource, and duration to deliver a diversion. No guarantee that future asset installation (expansion of OHPL) would not re-introduce risk. Might not be a feasible route to divert. Cheaper options available and therefore not in the consumer interest.	No	Not appropriate for use as a blanket remediation method and should be used in exceptional circumstances. High cost to eliminate risk is not practicable and does not offer consumers value. It would have to be a new build pipeline more than minimum 3km from existing route. Future electrical network changes may undo benefit. Whilst this does show as beneficial in the CBA, we have cheaper options which return a higher reduction in risk so will not procced with this option.

8.3 Volume Derivation

8.3.1 The options presented in this EJP have been developed using the International Standard for managing AC risk ISO18086. We have implemented its recommendations into our asset management practises for our pipelines. The below table summarises how the investments have been built for this funding request.

Table 9: How options presented in this EJP have been developed

Investment Name	Option References	RIIO-GT3 Volume	Total RIIO-GT3 Funding Request	How this has been developed?
AC Mitigation-Enhanced ILI	AC2	[redacted]	[redacted]	[redacted]

Investment Name	Option References	RIIO-GT3 Volume	Total RIIO-GT3 Funding Request	How this has been developed?
AC Mitigation - Survey	AC3	[redacted]	[redacted]	[redacted]
AC Mitigation Installation	AC4	[redacted]	[redacted]	[redacted]

8.4 Cost Derivation

8.4.1 Costs have been derived using a robust methodology using known data for activities which share the scope with the interventions within this EJP.

8.4.2 A specific example of the cost derivation for AC Mitigation is a recent National Gas Services estimate for "AC Interference mitigation projects SURVEY and DESIGN". This intervention was calculated utilising internal costs and allowed for the survey of high-risk AC corrosion pipelines and the design for their remediation. The cost used informed budgetary quotations from the supply chain and intelligence from subject matter experts to generate appropriate allowances for the scope. This included an assumption that there would be approximately 3 no. mitigations required per feeder. No allowance was included in this intervention for the physical mitigation of defects – only survey and design.

8.4.3 The project was deemed as having a medium risk based on complexity, cost and criticality meaning that a contingency of 15% has been applied to the net cost of the project.

8.4.4 Further cost breakdown for this EJP is provided in the Appendix.

Table 10: Option cost derivation

Intervention	Unit Cost (23/24 Price Base)	Unit of measure	Number of Data Points	Source Data	Breakdown
AC Mitigation-Enhanced ILI	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
AC Mitigation - Survey	£[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
AC Mitigation Installation	£[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Intervention	Unit Cost (23/24 Price Base)	Unit of measure	Number of Data Points	Source Data	Breakdown
Diversion of pipeline	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

8.4.5 A specific example of the cost derivation for AC Mitigation is a recent National Gas Services estimate for "AC Interference mitigation projects SURVEY and DESIGN". This intervention was calculated utilising internal costs and allowed for the survey of high-risk AC corrosion pipelines and the design for their remediation.

8.4.6 The cost used informed budgetary quotations from the supply chain and intelligence from subject matter experts to generate appropriate allowances for the scope. This included an assumption that there would be approximately 3 no. mitigations required per feeder. No allowance was included in this intervention for the physical mitigation of defects – only survey and design.

8.4.7 The project was deemed as having a medium risk based on complexity, cost and criticality meaning that a contingency of 15% has been applied to the net cost of the project

9 Options Considered

9.1 Options

9.1.1 This section summarises the options we have considered within this EJP.

Counterfactual (Do Nothing)

9.1.2 The counterfactual is to continue with existing pipeline inspection and remediation practices. The ILI tools currently used do not have the resolution to accurately pick up all AC corrosion features.

9.1.3 This option has been ruled out as it is not a tolerable level of risk to carry, and we would not be fulfilling our statutory responsibilities as a responsible operator.

Option 1

9.1.4 This is the option presented within this EJP. This option includes the installation of mitigation schemes to 11 pipeline sections identified during RIIO-T2 surveys, commencement of a cyclic programme of enhanced ILI to all high risk sections and assessment of the remaining 25 high risk sections.

9.1.5 This option maintains compliance with legislation and ISO 18086. No additional investment is propped through our predicative analytics model.

9.1.6 The proposed intervention volumes and associated spend are shown in table 10 below.

9.1.7 Option 1A included within the CBA is the same option as this but shown for consistency. This is because the deliverability assessment did not alter any investments proposed.

Option 2

9.1.8 This option is inclusive of the above but expands the installation of physical mitigation to all 36 high risk of AC Corrosion sections.

9.1.9 This option would be the optimum protection against AC Corrosion but as we have not undertaken the assessments to gather data could result in significant wastage if any sections are deemed to not be of risk of AC Corrosion.

Option 3

9.1.10 This option is the diversion of 11 sections away from their current location.

9.1.11 The benefit of this option is that they will no longer be located parallel to the electricity transmission network, it is not guaranteed to solve the possible influence of AC Corrosion.

9.1.12 It is of significant cost to the consumer, with cheaper options available to protect the NTS.

9.2 Options Technical Summary Table

9.2.1 Table 11 below shows a summary of the above options with Table 10 providing the breakdown of costs for options which have an associated cost.

Table 11: Options technical summary table (£m, 2023/24)

Option	First Financial Year of spend	Final Financial Year of Spend	Volume	Investment Design Life	Total Spend Request	Options Cost Summary
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Option	First Financial Year of spend	Final Financial Year of Spend	Volume	Investment Design Life	Total Spend Request	Options Cost Summary
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

10 Business Case Outline and Discussion

10.1 Key Business Case Drivers Description

10.1.1 All the options presented in this paper are driven by safety legislation together with third-party network activity, along with the environment in which the pipeline operates.

10.1.2 We have considered the impact of the following drivers for investment:

- Increased electrification within the UK with the push to Net Zero (both OHPL and rail systems) will increase the AC current in proximity with our buried pipelines. Our proposals allow NGT to understand changing risk profiles over time.
- Continued compliance with legislation such as PSSR to ensure that we adequately inspect our pipeline and validate their safe continued usage.
- Compliance with industry standards ISO18086 for managing AC corrosion risk.
- Protect members of the public from a loss of containment event.
- Protect long-term integrity of our pipeline assets to ensure a continued supply of service.

10.2 Business Case Summary

10.2.1 NGT has a duty to operate its high-pressure gas pipelines in compliance with PSSR and PSR legislation. Our investment proposed in this paper maintains statutory compliance whilst striking an appropriate balance between tolerable risk and value for money for consumers.

10.2.2 By selecting the highest risk sections to mitigate and study further, we have presented the lowest-cost option whilst adequately protecting our NTS from the threat of AC induced corrosion.

10.2.3 Our preferred options are to take forward a range of inspection, monitoring and mitigation options which offer a balance of cost vs risk.

10.2.4 We have appraised our suggested investment activity using the NARMs methodology which confirms that the option of surveying and mitigating is the lowest cost option to maintain compliance.

10.2.5 NGT has applied an assumption to the CBA using a corrosion growth rate of 1mm per year.

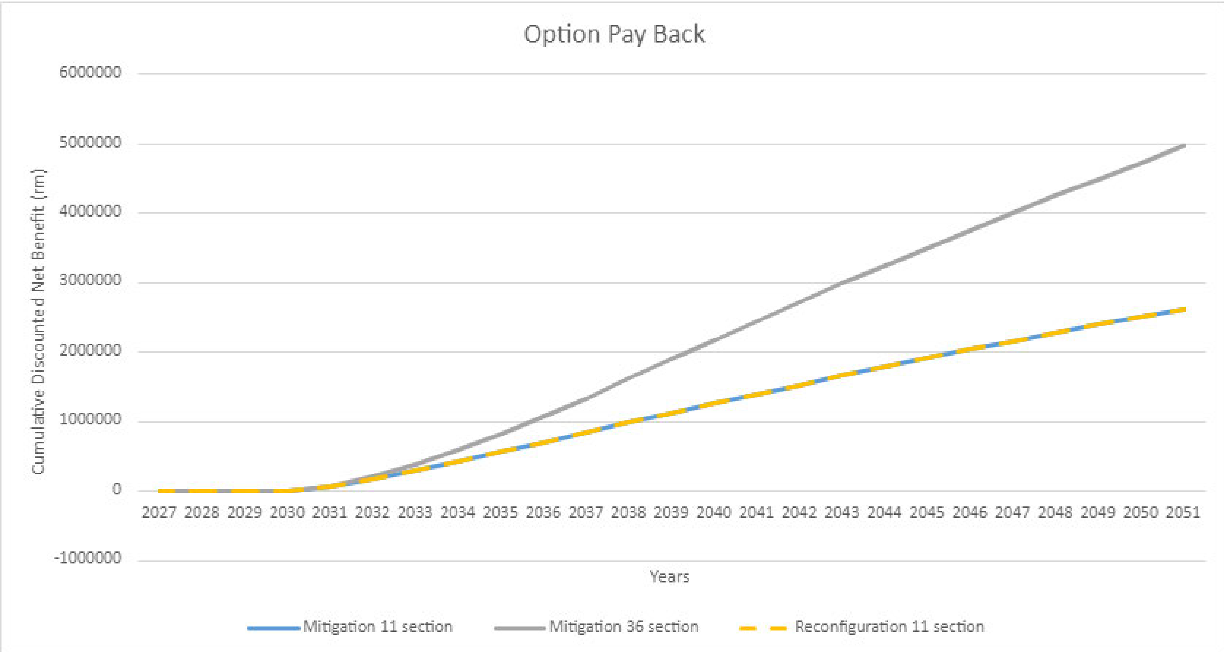

Figure 6: Graph showing Payback of options.

10.2.6 As can be seen above (the blue line), is what we are pursuing within this price control period to mitigate [redacted]. This offers a positive return for investment and would meet with ISO18086 standards for managing AC risk.

10.2.7 We intend to undertake assessments on the [redacted] during RIIO-GT3 with the ambition of mitigating these, where required, in the next price control period which would reflect the blue line in the above graph.

10.2.8 The CBA payback graph shown above applies a continual sustained corrosion growth rate to all P1 sections. However, this growth rate is not representative of how AC interference acts. During peak electricity demand it could reach levels in which corrosion occurs at an accelerated rate, but as electricity demand drops this would impact the corrosion growth rate.

10.2.9 Our confidence for Scope, Volume, and costs within this EJP is high. NGT has proposed the investment within this EJP is funded via baseline.

Table 12: Business case metrics of options (£m)

Option	Total Volume of Interventions	Total Spend Request	Outcome Risk end of RIIO-GT3	% change in comparison to start of RIIO-T2	PV Costs	PV Benefits	NPV	CB Ratio	Payback Period (from 2031)	% change in service risk measures compared to start of RIIO–T2				
										Financial	Health and Safety	Environmental	Availability and Reliability	Societal
Counterfactual	0	0	0.09864	2955281%	0	0	0	0	n/a	101%	4504644%	2630411%	2207296%	9770313%
Mitigation 11 section	11	5.3	0.04070	122.0%	3.39	6,190,630	6,190,624	931,692	3 years	101.50%	62.99%	267.93%	115.19%	129.63%
Mitigation 36 section	36	14.3	0.01350	115.3%	7.00	15,201,995	15,201,425	26,675	3 years	164.69%	32.94%	288.14%	106.30%	114.68%
Reconfiguration 11 section	11	591.8	0.04070	122.0%	290.70	6,190,630	6,190,630	451,135	3 years	101.50%	62.99%	267.93%	115.19%	129.63%

11 Preferred Option Scope and Project Plan

11.1 Preferred Option

11.1.1 Our preferred option is recorded as option one in the CBA. This preferred option to manage the AC corrosion risk includes a mixture of interventions listed in the below table.

Table 13: AC Inspection and Remediation RIIO-GT3 preferred option summary (£m, 2023/24)

		Volume	Unit of Measure	% Assets Intervened Upon	RIIO-GT3 Cost	Funding Mechanism	PCD Measure
AC enhanced In-line Inspection	Asset Health Risk Management	[redacted]	[redacted]	[redacted]	[redacted]	Baseline	NARMS
AC Mitigation	Asset Health Risk Management	[redacted]	[redacted]	[redacted]	[redacted]	Baseline	NARMS
AC Survey and Mitigation design	Asset Health Risk Management	[redacted]	[redacted]	[redacted]	[redacted]	Baseline	NARMS
	Total	[redacted]		[redacted]	[redacted]	Baseline	

11.2 Asset Health Spend Profile

[redacted]

Figure 7: Spend profile (£m 23/24)

11.3 Investment Risk Discussion

11.3.1 The risk associated with the preferred options are minimal. The volumes presented in this paper have been assessed using internationally recognised standards for managing AC risk and has been validated by [redacted].

11.3.2 There is the possibility of an increase in volume if NGT acquire operational data for electricity networks in Scotland. To mitigate this risk, we are participating in working groups hosted by UKOPA and HSE. As soon as any data is received, NGT will commence with a desktop mathematical assessment of AC risk outlined in ISO 18086 with a view to physical assessment in a future price control.

11.3.3 Our costs have been built through unit cost analysis and estimates from the market, however there is a risk that costs of materials may increase due to macro-economic conditions and customer and stakeholder demand. This shall partly be mitigated through the CPI-H inflation and real price effect mechanisms within our RIIO-GT3 regulatory framework.

11.4 Project Plan

1.1.1 Project delivery has been split into three phases which align with our Network Development Process (ND500) as follows. Commissioning dates are not relevant to all intervention types but take place at the end of the delivery phase.

Table 14: Delivery phase alignment with ND500

Delivery Phase	ND500 Stage Gate(s)
Preparation	T0, T1, F1 (Scope establishment), T2, F2 (Option selection), T3, F3 (Conceptual Design Development and Long Lead Items Purchase), T4
Delivery	F4 (Execute Project), T5, Available for Commercial Load (ACL), T6
Close Out	F5 (Reconcile and Close)

11.4.1 The below table shows the summary plan and provisional delivery phases for AC Corrosion Management sanctions within RIIO-GT3. Internal stakeholder engagement has identified when we can obtain network access, where required, to complete these works.

Table 15: Pipeline Portfolio Programme for RIIO-GT3 period

Sanction/Intervention	RIIO-T2		RIIO-GT3					
	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
T3 Pipeline AC Remediation Sanction								
T3 Pipeline PSSR Sanction								

11.4.2 The work has been profiled based on a deliverability assessment across the whole NGT plan. We have profiled the investment to ensure the enhanced ILI interventions match with the in-line inspection programme to avoid duplication.

11.5 Key Business Risks and Opportunities

11.5.1 The risk of not being able to deliver the volume of work is small. The ILI programme of inspection is well-established, and we can accommodate the addition of a Circumferential MFL tool within our current resource and tooling availability.

11.5.2 The intervention scopes presented in this EJP are clearly defined and understood. We have a good track record for delivering these scopes in RIIO-GT2 with no change to these scopes proposed for RIIO-GT3.

11.5.3 The delivery of mitigation systems is well understood. We have resource capable to deliver mitigation schemes and these do not require an outage to deliver.

11.5.4 Any changes to system operation or supply and demand scenarios will not impact upon the outcome of this justification paper.

11.6 Outputs included in RIIO-GT2 Plans

11.6.1 There are no outputs from RIIO-T2 plans to be included within RIIO-GT3.

12 Appendices

[redacted] [redacted]

[redacted]

[redacted] [redacted]

[redacted]

[redacted]