RIIO-T2 Re-opener

St Fergus Valve Actuators

Engineering Justification Paper
January 2023

nationalgrid

Contents

1. Executive Summary

1.1. National Grid Gas Transmission (referred to in this submission as 'NGGT') are submitting this need case, in accordance with the RIIO-T2 Engineering Justification Paper ("EJP") Guidance v2 document. The purpose of this stage of the process is to provide Ofgem with additional information that has been requested, that justifies the project need case, setting out the different options considered and requesting funding for the preferred justified within this paper. This EJP details investment for the decommissioning of the gas actuating pipework and the subsequent replacement of key Actuators at the St Fergus gas terminal. The Actuators in scope of this investment are gas-hydraulic Actuators, powered by a single 2"- 4" actuating gas pipework configuration.

1.2. This is part of a suite of documents, shown in Figure 1, and should particularly be read in conjunction with the St Fergus Site Strategy and its appendices. The St Fergus Site Strategy describes the gas terminal's function, its criticality to the network and the proposed investments in line with the site's short and long-term strategy. It also includes our Resilience Assessment as an appendix which assesses the potential for rationalisation across the site to optimise our proposed capex and long-term opex.

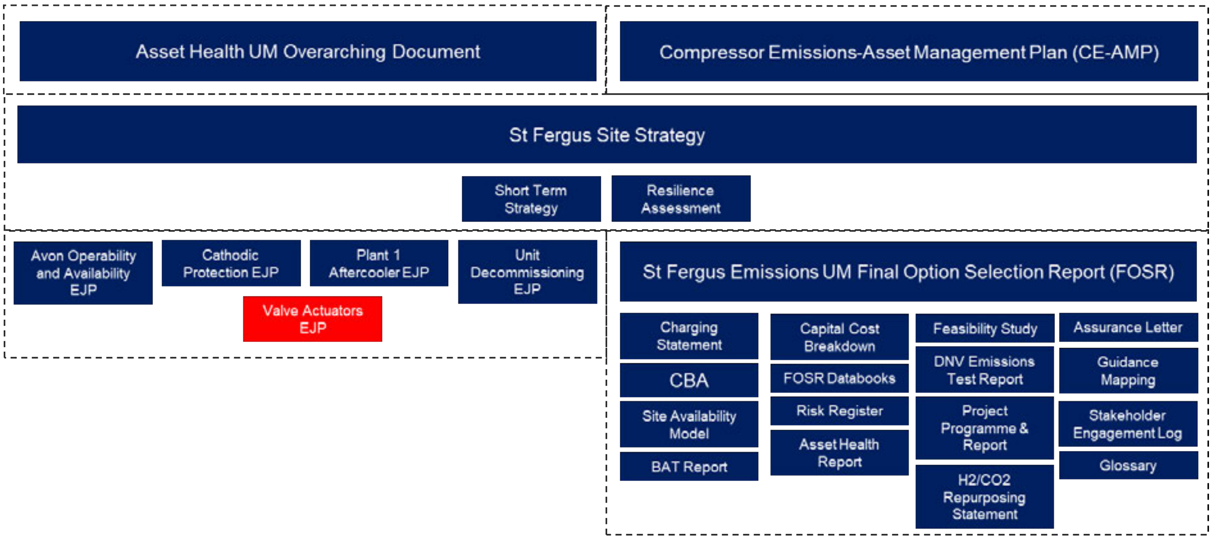

Figure 1: St Fergus Submission Documents Structure

1.3. Our St Fergus Short-Term Strategy, included in Appendix 10, provides certainty on the terminal operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. This strategy is the primary driver of Actuator volumes associated with compression units, ensuring the minimum Actuator population is intervened upon.

1.4. The Actuator gas pipework services a total of 143 valves at the St Fergus site. Of these, rationalisation aligned to the St Fergus short-term strategy has identified 119 Actuators and associated valves critical to safe and reliable operations at the St Fergus terminal, which operates 24 hours a day 365 days a year, regularly supplying in the range of 25% to 50% of the UK's natural gas supplies.

Requirement	Human Factors and Occupational Safety	Operationally speed critical	Safety critical	Start-up / shut- down automation	Total
Plant 1	5	3	22		**30**
Unit 1A		7		1	**8**
Unit 1B		7		1	**8**
Unit 1D		7		1	**8**
Plant 2	4	4	26		**34**
Unit 2B		7		1	**8**
Plant 4			8		**8**
Plant 6	3		12		**15**
Total	**12**	**35**	**68**	**4**	**119**

Table 1: Critical gas actuated valve location and function

1.5. The condition of the single feed pipework configuration presents significant safety and operational risks to both site personnel and site operations. 74 category 6, the highest categorisation value, and 243 category 5 corrosion defects have been identified on numerous points of the above ground gas pipework. [redacted] requiring NGGT to address numerous severe corrosion defects which included the majority of category 6 corrosion defects on the Actuator pipework at this site.

1.6. The gas pipework is a single point of failure and the only means to achieve valve management at scale and efficiently on site. Failure would eliminate valve actuation at this site and would render the site inoperable, and grossly uncompliant.

1.7. Alignment of valve and associated Actuator functionality to compression at St Fergus saw the Actuator investment, at RIIO-T2 business plan submission, forming part of the broader emissions re-opener proposal at St Fergus. However, noting the scale of corrosion defect [redacted] NGGT created a discrete, stand-alone investment for Actuation at the St Fergus site.

1.8. Ofgem broadly understood the investment need, and timing constraints, requiring further additional information to fully justify technology selection and efficiency of costs, mindful the complexity of the investment. This formed an Actuator investment re-opener in January 2023, in the RIIO-T2 Final Determination.

1.9. A range of options have been considered, with a large number being discounted during the option selection process due to the compliance required with COMAH, PSSR and DSEAR regulations. The remaining options have been assessed against a wide range of criteria; considering timely remediation due to safety, operability and legislative drives, mitigation of single point of failure status and efficient, controllable assured spend. Based on these core drivers, we recommend Actuator replacement using a mix of electric and electrohydraulic technology, and the decommissioning of the existing pipework as the preferable option.

1.10. Replacement of the gas pipework would be more costly, operationally inefficient and complex, resulting in significant delays in remediating risk at site, and would not remedy the single point of failure currently applicable at St Fergus. Where able, we propose utilising more cost-effective electric actuation. However, where operability and safety criticality require layers of protection beyond single point of failure, including but not limited to a necessity for systems to “fail safe”, we have recommended Electric Hydraulic actuation. This is due to its additional layer of protection should power loss occur and its functionality resulting in valves shutting should actuation completely fail.

1.11. The current estimated total cost of this investment is £23.089m (2018/19 price base). The estimated RIIO-T2 cost profile is shown in the table below. This project is at stage 4.4 in the

ND500 process: Detailed Design and Delivery. Therefore, the cost accuracy is estimated at +/- 10% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance. In order to update the licence terms within the Price Control Financial Model (PCFM), the request includes a negative value in the final year to provide the correct net position by year when accounting for baseline funding received.

£m 18/19	FY2022	FY2023	FY2024	FY2025	FY2026	Total
Total Cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Baseline	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Funding Requested	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	**22.240**

Table 2: Current estimated RIIO-T2 spend profile

1.12. This work is being delivered via a competitive call off the NGGT Asset Health framework and is bundled with the corrosion remediation and cathodic protection works at St Fergus to deliver value. In particular, corrosion remediation works and Actuator works are bundled on site for delivery, to maximise the work completed as part of each isolation at St Fergus. These isolations are a challenge to achieve, due to the requirement to maintain a gas path across the terminal, and the condition of the valves on site. These works have commenced, prior to funding being granted, due to the process safety risk that the actuating gas pipework poses in its current condition, with further deterioration expected.

1.13. We are making this funding application for the Actuators Programme RIIO-T2 investment costs through the Asset Health Re-opener, in line with Special Condition 3.14, requesting an adjustment to the value of the NARMAHOt term. This is summarised, along with other investments, within section 9 of the Asset Health Overarching Document provided as Product 1 of the January 2023 Asset Health Re-opener Submission. A draft of this paper was shared with Ofgem prior to this submission.

2. Introduction and Background

2.1 This paper provides the justification for the removal of the gas actuating pipework and the subsequent replacement of key Actuators at the St Fergus gas terminal. Funding for this activity was initially expected to tie into the wider St Fergus uncertainty mechanism due to the alignment of the Actuator requirements to the compression requirements. However, later in the RIIO-T2 business plan process NGGT made a separate request for funding to resolve significant corrosion risks relating to the actuating system that could not wait for decision in line with the uncertainty mechanism timeframes. [redacted] Ofgem understood the need for this investment but subsequently determined that additional information was required to fully justify the technology selection and ensure the programme represented the lowest overall cost given the complexity of the investment.

2.2 In developing our investment programmes at the St Fergus gas terminal since the RIIO-T2 Final Determinations we have adopted a two-phase strategy to ensure clarity between short-term asset health and long-term site operating strategy. Our St Fergus short-term strategy provides certainty on the terminal operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. The long-term strategy will deliver the enduring terminal solution, including gas compression, required for operation beyond 2030. As the short-term strategy delivers the compression requirements across Plant 1 and 2, this is the primary driver of Actuator volumes associated with compression units; ensuring the minimum Actuator population is intervened upon. The compression units required as detailed in the short-term strategy is provided within this document, but it is important that these two documents are considered in parallel.

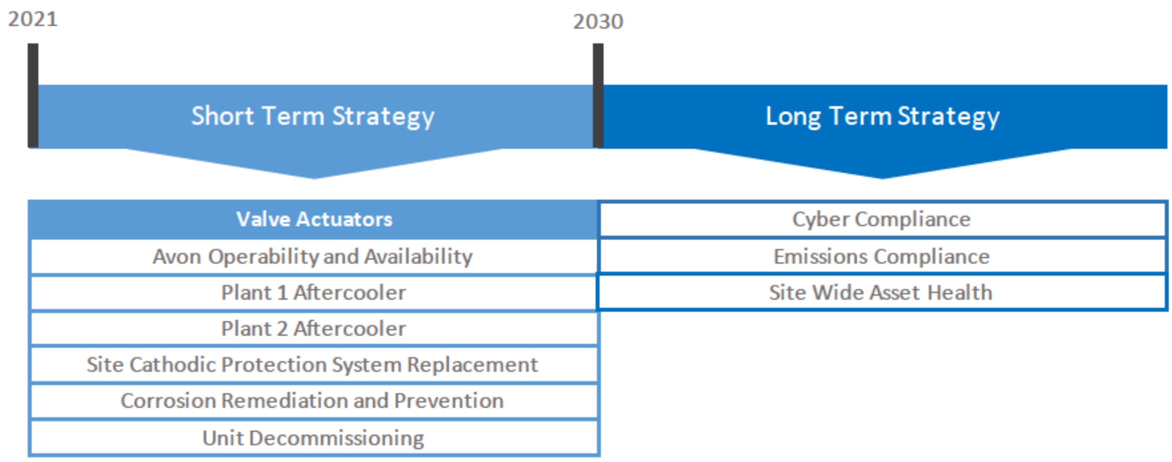

Figure 2: St Fergus strategies summary

2.3 The St Fergus Short-Term Strategy supports the decision to rationalise the compression units across Plants 1 and 2 to just four Avon units (1A, 1B, 1D and either 1C or 2B) and maintain these in operation to at least 2030. The strategy specifically recommends the selection of Unit 2B as the fourth Avon, however this does not change the total number of Actuators required compared to a Unit 1C. All Actuators associated with the wider Plant 2 assets (such as scrubbers and Aftercoolers) are to support all compression at the site, not specifically Plant 2 compression; more detail on this is provided in the Resilience Assessment appendix of the St Fergus Site Strategy. Furthermore, the strategy sets out the approach to cease investment in specific compression units and for the disconnection and ultimate decommissioning of these units ensuring unit rationalisation and the lowest overall cost to consumers to maintain plant availability and reliability.

2.4 The investment outlined in this justification paper concerns the valve actuation system which is fundamental to the safe and reliable operation of the St Fergus terminal and has been in service since the terminal was commissioned in 1977. The Actuators in scope of this investment are gas-hydraulic Actuators powered by a single 2”-4” actuating gas pipework. The condition of the pipework presents significant safety and operational risks to both site personnel and site operations due to many critical external corrosion defects and threats from ground movement which has collided Actuator pipework and equipment into main gas pipelines. A failure or isolation of the gas actuating pipework eliminates valve actuation operation of up to 143 valves and can render the terminal inoperable.

2.5 A failure on the actuating gas system due to corrosion or ground movement has the potential to cause a full cessation of flow through the Terminal. Dependant on the location, a single corrosion defect failure would render three out of four incoming supplies and associated systems unavailable. The loss of the actuating gas system on plant 2 would render plant 2, 4 and 6 unavailable resulting in major flow disruption through the Terminal and a high risk to security of supply. All four incoming valves are associated to Emergency Shut Down (ESD) systems (with multiple additional ESD systems downstream), if actuating gas supplies are lost to these valves, they must be left in their fail-safe position (closed) which would cease flow through the respective incomers. One further failure on Plant 1 actuating gas system or outage work being conducted on plant 1 at the same time would result in a full cessation of flow through the terminal and a gas supply emergency. Each of the valve Actuators that are planned for replacement are either associated to an ESD system or safety critical process and must be included in the replacement programme to reduce the risk of failure.

2.6 The original design of the gas actuating pipework presents a single point of failure and outages on this pipework are difficult to achieve without interrupting terminal availability. These design issues have meant the system has been in near constant use since commissioning and present challenges in managing the active corrosion.

2.7 St Fergus is a site governed under the Control of Major Accident Hazards (COMAH) Regulations 2015 and as such is subject to numerous requirements to demonstrate that risk from and within the facility is understood and is being managed appropriately. [redacted] 172 category 6 defects requiring remediation, with 65 of these (38%) directly related to the actuating Gas pipework configuration.

2.8 Over a period of 3.5 years many of these defects have been mitigated through temporary measures and repairs. One mitigation due to the corrosion identified was a 20% reduction in the pipework pressure from 35 bar down to 28 bar. This is the maximum pressure that the pipework is re-pressurised to, now a manual task carried out multiple times per day. Other mitigations include changing the Shafer Gas Actuators to manual gear boxes and taking a section of the pipework in Plant 1 Blending out of service. The remainder of defects have been risk assessed to allow operations to continue while engineering solutions to eliminate the present corrosion and subsidence risks were developed.

2.9 In addition to the pipework integrity issues, the Shafer gas-hydraulic Actuators have seen multiple failures and have 275 defects. The Actuators operate valves to control numerous process safety systems and as such represent significant risks in their own right. They have failed multiple proof-tests and actual demands. We have investigated these issues multiple times, but they recurringly fail and cannot meet the level of risk reduction they should in an emergency situation.

2.10 The HSE have a minimum expectation that we follow best practice. The existing Actuator arrangement does not fail safe which prevents us from achieving our functional Safety Integrity Level (SIL) of risk reduction.

2.11 Work to deliver the replacement valve actuating system could not wait until the re-opener date provided by Ofgem in the RIIO-T2 Final Determinations due to safety consideration [redacted]. On this basis, we have initiated work and therefore this justification paper is now retrospective in nature.

3. Equipment Summary

3.1 Comprehensive background information about the St Fergus Gas Terminal is available in the St Fergus Site Strategy provided with the Emissions Final Option Selection Report (FOSR).

3.2 A site wide valve actuation system powered by a single gas actuating pipework operates numerous safety valves, emergency shut down systems, vent systems, automated start-up and shut down processes and isolation valves. In total the gas actuating pipework system currently provides the power for the operation of 143 gas-hydraulic Shafer Actuators across the terminal, critical to its safe operation.

Figure 3: Typical gas-powered Actuator at St Fergus terminal

3.3 The gas actuating pipework configuration was designed and built as part of the original terminal development in 1977 and has been in operation since. The pipework configuration stretches approximately 5.6km and is largely buried. This pipework carries high pressure natural gas provided directly from natural gas passing through the terminal via 2”-4” diameter pipework that powers the 143 valve Actuators to enable valve operation.

3.4 In line with the St Fergus Short-Term Strategy, emissions legislation cut off dates and proposed compressor unit decommissioning, 119 of the 143 Actuators require investment to enable the safe disconnection and removal of the gas actuating pipework whilst maintaining site operation through alternative valve actuation means. There are 24 Actuators which do not require investment as these are associated (eight each) with three gas compressors which are not required in the Short-Term Strategy. Units 2C and 2D are not required in either the short or long-term strategies and have been proposed for decommissioning. Unit 1C is not currently operational but is being retained for now so that it is available for potential long-term solutions. This means that it does not require replacement Actuators in the same time period as the operational units, and if it is not needed for the long-term future of the site then it will also be decommissioned at an appropriate opportunity.

Requirement	Human Factors and Occupational Safety	Operationally speed critical	Safety critical	Start-up / shut-down automation	**Total**
Unit 1C		7		1	**8**
Unit 2C		7		1	**8**
Unit 2D		7		1	**8**
Total	**0**	**21**	**0**	**3**	**24**

Table 3: Actuator volume removed from original scope

3.5 The terminal operates 24/7/365 and is not afforded regular outages from sub-terminals to undertake maintenance. Sections of Plant 1 and Plant 2 serve as redundancy for each other allowing NGGT to undertake statutory inspections and critical testing of our safety critical and emergency shutdown system in addition to any maintenance needed because of regular inspections and testing. The scrubbers, metering, suction / discharge manifolds and Aftercoolers are interchangeable to enable maintenance and therefore can be viewed separately to the need for compression across the two plants. Numerous Actuators across both plants are required to provide this interchangeability as shown in table 1 where the Actuators needed are detailed on separate lines from the Actuators associated specifically with the compression.

3.6 An overview of the 119 valve Actuator assets in scope of this justification paper is provided below detailing the plant location as well as the classification of operation. A detailed list of all Actuators in scope is provided in Appendix 2.

Requirement	Human Factors and Occupational Safety	Operationally speed critical	Safety critical	Start-up / shut-down automation	**Total**
Plant 1	5	3	22		**30**
Unit 1A		7		1	**8**
Unit 1B		7		1	**8**
Unit 1D		7		1	**8**
Plant 2	4	4	26		**34**
Unit 2B		7		1	**8**
Plant 4			8		**8**
Plant 6	3		12		**15**
Total	**12**	**35**	**68**	**4**	**119**

Table 4: Minimum Actuator volume requirements for ongoing safe operation

3.7 The valve Actuators in scope of this justification paper have been classified into four categories of operation for assessment:

3.8 Human Factors and Occupational Safety
There are 12 valves that are too large for an operator to hand-actuate. The gearing of the hand crank mechanism into the actuation screw means that for large valves, an operator could be required to operate a manual handle for several minutes. Additionally, the gearing may be such that the force required to turn the Actuator wheel is excessive. Furthermore, there is evidence of valves at St Fergus being in a poor state, passing gas and being difficult to actuate due to degraded lubrication and corrosion. Exposing an operator to occupational risk while also exposing them to the major accident hazard of working on live equipment, is not good practice and is therefore not managing risk to be As Low As Reasonably Practical (ALARP).

3.9 Operationally Speed Critical
There are 49 valves which are not directly safety critical in normal operations, but which become safety critical during abnormal operations such as an Emergency Shut Down (ESD) scenario or during inspection and repair works.

3.10 Safety Critical
There are 68 valves which are explicitly Safety Critical with a criticality higher or equal to the equivalence of serious harm or death where failure to operate could lead to a serious process safety incident.

3.11 Operational Start-up / Shut-down Automation

There are six valves which are required to be automated because they form a step in the facility automated start-up and shut-down processes. Start-up and shut-down processes are high risk activities and cannot rely upon manual control. Process upsets and the related process safety risk are intolerable and are set out within the COMAH case as safety barriers.

4 Problem Statement and Needs Case

4.1 The actuating gas pipework is a deeply aged asset. Whilst the St Fergus terminal has been operated and maintained for over 40 years with minimal disruption to its upstream and downstream customers, this is a testament to the original design and to the capability of the maintenance and operations teams. Nevertheless, ageing mechanisms of corrosion, geotechnical instability and fatigue, have acted upon the facility's equipment and now the risk from those degraded equipment items and systems is intolerably high.

4.2 The intolerability of the risk is uncovered when the relatively modern principals of[1], whole life asset management and Reliability, Availability and Maintainability (RAM) optimisation are applied and particularly then considered in light of the requirements under the COMAH regulations. [redacted] significant backlog of potentially serious defects on the Actuator gas pipework, highlights the severity of the situation. The inability of the St Fergus teams to be able to address and mitigate all the original defects [redacted] is testament to the difficulty in achieving the required isolations to be able to safely inspect those defects in detail, let alone to affect repairs.

4.3 Ongoing risk assessments have taken place [redacted] to provide assurances that risks are being managed and progress is being made to resolve defects. [redacted]

4.4 However, it is not possible, desirable nor acceptable to continue risk assessing away critical works, even where the quantitative result of an as low as reasonably practical ("ALARP") assessment may indicate that a given defect's risk continues to be ALARP; before reaching the quantitative 'loss of life' calculation within the ALARP principal, there are simple tests to consider such as: is the situation being managed in a way similar to diligent Operators, and are the facility's standards being followed. For these reasons, this method of managing the defects was time-limited to 2022, with the firm anticipation that the residual defects would be removed or resolved before that date.

4.5 The integrity of the pipework and therefore the safe and reliable operation of the associated Actuators is the main factor for investment. However, RAM issues, specifically the risk of single point failure causing catastrophic outage, and the difficulty in configuring isolations to facilitate inspection and repair of the plant, are compelling drivers in their own right for removal of the pipework configuration. If the actuation system were to be designed today, the facility would not be designed with the pipework configuration it currently has because of the RAM risk.

4.6 The site is in an aggressive coastal location on reclaimed land that is relatively unstable over the long-term with groundwater challenges. Couple this with the failure of the Corrosion Protection (CP) system, which may not have been providing protection for many years, and periods of time where coating systems were not fully maintained, then the environment has been an increasing and poorly mitigated threat on the equipment.

4.7 Maintenance and investment have been unable to keep up with the growing number and severity of defects. This is partly because the system requiring the work, the Actuator pipework, is not designed well to allow for maintenance. Therefore, maintenance activities require substantial isolations which are not readily available and are disruptive to operations.

4.8 In order to mitigate some of the damage at site, the operating envelope of key systems has been optimised (reduced operating pressure) and this has allowed operations to continue while temporarily extending the duration that the facility risk can be considered ALARP, but this is a temporary measure.

[1]See "Relative Risk Assessment Report" compiled by [redacted] (Appendix 4)

4.9 The lifecycle strategy for the site has meant that major works, such as refurbishing the damaged elements of the Actuator system, have been viewed against an uncertain or changing decision horizon and the criticality of continuing to deliver gas into the network. The safety implications of the damage could be rationalised quantitatively in the short term. The consequence of delaying taking down the plant to facilitate the major works, is that a greater number of and more serious defects, have grown and now the system's integrity is a serious threat, while the opportunities to demonstrate the plant's risk is being managed ALARP [redacted].

4.10 The existing Shafer Actuators operated via the actuating pipework are generally in a poor state of condition due to age. These Actuators are not DSEAR compliant and fall short of modern functional safety standards. A total of 28 Shafer Actuator overhauls were undertaken during RIIO-T1 in an attempt to get on top of the deterioration, however increasing failures continued to be observed. In the last year ESD systems have failed to operate effectively under testing conditions on four separate occasions (see example ESD failure incident investigation reports provided in Appendix 5). It is of note that failure of an Actuator that was overhauled in RIIO1 was the root cause of the latest ESD failure.

4.11 As of September 2021, there were 352 open defects associated with the gas hydraulic Actuators that are powered by the gas actuating pipework. A summary of these by defect category is provided below.

Defect Category	Defect Count
Breakage	1
Corrosion	284
External Corrosion	10
Leakage	6
Leakage - Oil/Water	1
Mechanical damage	7
Misalignment	2
Obsolete Equipment	5
Other	21
Restricted Movement	1
Structural failure	8
Subsidence	2
Wear	4
Total	**352**

Table 5: Actuator defect count (Sept-21)

4.12 As of September 2021, there were a further 171 open DSEAR defects associated with the gas hydraulic Actuators that are powered by the gas actuating pipework. A summary of these by defect category is provided below.

Defect Category	DSEAR Defects
Breakage	2
External Corrosion	58
Internal Corrosion	1
Obsolete Equipment	19
Other	53
Perished	7
Wear	31
Grand Total	**171**

Table 6: Actuator DSEAR defect count (Sept-21)

4.13 As of September 2021, there were Category 4-6 CM4[2] corrosion defects associated with the gas actuating pipework. [redacted] 172 category 6 defects requiring remediation, with 65 of these (38%) directly related to the actuating Gas Pipework system.

4.14 To demonstrate the scale and complexity of pipework defects a range of typical examples is shown below:

Figure 44: Corrosion and ground movement threats to Actuators

Figure 5: Temporary structure mitigating risk from clashing Actuator gas pipework movement

[2] CM4 is National Grid Gas Transmission's Corrosion Management policy. Document provided with this submission for reference

Figure 6: Actuating pipe clashing with main gas line due to ground movement

Figure 7: Corrosion under pipe support - a difficult failure to identify

Figure 8: Damaged pipe support through corrosion and movement

Figure 9: Through wall corrosion requiring replacement to continue operation

Figure 10: Through wall corrosion leading to pinhole leak requiring replacement

4.15 Due to the original design of the Actuating pipework, gaining isolation to repair defects on many sections of the system is not possible without shutting down significant portions of the entire terminal. As such, nine separate Plidco Clamp repairs (see register in Appendix 6) have been implemented to manage significant corrosion defect risks and avoid significant plant outages to repair on the Actuating pipework. These repairs are deemed temporary and as such will need to be cut out and replaced if the Actuating pipework is to remain in use.

Figure 11: Temporary Plidco Clamp on Actuating pipework riser

Figure 12: Temporary Plidco Clamp on Actuating pipework at pit wall transition

4.16 In summary, the actuation system at St Fergus presents a range of significant risks that must be mitigated in full, [redacted] As such, NGGT embarked on a major programme of works recognising the spend at risk (and associated RIIO-T2 Uncertainty Mechanism) to ensure both the safe operation of the terminal and the security of supply it delivers.

5 Probability of Failure

5.1 The severity and prevalence of Actuating pipework corrosion defects, coupled with four separate findings of through wall corrosion/leaks and the range of temporary repairs and mitigations currently in place, shows that asset failure is occurring and will continue until intervention takes place.

5.2 A significant percentage of the Actuating pipework is buried and cannot be directly inspected. Issues with associated complex CP systems to protect this pipework have been prevalent for some years and therefore there is uncertainty as to the true condition of the buried pipework giving rise to broader failure modes and associated risks.

5.3 Given the detailed survey and defect information [redacted] assessing the condition status further to support understanding the probability of failure is not required as the Actuating pipework asset can largely be considered at end of life.

5.4 Existing Shafer Actuators have seen increasing defects and failures over recent years. ESD tests have failed on multiple occasions and as such the ESD testing schedule has been required to reduce from yearly to 6-monthly.

5.5 Existing Shafer Actuators have over 500 outstanding standard and DSEAR defects recorded. The scale of the defects and the observed increasing failures of critical safety systems demonstrates actual failure under testing scenarios and therefore a high probability of failure under live scenarios.

6 Consequence of Failure

6.1 There are multiple realistic failure modes for which this investment seeks to eliminate. These failure modes have the ability to shut down the entire terminal operation for varying periods of time. In all cases the consequences will be catastrophic from a financial, safety and reputational perspective. Compensation costs to Shippers would run into millions per day, upstream oil production would likely cease leading to significant venting/flaring, UK gas security of supply would be significantly compromised, Scottish distribution pressures would become unmanageable under most demand scenarios and the reputational impact could result in significant limitations for our ability to operate, notwithstanding the risk to site personnel. Quantifying these high impact and compounding risks is not straightforward but it can be safely assumed that any failure as described below would result in costs far outweighing any of the investment options outlined in this paper.

6.2 Focusing on the constraint costs at the terminal, the Uniform Network Code (UNC) Section I liabilities for total failure of the terminal operation can be calculated using relatively simple principles to demonstrate a daily cost. This approach aligns with the approved methodology utilised by the System Operator to forecast constraint risk and for St Fergus the cost assumption is [redacted].

6.3 The average St Fergus supply per day for the 2-year period from Nov-19 to Nov-21 is shown below.

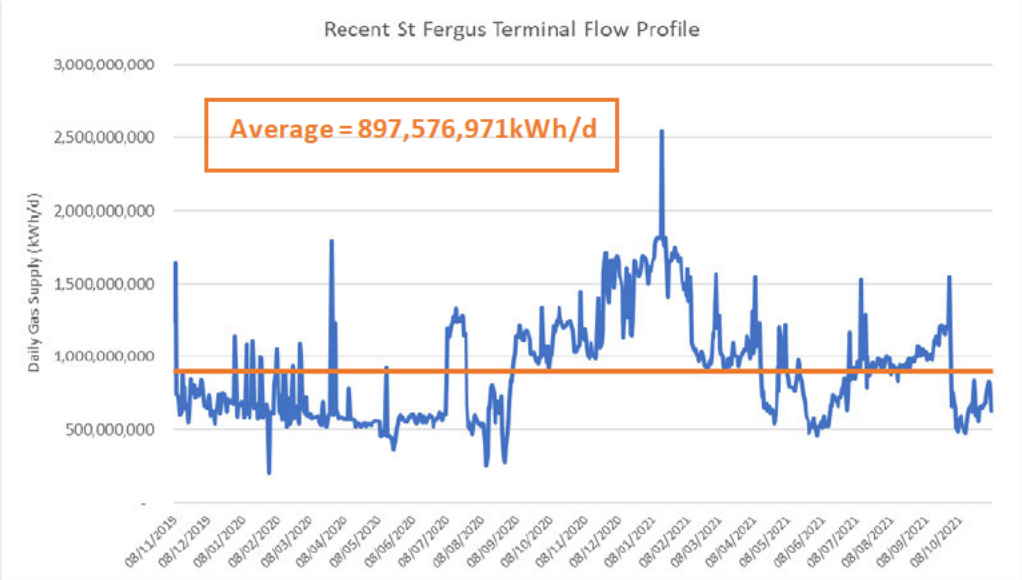

Figure 13: St Fergus Terminal flow profile

6.4 The average daily supply from St Fergus terminal over the last 2 years is 897,576,971kWh/d, utilising the constraint cost assumption of [redacted]h equates to an average daily constraint cost of [redacted].

6.5 Return to service for a failure of this kind is generally assumed to be three to seven days. Therefore, a failure resulting in terminal shutdown would on average bring costs in the range of [redacted].

6.6 [redacted]

6.7 There are single points of failure on the Actuating pipework which can shut down the entire actuation system rendering the terminal in operable for an extended period of time.

6.8 A failure of the ESD system when it is called upon in an emergency could result in an uncontrolled loss of containment. Given the COMAH status of the terminal this could have catastrophic consequences for site staff, the environment, as well as NGGT's reputation and its ability to operate.

7 Options Considered

7.1 In total, seven options are considered here for management of the condition issues and associated risks as outlined in section 4. Of these seven options, five are immediately discounted as they are not viable for compliance reasons, the reasoning being outlined below. Options 6 and 7 are then expanded upon to outline the pros and cons to support the final option selection.

Options discounted (1-5)

Option 1: Do Nothing

7.2 Continue to operate without resolving Actuating pipework defect risk:

- **This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.**
- This option would not meet the expectations set out by the HSE.

Option 2: Repair/Replace on failure

7.3 Operate with a reactive maintenance approach to Actuating pipework defects on a "fix on fail" basis:

- **This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations.**
- This option would not meet the expectations set out by the HSE.

Option 3: Proactive risk assessment and rolling mitigation of defects

7.4 Undertake continuous risk assessments of Actuating pipework defects intervening proactively to mitigate defect risk:

- **This option maintains the status quo and is not viable due to the breadth and scale of defects that will require significant ongoing outages to manage.**
- Risk assessments undertaken and [redacted] demonstrate that failing to eliminate the significant overall risk of continuing to operate the Actuating pipework is not ALARP and is untenable given the COMAH status of the site.

Option 4: Replace actuation power source with gas bottles

7.5 Remove Actuating pipework from operation and replace power source with high pressure bottled gas to drive Actuators:

- **This is not a viable option for providing power to ESD and safety critical valves.**
- This option would be viable for process automation and valve where human factor issues exist.
- An alternative power source would be required for ESD and safety valves so most of the Actuating pipework would be required to continue operation or be replaced (and rationalised where possible).
- This option introduces perpetual ongoing opex and logistics cost increases to maintain bottle pressure.
- This option introduces manual handling risks for site operators requiring risk assessment and likely handling and access equipment for certain areas of the site which are hard to access.

Option 5: Replace actuation power source with portable air compressors

7.6 Remove Actuating pipework from operation and replace power source with portable air compressors to drive Actuators:

- **This is not a viable option for providing power to ESD and safety critical valves.**
- This option would be viable for process automation and valve where human factor issues exist.

- An alternative power source would be required for ESD and safety valves so most of the Actuating pipework would be required to continue operation or be replaced (and rationalised where possible).
- This option introduces perpetual ongoing opex and logistics cost increases to maintain portable air compressors.
- This option introduces additional failure modes and maintainability issues, and the risk would not be considered ALARP or best practice when compared with other suitable and readily available technologies.

Options Progressed for Further Assessment (6 and 7)

Option 6: Replace Actuating Gas Actuating pipework

7.7 Install a new actuating gas pipework configuration and decommission the old pipework, providing a new high-pressure system to power the existing Shafer Actuators on Plants 1, 2, 4 and 6.

7.8 The length of the existing pipework is provided below, and this can be assumed to be the minimum length required for a replacement system. Any new design would be required to provide for redundancy and interconnection between plants to allow maintenance and remove the single point of failure associated with the existing pipework; thus increasing the length of pipework required.

Terminal area	Length (m)
Plant 1	1,871
Plant 2	1,890
Plants 4 & 6	1,890
Total	**5,651**

Table 7: Existing lengths

7.9 There are sub options associated with an actuating pipework replacement:

1. Replace like for like utilising natural gas as the high-pressure medium to provide power to the Actuators
2. Install a compressed air system to provide the high-pressure medium to power to the Actuators

7.10 These two options have a range of competing pros and cons that have been considered. Where there is additional cost or impact this is highlighted in red:

Like for like replacement	Compressed air system
Gas pressure is provided by an onsite pressure reduction installation taking advantage of the existing natural gas supply pressure	Additional air compression units with redundancy, control / electrical systems and associated buildings to house systems required which also attracts a higher associated OPEX to maintain
Any replacement actuating gas system that had pipework not provided with a physical barrier to any jet flame resulting from a material failure, gas loss and subsequent ignition would need to be buried or encased in concrete	Pipework can be installed above ground due to the lack of ignition source of a compressed air medium
Significant logistical complexity, time to complete, risks and high cost associated with major excavation and installation of new buried pipework on a live COMAH site	Compressed air actuating pipework would be simpler and less costly to install but would require pipe bridges and some below ground pipework for access purposes to existing assets
Natural gas is vented on each valve actuation	Air is vented on each valve actuation

Table 8 Comparison of key competing benefits and risks of actuating pipework gas power medium

7.11 Both options summarised above present logistical, design, risk, and cost challenges. However, the time and cost associated with excavating and burying over 5km of pipework at the terminal alone would far outweigh the cost required to take forward a compressed air system. On this basis, and given the additional cons outlined above, a like for like replacement can be ruled out in favour of a compressed air system when considering a replacement actuating pipework configuration. The broader pros and cons of this approach are now outlined below.

7.12 Pros:

- Existing actuating pipework configuration would be decommissioned eliminating all associated corrosion risk.
- Single point of failure associated with existing actuating pipework would be designed out.
- Compressed air powered actuating pipework would eliminate direct greenhouse emissions currently present with existing systems through release of methane on actuation.

7.13 Cons:

- The complexity of the design and installation of at least 5.6km of 40 bar pipework and the associated air compressions systems/controls at a live terminal whilst continuing operations brings significant cost and programme risk.
- The design process would extend the time frames for meeting safety compliance in line with the HSE's expectations.
- The defects, risks and failures associated with existing aged Shafer Actuators would persist and major overhaul (with potential replacement) of these Actuators will therefore be required to demonstrate the capability of critical safety systems at a COMAH site at additional future cost
- Numerous double block and bleed valve assemblies would be required to enable isolation for maintenance increasing complexity and cost.
- Plant outage programme to bring new actuating pipework online would be complex and extensive
- Ongoing opex increases to maintain air compression unit and the entire actuating pipework and its valve assemblies.

Option 6 Cost Assessment

7.14 In 2017 a Conceptual Design Study and associated cost estimates for actuating pipework replacement were developed (see Appendix 7). This assessment (uplifted to 18/19 prices for consistency) forms the basis for the pipework replacement cost. Two additional elements are added this cost providing an assumed cost for the required air compression system and additional Shafer Actuator overhauls required.

Programme Element	Unit Cost	Cost Evidence	Volume	Price Base	Price Base Conversion	Investment Value (18/19 Prices)
Actuating pipework replacement	[redacted]	MWC quote based on conceptual design for bespoke stainless steel above ground actuating gas pipework at St Fergus	[redacted]	[redacted]	[redacted]	[redacted]
Air compressors + controls/ electrical	[redacted]	Based on outturn cost of replacing Air compressors at Alrewas Compressor station	[redacted]	[redacted]	[redacted]	[redacted]
Shafer Actuator overhauls	[redacted]	Based on outturn cost of RIIO1 overhaul of 28 failed Shafer Actuators at St Fergus	[redacted]	[redacted]	[redacted]	[redacted]
			[redacted]	[redacted]	[redacted]	[redacted]

Table 9: Option 6 cost assessment

7.15 There are multiple risks associated with the above cost assumptions:

- The actuating pipework cost assumptions were provided by [redacted] (St Fergus RIIO-T1 Asset Health Main Works Contractor). [redacted] repeatedly underestimated the complexity and therefore the cost to complete their work at St Fergus and as a result RIIO1 projects were regularly resanctioned from initial estimates and compensation events were repeatedly raised.

- Whilst the Shafer overhaul costs are based on actual Shafer overhaul outturn costs at St Fergus, failures have since been seen on overhauled Shafer Actuators. This suggests replacement may become a primary option for certain failure modes therefore increasing costs further.

- The air compression system at Alrewas is of a significantly smaller size than the one that would be required at St Fergus and is likely to be a low estimate.

<u>Option 7: Replace Actuators with electric/electrohydraulic Actuators negating the need for actuating pipework</u>

7.16 Replace existing gas-hydraulic Actuators with a mix of electric and electrohydraulic Actuator technology allowing for compliant valve operation and the decommissioning of the existing actuating pipework.

7.17 As noted in section 3 there are 119 Actuators required for the ongoing safe and reliable operation of the terminal. A full review of valve actuation needs has been undertaken (see Appendix 2) to ensure the least cost technology option can be selected for each valve.

Requirement	Human Factors and Occupational Safety		Operationally speed critical		Safety critical		Start-up / shut-down automation		Total
Replacement Solution	direct electric	electro-hydraulic	direct electric	electro-hydraulic	direct electric	electro-hydraulic	direct electric	electro-hydraulic	
Plant 1	5		1	2		22			**30**
Unit 1A				7			1		**8**
Unit 1B				7			1		**8**
Unit 1D				7			1		**8**
Plant 2	4			4	1	25			**34**
Unit 2B				7			1		**8**
Plant 4						8			**8**
Plant 6	3					12			**15**
Total	**12**		**1**	**34**	**1**	**67**	**4**		**119**

Table 10: Overview of Actuator least cost technology requirement by location

7.18 Pros:

- Eliminate the need for the gas actuating pipework entirely thus eliminating all associated corrosion defect, ground movement and single point of failure risks
- Eliminate risks associated with aged Actuators and their associated defects and DSEAR non-compliance issues
- Alternative valve Actuator technology options eliminate direct greenhouse emissions currently present with existing systems through release of methane on actuation.
- Lower cost than a full actuating pipework replacement and Actuator overhaul (Option 6)
- Reduced flammability risk (natural gas power source for Shafer Actuators)
- There are no standalone reservoir/accumulator vessels associated with this option, thus providing potential operational and maintenance cost reductions
- Self-contained electrohydraulic Actuator units provide full containment of components in an area noted for its harsh environment thus providing a high level of corrosion prevention
- Adoption of existing cable trenches reduces installation cost
- Reduced site disruption, without recourse to have to route a pipeline for the motive force.

7.19 Cons:

- Plant outage sequencing to install new Actuators would be complex and extensive
- Valve isolations would be for longer periods than required for actuating pipework replacement (although recognising that overall programme will be shorter)
- Electro-hydraulic Actuators are new technology to site requiring associated training and revised maintenance schedules / work orders

7.20 A Best Available Techniques (BAT) assessment (see Appendix 3) commissioned and delivered by [redacted] in 2015 assessed the range of Actuator technology options available for valve applications at St Fergus. This assessment supports the decision to install electro-hydraulic Actuators for ESD/safety systems and electric Actuators for non-ESD/safety systems.

8 Option Analysis and Selection

8.1 Considering the above rationale and options assessment, the following table provides a summary of the options considered.

		Options Considered						
Solution considerations		Option 1 Do Nothing	Option 2 Fix on Fail	Option 3 Risk Assess	Option 4 Gas Bottles	Option 5 Portable Compressors	Option 6 Replace Actuating pipework	Option 7 Replace Actuators
Meeting HSE Requirements		Fail - risk prohibition notice	Fail - risk prohibition notice	Fail - risk prohibition notice	Not deemed to be ALARP but could deliver to timescales	Not deemed to be ALARP but could deliver to timescales	Longer programme of works delaying resolution	Delivers in line with HSE expectations
Cost		Lowest	Low	Medium - long term proactive repair programme	Medium/High – new actuating pipework or alternative Actuator technology required for remaining valves	Medium/High – new actuating pipework or alternative Actuator technology required for remaining valves	High - significant cost to design and install over 5km of new pipework	Medium - 119 new Actuators to be installed
Compliance	COMAH	Non-complaint	Non-complaint	Non-complaint	High - Option does not meet safety standards for safety critical systems	High - Option does not meet safety standards for safety critical systems	Compliant	Compliant
	PSSR	Non-complaint	Non-complaint	Non-complaint	Compliant	Compliant	Compliant	Compliant
	DSEAR	Shafer Actuators remain non-compliant with DSEAR	Shafer Actuators remain non-compliant with DSEAR	Shafer Actuators remain non-compliant with DSEAR	Shafer Actuators remain non-compliant with DSEAR	Shafer Actuators remain non-compliant with DSEAR	Shafer Actuators to be overhauled bringing into compliance	DSEAR compliant Actuators
Environmental Impact		Natural gas vented on actuation	Natural gas vented on actuation	Natural gas vented on actuation	No greenhouse gas vented on actuation	No greenhouse gas vented on actuation	No greenhouse gas vented on actuation	No greenhouse gas vented on actuation
Maintenance	Ongoing OPEX	Low	Medium - continuous OPEX challenge to maintain	Medium - continuous OPEX challenge to maintain	High - introduces and ongoing programme of daily bottle management	High - Introduces ongoing inspection and maintenance programme for multiple small compressors	Medium - introduces additional maintenance requirements for site wide air compression system	Low - removes significant effort for ongoing defect management of actuating pipework and Shafer Actuators
	Risk	High - unsafe for personnel to work in vicinity of unmitigated defects	High - unsafe for personnel to work in vicinity of unmitigated defects	Medium - risk prevalent but managed through ongoing mitigations	Medium - introduces ongoing manual handling challenge	Low - (assuming actuating pipework removed!)	Significant quantity of new above ground pipe will present additional risk to routine site operations	Low - majority of significant site defects removed. Actuating pipework risks eliminated
Operational Resilience	Single Point of Failure	Actuating pipework SPOF persists	Actuating pipework SPOF persists	Actuating pipework SPOF persists	Actuating pipework SPOF designed out	Actuating pipework SPOF designed out	Actuating pipework SPOF designed out	Actuating pipework SPOF eliminated
	Security of Supply	High risk of failure	High risk of failure	High risk of failure	Additional Actuator system risks introduced	Additional Actuator system risks introduced	Aged Shafer Actuators remain a risk to Safety critical valve systems	Low. SPOF eliminated and Shafer Actuator risks removed
Overall viability		Not viable	Not viable	Not viable	Not viable	Not viable	Viable	Viable

Table 11: Options comparison

9 Final Option Selection, Cost and Programme

9.1 The assessments outlined in this paper and the associated discounting and costing of options demonstrates there is only one cost effective and logical option to take forwards: Option 7 - Replace Actuators with electric/electrohydraulic Actuators negating the need for actuating pipework.

9.2 The focus is therefore on ensuring this is delivered at the lowest overall cost. The following factors support this:

- The St Fergus Short Term Strategy confirms minimum compression units eliminating three units and the associated 24 Actuators from the needs case.
- The case-by-case valve actuation needs assessment ensure the lowest cost technology selection is taken forward for each replacement.
- The competitive tender process undertaken for the Main Works Contractor provides assurance that best market rate is paid for the programme.

9.3 The Actuator works were tendered as a package including corrosion remediation and cathodic protection upgrade, in accordance with NGGT tender procedures. These works were competitively tendered on our minor gas construction framework, which contains six contractors capable of carrying out these types of works. This is a two-stage tender process;

- Tender information (including scope of works) is sent to all contractors on the framework for pricing against the scope. In this stage, three of the six suppliers submitted a quote, and these were assessed against pre-communicated commercial and technical scoring criteria
- A select number of competitive bids are then taken forward for further assessment, clarification, and negotiation. In this tender, all three returns were taken into this stage to give us the best technical and commercial tender.
- The best commercial and technical tender is then selected for award.

9.4 In this instance, the contract was awarded as a two-part design and build contract;

- Stage 1 was for design work only on Actuators and cathodic protection, and a small amount of design and build corrosion management scope due to the timescales in place to meet customer outages [redacted]
- Stage 2 was an "opt-in" whereby the output and costs developed in stage 1 were assessed before progressing to the build option for the remainder of the works. This enables NGGT to assess value for money before committing to the entire contract.

Final cost and programme

9.5 The table below, Table 12 provides a breakdown of the final costs for the project split by several categories. Due to this project being in delivery, and NGGT committing to spend due to the urgency of the project, the risk pot as shown in the table below is much less than would normally be expected. This is because the risks have either materialised or been retired.

9.6 In addition, some of the costs on this project were incurred during RIIO-T1. These are not being requested in this submission, however, would be predominately indirect design costs.

	Cost Category	Outturn Costs (£m)	Costs (£m) 2018/19 Price Base
	OEM costs	[redacted]	
Direct	EPC Estimate		
Indirect	EPC PM		
Direct	EPC Site Establishment		
Direct	NGGT Direct Company Costs		
Indirect	NGGT Indirect Company Costs		
	Contractor Risk		
Direct	NGGT Project Risk		
	FEED		
	Development / Optioneering		
	Land / Easements		
	TOTAL	**£26.952M**	**£23.089M**
	Direct	[redacted]	
	Indirect		

Table 12: Breakdown of Project Costs

9.7 Table 13 shows the spend profile for our preferred option in 2018/19 pricing. In order to update the licence terms within the Price Control Financial Model (PCFM), the request includes a negative value in the final year to provide the correct net position by year when accounting for baseline funding received[3].

£m 18/19	FY2022	FY2023	FY2024	FY2025	FY2026	Total	Comments
Actuators Programme	[redacted]						
Actuators Programme							

Table 13: Spend Profile of Preferred Option

9.8 [redacted]

9.9 [redacted]

[3] Baseline funding post T2 BP ongoing efficiency & capitalised Opex adjustment

RIIO-T2 Volume UIDs

9.10 Costs associated with this project have been assigned against the RIIO-T2 Unique Identifier (UID) [redacted] - ST FERGUS TERMINAL - Process Valve Actuator Replacement. The table below provides a summary of the UIDs and associated funding for the scope of works proposed in this paper.

UID	Baseline volume of Intervention (By PP)	Baseline total funding available (£ 18/19)	ECC unit cost (£ 18/19)	Current volume of intervention	ECC total funding required (£m 18/19)	Output Year	UID funding requested through UM (£m)
	(by unit of measure)			(by unit of measure)	£23.08		
[redacted]							
Totals		£0.85			£23.09		*£22.24*

Table 14: UID Details

9.11 The cost accuracy at this stage of the project is estimated at +/-10% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

9.12 This report has explained the safety concerns NGGT has regarding the actuating pipework and the implications of these on terminal operations. The intervention is necessary to ensure the safety of site personnel and ongoing 24/7/365 operation of the terminal facility. Removal of the gas actuating pipework and the subsequent replacement of key Actuators at the St Fergus gas terminal totals £23.089m (18/19 Prices). We are requesting the funding for the outturn costs, the majority of which have already been spent or are committed, through this Asset Health Uncertainty Mechanism re-opener.

NARMs Benefit

9.13 Following discussions with Ofgem in the NARM Development Monthly Meetings, it is proposed that for simplicity all the investments that arise from the UMs are collated and one NARMs update is provided after the Plant & Equipment submission. For further details and a summary of UIDs please see Section 7 and Appendix 2 of the Asset Health UM overarching Document.

Deliverability Challenges

9.14 Deliverability challenges that have manifested since this work was first scoped and presented in the RIIO-T2 business plan have had an upwards pressure on costs.

9.15 There are significant challenges in being able to achieve isolations on site and arrange outages with customers, whilst also maintaining a gas path through the terminal. There are many valves on site which do not seal, and therefore limit the size of isolations that can be applied.

9.16 In order to maintain a gas path, the replacement of Actuators has required splitting into 17 separate work packs, many of which must be sequenced to avoid a loss of capability. This way of delivering the work is significantly less efficient than having large CDM (Construction Design and Management) areas in which Actuator work can be progressed at pace. However, this approach offers value to the consumer through our ability to maintain flows.

9.17 There is also additional scope required, which was not foreseen before detailed design had commenced. Mass flow controllers for each compressor package are currently powered from actuating gas, these will require replacement or modification before the actuating gas pipework can be decommissioned.

9.18 Several valves will require replacing, due to their incompatibility with the current Actuator design. These valves have sealant lines passing through the stem, and not on the outside of the valve as per normal design. The design team have exhausted available options to modify the valve or Actuator to make fit.

9.19 We are currently undergoing a review on deliverability, using what has been learned over the first block of Actuator replacements to inform how this will impact the programme and/or costs, and to determine more efficient ways of delivering.

10 Appendices

10.1 Appendix 1 – Detailed Asset List

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

10.2 Appendix 2 – Actuator BAT assessment report ([redacted] 2015)

File provided:

Theme 2 Actuator BATS Study Rev B.pdf

10.3 Appendix 3 – Corrosion reports and data extracts.

This data is available on request. Significant quantities of live data available in multiple formats

Detailed overviews of corrosion data are provided in the ALARP demonstration studies included in Appendix 8

10.4 Appendix 4 – ESD testing failure reports (Shafer Actuator Failure)

2 incident reports are provided to demonstrate the Shafer Actuator root cause of ESD failure:

St Fergus Unit 1B ESD FINAL SO 03022020_.pdf

St Fergus ESD Testing V12002 V21022 (Rev 1.2).pdf

10.5 Appendix 5 – Actuating pipework temporary fixes

Plidco clamp register file:

St Fergus Plidco Clamp Register.docx

10.6 Appendix 6 – [redacted] Actuating pipework replacement CDS and cost assessment

Conceptual Design Study file:

SF-actuating gas CDR-338113TH00_RP0006.pdf

Power Gas Actuating Pipework Replacement High Level Option/Costing Report

App A.1 - High Level Pricing and Options Report.pdf

10.7 [redacted]

[redacted]

10.8 Appendix 8 – ALARP Assessment

St Fergus Electro-Hydraulic Valve Actuator ALARP Assessment (2018)

10.9 Appendix 9 – Supplementary Questions and NGGT Responses

Ofgem supplementary questions submitted in response to an early draft and NGGT responses:

20220606_StF Actuators SQ Log

10.10 Appendix 10 – St Fergus Short-Term Strategy

Full report provided, filename:

RIIO-T2 St Fergus Short Term Strategy V7.pdf

10.11 Appendix 11 – Project Programme

St Fergus PAC3419 Actuators November 2022 Programme