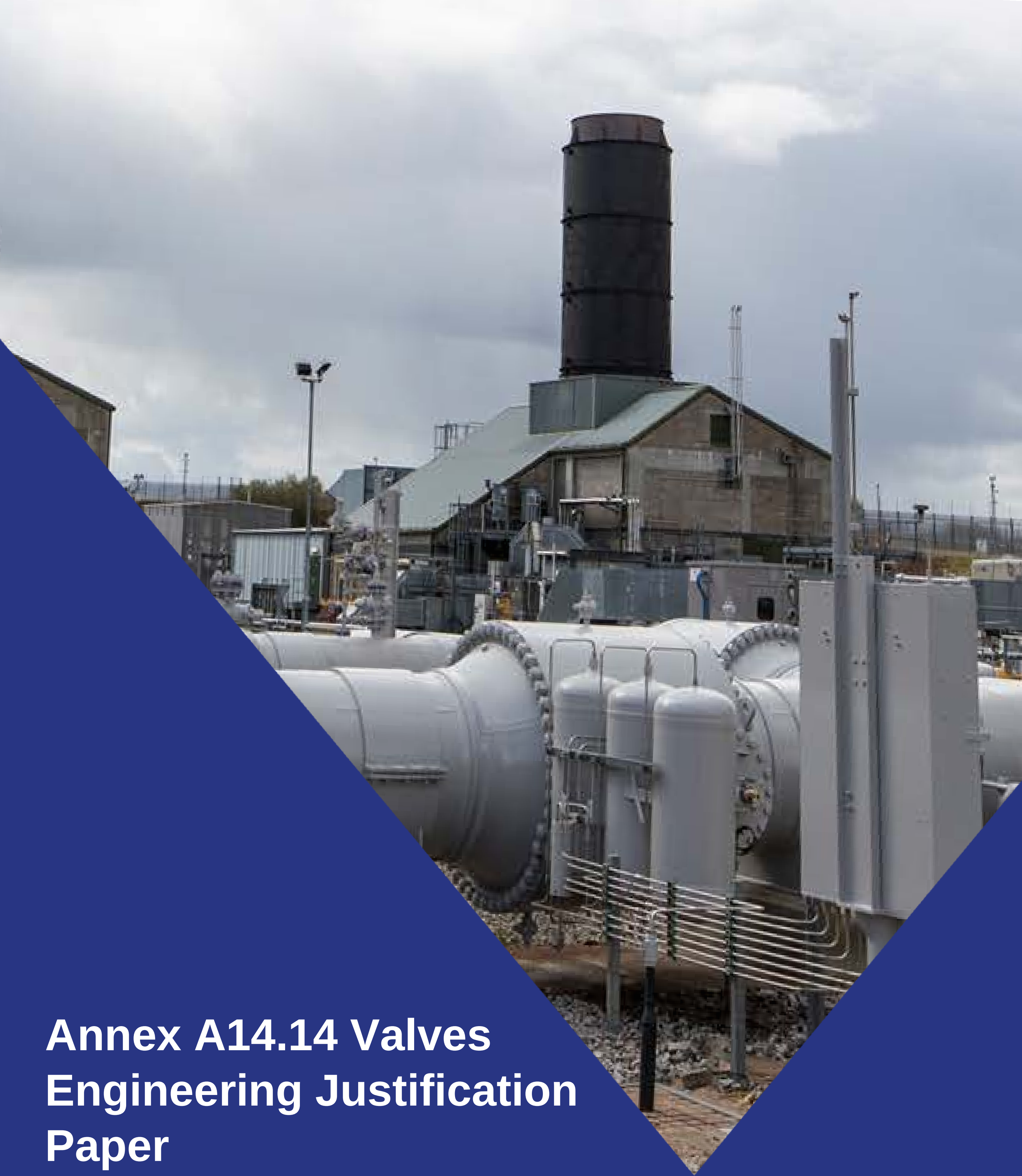


Annex A14.14 Valves Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Executive Summary

Introduction

To maintain the ongoing safe, secure and reliable operation of the UK Gas National Transmission System (NTS) it is imperative that the health of the assets that constitute the NTS is carefully managed.

Our Asset Health programme is an ongoing plan of works that assures this and consists of 7 core asset themes of work. This document outlines our approach to the management of our Valve assets to meet desired regulatory, stakeholder and financial outcomes. A 10-year view has been taken, covering the RIIO-2 and RIIO-3 regulatory periods to ensure a balanced, lifecycle approach to asset management.

The Valve asset health theme has no sub-themes and seeks to address defects on 8% of the valve population during RIIO-2. In total, we propose to spend £63.1m (10.2% of the 7 themes that comprise the overall asset health plan) ensuring risk levels are maintained on our Valve assets during RIIO-2.

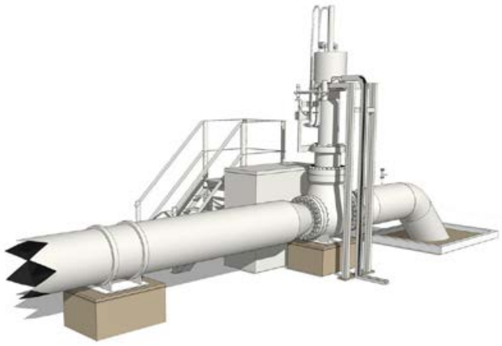
Sub-theme	Intervention Volumes	Cost
Valves	758	£63,145,760
Total	**758**	**£63,145,760**

The profile of Valve asset health investment for the 10-year period, derived from the volumes of work and the unit costs, is shown in the table below:

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total	6,361	13,875	14,608	13,948	14,355	14,907	15,083	13,429	9,706	8,161
	63,146					**61,286**				

The Assets

The Valve asset base includes over 30,000 isolation and control valves in the range of ½" to 48" in diameter. 66% of these are less than 4" diameter. The Valves asset is made-up of **Locally Actuated Valves (LAV)** which enable sites, pipelines or pipework sections to be isolated, **Remote Isolation Valves (RIV)** which enable a site or pipeline to be isolated remotely in the event of an emergency or planned operation, **Process Valves (PV)** which allow isolation of a site or section of site pipework as part of normal site operations, and **Non-Return Valves (NRV)** which ensure process gas flows in the desired direction whilst preventing reverse flow and segregating pressure between systems.



Typical above-ground Remote Valve Configuration

Valves are an essential part of a functioning NTS, controlling the flow of gas and isolating it to allow safe intervention for operational or integrity reasons. These installations tend to be at above ground installations, terminals and off-takes. However, a high proportion of the valves are buried. The distributed and hidden nature of the asset makes it time consuming and expensive to inspect and test the valves.

Over 68% of the valves, of 4” diameter and above, are over 40 years old with original design lives of around 30 years. This would increase to over 81% by 2031 without intervention. The number of defects associated with valves are predicted to rise significantly as the relevant deterioration mechanisms are time and use dependent. Proactive intervention is required to avoid unmanageable levels of defects, together with the associated adverse impacts on the safety, operation and availability of the NTS and any potential legislative non-compliance. Further information can be found in section 3.

Impacts of no investment

- Safe isolations are becoming increasingly complex, time consuming and expensive due to internal leakage across isolation valves;
- Isolations will require increasing lengths of the NTS to be vented with an increased environmental impact;
- The continual passing of gas from vent and sealant lines and stem extensions to atmosphere will increase safety hazards as well as environmental impacts;
- Increased outage time due to valve failures related to obsolete assets and the unavailability of spares;
- Increased risk of impacting supplies, as a growing number of outages on the NTS are required to resolve valve defects.

The increasing age of the asset and the related defect count means that these consequences become more likely and drive an increasing risk profile over the period. Further information can be found in section 4.

Proposal Development

The development of the final Valve proposals for RIIO-2 have focussed on ensuring the right blend of intervention categories (refurbish, replace etc.) whilst balancing cost and risk. Learning from RIIO-1 has heavily influenced our approach and our plans aim to maintain a steady rate of investment to ensure deliverability and consistency to maintain risk.

In defining our proposed intervention approach, we have considered six programme options and compared these against a Baseline option that assumes a reactive intervention stance. In deciding on the proposed intervention strategy, we have considered the ability to meet the desired engineering and stakeholder outcomes and the resulting cost-benefit.

All options considered are cost beneficial over the 45-year period. The proposed option is to Maintain Risk which pays back in 34 years and is significantly cost beneficial after 45 years. Whilst not the most cost-beneficial option our proposal delivers the desired outcomes at the least cost focusing on those valves that have the most impact on risk.

In choosing the option to be carried forward into our plan we have considered the results of our CBA analysis amongst a range of other factors, examples set out below:

- The need to achieve legislative compliance may not necessarily be reflected through the quantified benefits delivered through a cost beneficial investment option, for example, the [redacted] will not tolerate a planned increase in safety risk, regardless of the economics.
- Where there is a backlog of known asset failures to be resolved, this will not always be reflected by the CBA as the risk valuation is calculated using an expected rate of future defects across the whole population of an asset type.
- Our understanding of individual asset condition has improved during RIIO-1 but there are still gaps in our knowledge. Our plan reflects the need for a likely practical mix of intervention categories once specific assets are surveyed and their true condition and risk are understood. For example, a plan based upon 100% refurbishment may require a high number of replacements should a proportion of the assets be determined as non-serviceable.
- The need for a deliverable programme of work, both in terms of planning outages, resource availability and contract efficiency. For example, through “bundling” work it may be more cost-effective to undertake alternative interventions to achieve reductions in contract costs, minimise outage risks or avoid an early repeat intervention in future RIIO periods.

The table below summarises the key considerations when developing this theme of work.

To deliver these outcomes….
• Meet legislative requirements and agreed safety standards
• Ensure valves perform their function continually and reliably, particularly in an emergency
• Manage obsolescence effectively
• Decommission and remove assets that are no longer required
• Reduce the environmental risk of emissions
• Maintain reliable energy supplies across the NTS
• Meeting the expectations of our customers and stakeholders and keeping risk stable

…by intervening like this…
• Simplifying the asset by removing Block Valves and converting RIVs to LAVs where appropriate • Replacing actuators and valves where this is the most economical course of action including replacing obsolete electrical actuators that do not meet Dangerous Substances and Explosive Atmosphere Regulations (DSEAR) requirements • Refurbishing and repairing valves to address vent and sealant line, and stem leaks to atmosphere and unacceptable internal leakage across the valve • Responding to arising defects using a risk-based prioritisation process
…based on this knowledge:
• An asset-specific risk-based review of the results of routine inspections, maintenance and investigations already undertaken • A site-specific risk review of the Block Valves sites to determine which of those need to be retained or could be decommissioned • A forecast of the valve defects and associated risks following routine interventions • A survey of the complete DSEAR assessments to identify and assess non-conformances to the standard • Knowledge of the volumes of assets that are currently obsolete or forecast to be obsolete during the investment period.

RIIO-2 Valves Asset Health Investment Proposal Summary

Valve Asset Health investment proposal headlines

- The total RIIO-2 proposed expenditure for this theme is £63.1m
- 100% of the Valve Asset Health proposals deliver NARMs outputs and 22% of this is driven by Legislation/Safety Case
- 98% of our Valves programme is based upon interventions to address known defects (29%) and high confidence work volumes based on historical trends (69%).
- The valve asset health theme in its entirety is cost beneficial and pays back within the period defined by Ofgem
- Valve asset health costs are reducing from RIIO-1
- Volume data confidence is high across the whole theme as these proposals and the associated work packages reflect the RIIO1 programmes of work and is largely based on known defects.

A range of options has been considered for this theme of work:

Sub-theme	RIIO-2 Plan (£)	Percentage of Theme	Options considered	Option summary / considerations
Valves	£63,145,760	100%	6	A wide range of options assessed to balance cost/risk are detailed within this justification report for this significant area of work. The preferred option represents the lowest whole life cost to maintain the current levels of risk on our valve assets

We have estimated unit costs across all our proposed Valves interventions either from historical outturn data points, from supplier quotations or from other estimation methods (such as extrapolation to similar types of work or from reviewing industry benchmarking data). Our approach has been primarily based top down from final actual costs combined with bottom up from estimating procedures and supplier rates or quotations. We have challenged our costs through internal benchmarking review with current supply chain partners combined with use of benchmarking data where this exists.

All the unit costs include the efficiencies resulting from bundling delivery programmes across asset classes and within available outages and efficiencies resulting from our innovation projects where these are proven to deliver benefits and can be utilised in the planned investments.

There is a large volume of valves on the NTS in comparison to other asset types, which provides a substantial number of historical outturn cost data points. 91% of the Valves investment is supported by historical outturn costs of which the majority (over 80%) is informed by at least three data points.

There are many factors that differentiate valve costs, which therefore provide a degree of uncertainty in the unit cost estimates. The size, type (e.g. bidirectional versus singular) and scope of the intervention (e.g. replacement of valve versus sealant injection) can all vary by project and impact the cost of works.

The complexity of the work mix carried out as part of a project contributes to the level of certainty that can be derived from historical outturn costs. There can be numerous works carried out as part of a valve intervention, which can include excavation and construction of temporary access roads which can increase specific project costs by many hundreds of thousands of pounds. Increased complexity in the work mix introduces more uncertainty to the direct costs and greater variation in indirect costs that can allocated to a UID.

The table below summarises the evidence used to produce the Valves unit costs.

Investment sub-theme	Secondary Asset Class	RIIO-2 Business Plan	Evidence		
			Outturn	Estimated - Quotation	Estimated - Other
Valves	Locally actuated valves	[redacted]	92%	0%	8%
	Non-Return Valve	[redacted]	100%	0%	0%
	Process valves	[redacted]	98%	0%	2%
	Remote Isolation Valves	[redacted]	73%	0%	27%
Total		[redacted]	91%	0%	9%

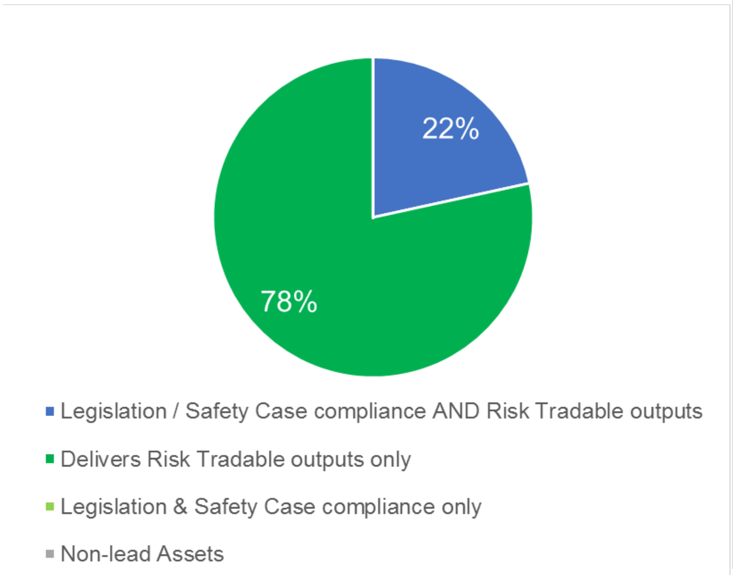
We have set out full details of our process for estimating unit costs across our asset health proposals in our Asset Health Unit Cost Annex.

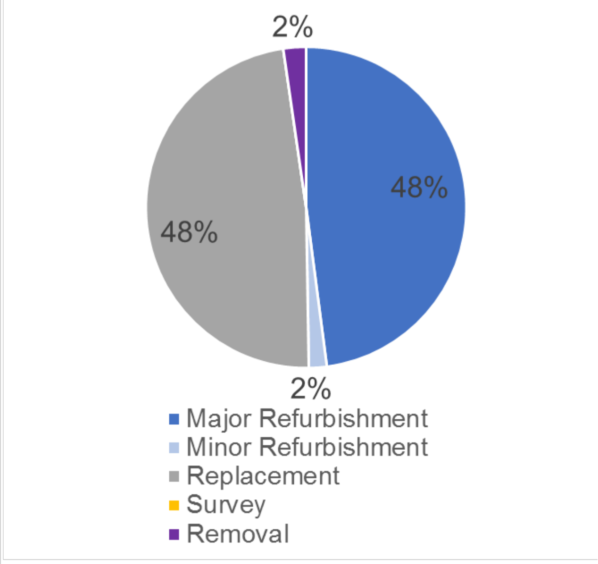
The RIIO-2 Asset Health Valve theme and intervention costs and volumes by output are provided below. All costs are in thousands (£000).

Interventions	RIIO-2 Volumes[1]	Legislation/ Safety Case & Risk Tradable	Risk Tradable	Legislation & Safety Case	Non-lead Assets
Valves	[redacted]				
Locally Actuated Valve - Block Valve Replacement	[redacted]	£0	£2,895	£0	£0
NRV Major Overhaul - 36" NRV	[redacted]	£8,244	£0	£0	£0
NRV Replacement - 8" NRV	[redacted]	£436	£0	£0	£0
Process Valve Actuator Replacement	[redacted]	£0	£3,209	£0	£0
Process Valve Replacement	[redacted]	£0	£6,011	£0	£0
Process Valve Stem Seal Replacement	[redacted]	£0	£0	£0	£0
Process Valve Vent & Sealant Line Major Refurb	[redacted]	£0	£350	£0	£0
Process Valve Vent & Sealant Line Replacement	[redacted]	£0	£3,066	£0	£0
Remote Isolation Valve - DSEAR Actuator Replacement	[redacted]	£3,303	£0	£0	£0
Locally Actuated Valve - DSEAR Actuator Replacement	[redacted]	£1,126	£0	£0	£0
Remote Isolation Valve Actuator Replacement	[redacted]	£0	£2,754	£0	£0
Remote Isolation Valve Removal	[redacted]	£0	£31	£0	£0
Remote Isolation Valve Replacement	[redacted]	£0	£2,489	£0	£0
Remote Isolation Valve Stem Seal Replacement	[redacted]	£0	£431	£0	£0
Remote Isolation Valve Vent & Sealant Line Replacement	[redacted]	£0	£2,776	£0	£0
Locally Actuated Valve Actuator Replacement	[redacted]	£0	£4,024	£0	£0
Locally Actuated Valve Replacement	[redacted]	£0	£4,831	£0	£0
Locally Actuated Valve Stem Seal Replacement	[redacted]	£0	£887	£0	£0
Locally Actuated Valve Vent & Sealant Line Minor Refurbishment	[redacted]	£0	£1,136	£0	£0
Locally Actuated Valve Vent & Sealant Line Replacement	[redacted]	£0	£10,794	£0	£0
Locally Actuated Valves - Block Valve Removal	[redacted]	£0	£1,415	£0	£0
Locally Actuated Valve Replacement (St Fergus)	[redacted]	£0	£129	£0	£0
Remote Isolation Valve Stem Seal Replacement (St Fergus)	[redacted]	£0	£30	£0	£0
Remote Isolation Valve Vent & Sealant Line Replacement (St Fergus)	[redacted]	£0	£34	£0	£0
Remote Isolation Valve Actuator Replacement (St Fergus)	[redacted]	£0	£106	£0	£0
NRV Replacement - 8" NRV (St Fergus)	[redacted]	£11	£0	£0	£0
Locally Actuated Valve Vent & Sealant Line Replacement (St Fergus)	[redacted]	£0	£136	£0	£0
Locally Actuated Valve Actuator Replacement (St Fergus)	[redacted]	£0	£35	£0	£0
NRV Major Overhaul - 36" NRV (St Fergus)	[redacted]	£511	£0	£0	£0
Process Valve Replacement (St Fergus)	[redacted]	£0	£1,033	£0	£0
Process Valve Stem Seal Replacement (St Fergus)	[redacted]	£0	£60	£0	£0
Process Valve Vent & Sealant Line Replacement (St Fergus)	[redacted]	£0	£170	£0	£0
Process Valve Actuator Replacement (St Fergus)	[redacted]	£0	£424	£0	£0
Remote Isolation Valve Replacement (St Fergus)	[redacted]	£0	£258	£0	£0
Total	[redacted]	**£13,630**	**£49,516**	**£0**	**£0**

[1] Where 'rounding' has resulted in volumes being presented as a zero, we have included a decimal place to illustrate the proportion of investment phased in RIIO-2 (remainder in RIIO-3).

Valve Asset Health theme outputs and intervention categories:

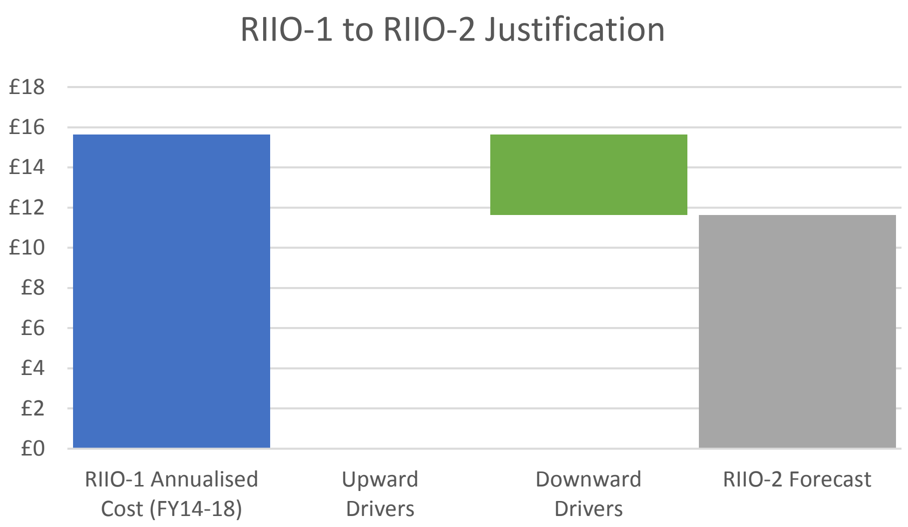




Comparing our RIIO-2 proposal to our RIIO-1 programme

The annualised RIIO-2 spend has decreased when compared to RIIO-1 from £16.1m to £11.6m for the Valves Asset Health theme.

Note that this cost information is annualised to provide a comparative cost per year and the total RIIO-2 forecast below also includes the application of our agreed efficiency target within the downward drivers.



Upward Drivers

Knowledge of the condition of our valve assets entering RIIO-1 was well understood. These assets come under primary containment as well as safety systems to isolate our pipelines in emergency situations. Therefore, effort and expenditure were focussed on these assets during RIIO-1. We continue to assess and invest in our valve assets on an ongoing basis and whilst volumes of interventions are largely similar in RIIO-2, lessons learned and best practice from

RIIO-1 ensures a lower overall cost per unit whilst we maintain a smoother delivery profile. Therefore, there are no upward drivers impacting the change from RIIO-1 to RIIO-2.

Downward Drivers

Several specific innovations have been developed during RIIO-1 and these will continue to be benefitted from through our RIIO-2 valve campaigns. We have reviewed our valve technical standards with a focus on efficiency within our Richmond programme which will lower costs for all future valve replacement. We have also recently launched the “Refurb & Re-life” team within our Pipelines Maintenance Centre (PMC) department. This team will enable the lowest cost interventions on valves and a range of other assets through expert knowledge, detailed surveys and a strong incentive to minimise costs to extend asset life that can be gained though in house-experts.

Table of Contents

1. Summary Table

Name of Scheme/Programme	*Valves*
Primary Investment Driver	*Asset Health*
Scheme reference/ mechanism or category	*A22.14*
Output references/type	-
Cost	*£63.1m*
Delivery Year	*2022-2026*
Reporting Table	*3.03b*
Outputs included in RIIO-1 Business Plan	-

2. Introduction

Structure of the Case

2.1. This document summarises the justification for the required investment in valves installed on the High-Pressure Gas National Transmission System (NTS). All valves have been assessed using a consistent overall risk based analytical framework.

2.2. The investment case for valve investment is set out in the following sections of this document:

- **Introduction** – this section sets out the structure of the case and an overview of valve assets on the NTS
- **Equipment summary** – provides a summary and profile of the asset base
- **Problem statement** – describes the issues facing the assets, drivers for investment and impact of no investment
- **Probability of failure and Probability of consequence** –sets out the way the assets fail and the subsequent stakeholder impacts
- **Options considered** – describes the potential mix of interventions to be considered for each of the assets within a range of programmes with differing objectives
- **Business case outline and discussion** – sets out the preferred programme option and reasons, given the cost benefit analyses and assessment of other drivers, stakeholder requirements and business objectives
- **Preferred option and plan** – sets out the final selected option restated, along with the spend profile.

Overview of Valves on the NTS

2.3. Valves are essential to the safe and reliable operation of the NTS and cannot continue to be operated without significant investment in the existing valve population. A large proportion of which has now exceeded its design life and requires an asset intervention. The investment set out in this paper seeks to maintain the current level of operational and safety risk across the network, upgrade obsolete systems where it can be shown to be cost effective to do so and ensure that the network is compliant with all relevant legislation and standards subject to a review demonstrating that the valve continues to be required.

2.4. Failure to support this investment programme will result in progressive deterioration of the capability, reliability and above all safety of the network. Where safety cannot be maintained to an acceptable As Low as Reasonably Practicable (ALARP) standard in line with the requirements of the Health and Safety Executive (HSE) and the Gas Safety Management Regulations 1996 (GS(M)R), consideration should be given to removing sections of the network from service until systems can be appropriately upgraded.

2.5. Provision of isolation valves at regular intervals is a requirement under the Pipeline Safety Regulations to ensure that any affected section of feeder can be isolated and made safe in a timely manner in the event of an incident. Other valves are required across the network to allow equipment to be safely isolated and vented for inspection or maintenance activities, to allow isolated systems to be safely returned to service, to prevent reverse flow in the network. Some valves have safety functions and as such are required to achieve certain standards of reliability.

2.6. Since the NTS was originally designed and constructed, the standards for isolations for maintenance as set out by the HSE in HSG253 (The safe isolation of plant and equipment) have increased and many sites cannot achieve the currently recommended standards in terms of number and type of isolation required.

2.7. There are approximately 30,000 valves currently in service across the NTS ranging in size from ½" to 48" nominal diameter. Apart from small diameter instrument valves (1" nominal diameter and below) which are manufactured from stainless steel, all valves and associated equipment and systems are fabricated primarily from carbon steel and thus need to be protected from corrosion.

2.8. Most valves are buried at depths of between 0.8 and 4.5m to the crown of the pipe. Larger diameter valves (typically 12" nominal diameter and above) are of fully welded construction and welded into the pipework to minimise the risk of leakage.

2.9. More than 68% of the valves across the NTS have now exceeded their original design life. All valves deteriorate in service because of wear and other damage to the internal sealing surfaces and corrosion affecting the pressure containing parts of the valve.

2.10. Any failure to seal reliably renders a valve unusable. Where a valve becomes unusable the following may result:

- The valve becomes a safety risk
- The feeder section is non-compliant with the Pipeline Safety Regulations
- The valve may prevent safe and reliable operation of the network (including offtakes, thus putting customer supplies at risk))
- Much larger sections of the network need to be isolated to achieve a safe isolation
- Devices such as insertion stopples may be required (entailing significant time, cost and additional risk).

2.11. The design and installation of most of the valves in use across the NTS means that there is only a limited amount of maintenance work that can be undertaken in situ. If valve sealing performance cannot be remediated on the day, e.g. minor repair. Then the asset is registered for further investigation, enhanced maintenance and/or intervention. If following any of these established techniques, removal and replacement is generally the only option to restore valve performance.

2.12. Any intrusive or replacement work on feeder valves requires the feeder to be purged to air before cutting and welding can safely be undertaken. Isolating and purging a feeder is expensive and time consuming and to maximise delivery efficient, any remediation work will consider and bundle (where appropriate) all valves in a given section of feeder (including any which are expected to require intrusive work soon).

2.13. Valves can be operated manually or by powered actuators. Actuated valves can be controlled locally and / or remotely from Gas National Control Centre (GNCC). Many of the gearboxes used for manually operated valves are life expired and need replacement whilst many of the actuators and associated control systems in use across the network are obsolete (not necessarily an issue per se but one which can cause significant delays returning an installation to service after a failure if spares are not available). Many of the electrically powered actuators currently in service cannot be shown to meet the requirements of the Dangerous Substances and Explosive Atmosphere Regulations 2002 (DSEAR) legislation or IEC61508 (Functional Safety standards) for safety systems.

3. Equipment Summary (£63.1m)

3.1. Valves are installed throughout the NTS to enable effective isolation of sections of the network, limit gas loss in an emergency, manage flow direction, facilitate maintenance, repair, modification, testing and commissioning, and to enable safe and effective start-up and shutdown. There are valves operating in all areas of the NTS and which control or isolate gas into, out of and around the pipeline network, plant and equipment.

3.2. Valves may be manually operated, automatic or remotely controlled depending on the purpose they serve.

3.3. Valves fulfil the National Grid operational and legal requirements of the Pipeline Safety Regulations (PSR) and Gas Safety (Management) Regulations (GS(M)R) to provide:

- effective isolation of sections of the NTS to allow safe working; and
- the ability to safely shutdown and isolate sections of the NTS in the event of an incident.

3.4. There are over 10,000 valves with diameters ranging from 4" to 48” installed on the NTS, with a further 20,000 between 1/2" and 4". They are defined by their key purposes as follows:

- **Locally Actuated Valves (LAV) -** enable a site, pipeline or pipework section to be isolated by means of local operation in the event of an emergency or planned operation. They make up 80% of the total number of valves on the NTS.
- **Remote Isolation Valves (RIV) -** enable a site or pipeline to be isolated remotely by Gas National Control Centre (GNCC) in the event of an emergency or planned operation. These valves need to be reliable to ensure they will operate in the event of an emergency and enable National Grid to meet legislative, regulatory and commercial obligations. They account for 9% of the total number of valves on the NTS.
- **Process Valves (PV) -** allow isolation of a site or section of site pipework by the site, station or unit control system as part of normal site operations. These valve assets have a direct impact on the site reliability, availability, maintainability and safety. They make up around 9% of the total number of valves on the NTS.
- **Non-Return Valves (NRV) -** ensure process gas flows in the desired direction whilst preventing reverse flow and segregating pressure between systems. NRV’s are used for flow direction control and on the main station by-pass to control station discharge flow when on-line, allowing flow onto the NTS in the desired direction only. NRV's are also positioned to suit either series and/or parallel unit operation when multiple machines are designed to run together. They make up around 2% of the total number of valves on the NTS.

Location of Valves

3.5. Valves are installed in different operational locations, for example, compressor sites, block valve sites, multi-junctions, terminals and off-takes. A high proportion of valves (along with the associated pipework) are buried at depths ranging typically between 0.8 and 4.5m to the crown of the pipe.

3.6. Block Valve sites are located throughout the NTS. There are 227 Block Valve sites installed on cross country pipelines each typically consisting of a configuration of 6 LAVs. These sites limit gas loss in an emergency, facilitate maintenance, flow direction, repair, modification, testing and commissioning on the pipeline network. See the figure below.

Valve Volume

3.7. The table below shows the number of valves, 4" and above, by valve type on all sites.

Number of valves 4" and above by type

Valve Type	Total Volume
Locally actuated valves	8,017
Non-Return Valves	148
Remote Isolation Valves	837
Process Valves	885
Total	**9,887**

Pressure Ratings

3.8. Valves typically operate at the full pressure of the NTS, which ranges from 70 bar to 94 bar. However, valves typically located on Exit Points for example operate between 31bar to 70bar.

3.9. Valve actuators of type Schafer Rotary Valve – (Gas Over Oil) contain pressure vessels that operate between 7bar and 94bar and are therefore subject to the requirements of the Pressure Systems Safety Regulations 2000 (PSSR).

Valve Design

3.10. To minimise the risk of gas leakage, most large ball valves across the network are of fully welded construction. Whilst this minimises the risk of leakage of gas from the valve body, it restricts the ability to undertake much remedial maintenance on the valve and to repair any leakage across the seal faces. All maintenance work on valves must therefore be undertaken external to the main valve body. Large diameter ball valves are equipped with auxiliary connections which allow the seals to be flushed to remove debris with OEM recommended lubricants or other specialist sealants as an enhanced maintenance option.

3.11. A typical configuration of a ball valve assembly is provided in Appendix A. This shows all the main elements of a valve together with their purpose.

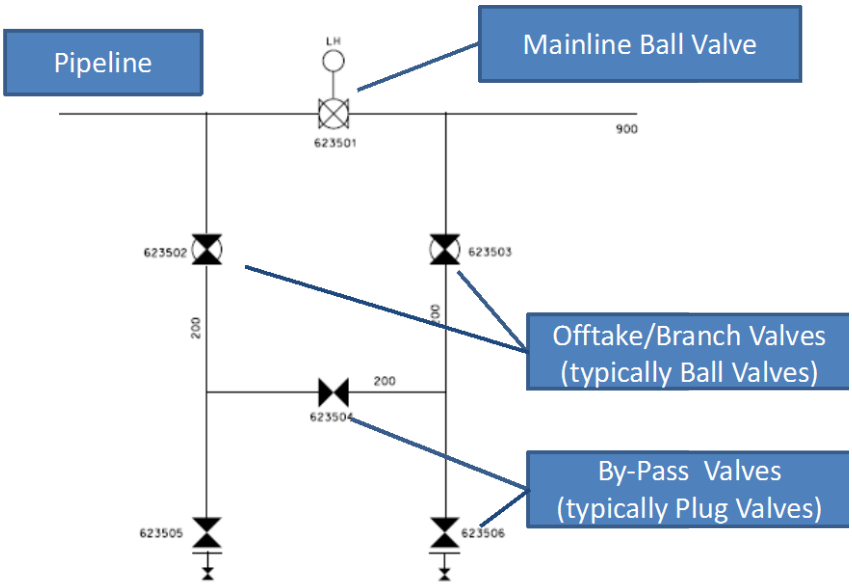
3.12. The design of the ball valves used as isolation valves across the network is such that they will suffer serious damage to the sealing surfaces if the valve is opened against an excessive differential pressure (typically more than 2 – 3 barg). This is one of the common causes of seal damage to ball valves. To minimise this risk small bore (2”) bypass valves are provided around the valve to equalise the pressure across the valve prior to opening. LAVs RIVs and PV may have a differential pressure interlock valve fitted to prevent the main line valve from being inadvertently opened against an excessive differential pressure.

Isolation Valves

3.13. The most common use for valves across the NTS is to provide isolation on sections of feeder or items of plant and equipment. This includes all Locally Actuated valves (LAV), Remote Isolation valves (RIV) and Process Valves (PV).

3.14. Isolation valves on compressor stations and terminals are located as close as possible to the equipment they isolate. Isolation or ‘block valves’ in feeders are typically located at intervals of between 15 and 40km to comply with the PSR and GS(M)R requirements to be able to vent down a section of pipework within 12 hours in the event of an incident. A typical block valve installation is shown in the figure below.

Typical block valve installation



3.15. Most of these isolation valves are large diameter, line size valves typically 24” and above. The only type of valve suitable for this type of application is the ball valve (See Appendix A for the description of a typical ball valve).

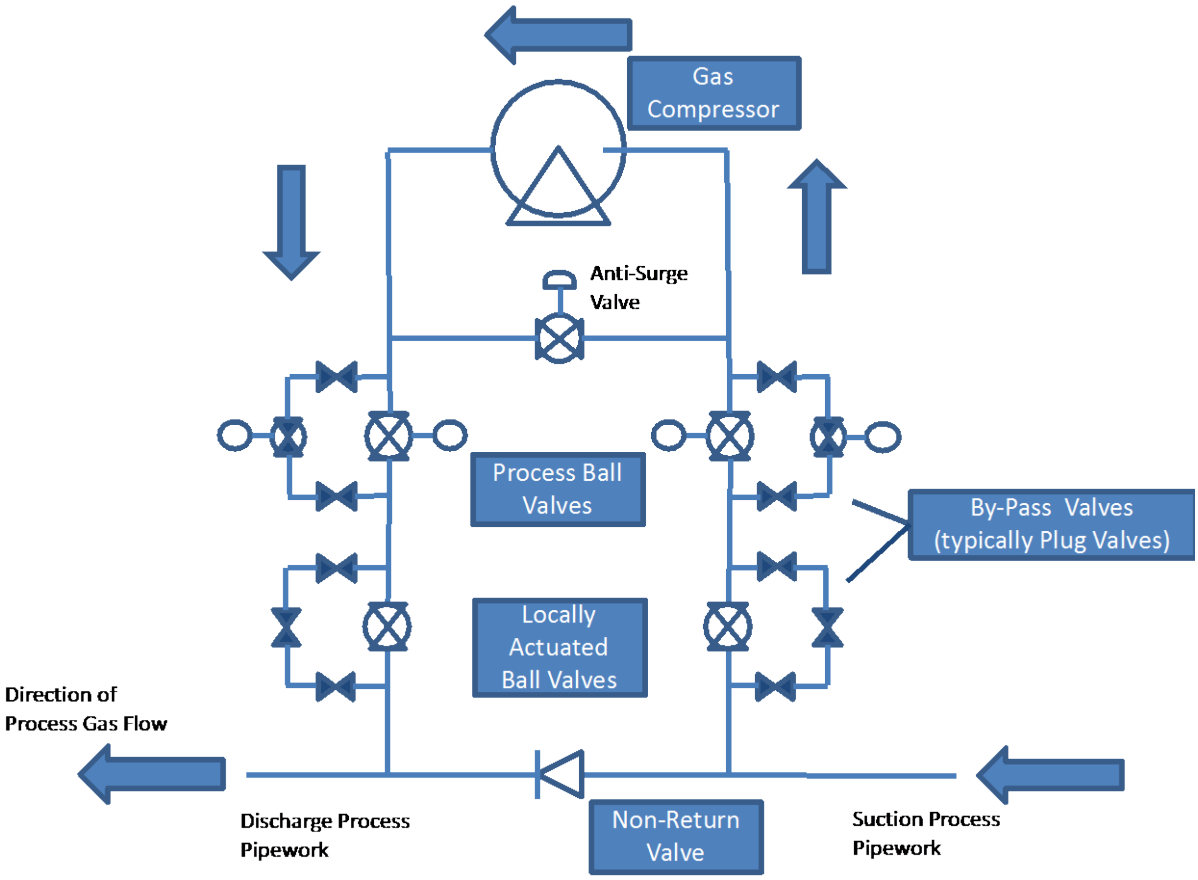
3.16. For most high-pressure gas applications, a double isolation with an intermediate atmospheric vent is required. This is to comply with HSG253 (The safe isolation of plant and equipment) which sets out requirements for the safe isolation of plant and equipment to allow work to be undertaken. In most cases, and via a risk assessment, this is achieved within a single valve which has two seals and a vent line between. Alternatively, two individual valves (i.e. double block and bleed) can be used with a with a separate vent valve between them.

3.17. Where double block and bleed isolations cannot be provided, either due to the design of the valve or damage to the sealing surfaces of the valve, an additional in-line valve must be used to provide the necessary isolation. Provision of safe isolations is a major challenge facing us.

Non-Return Valves

3.18. Non-return valves (NRV) prevent the unwanted reverse flow of gas from high to low pressure. Non-return valves are primarily used in compressor stations to prevent the recycling of gas from discharge to suction. A typical non-return valve installation is illustrated in the figure below:

Typical AGI Valve arrangement



3.19. NRVs rely on mechanical action (spring or deadweight) alone. The mechanical forces exerted on the internal components of a non-return valve in operation result in progressive damage to the soft and hard parts. Most large diameter (36") NRV's can either be accessed internally or removed for major overhaul.

Small Bore Valves

3.20. Small bore (typically 2" diameter) plug valves are provided to equalise the pressure across large diameter ball valves prior to opening. Plug valves are much more resilient to being opened against a high differential pressure and are used to minimise the risk of damage to the main ball valve. A typical plug valve by-pass installation is shown in the figure above.

Valve Operation

3.21. Valves may be operated manually or by means of a powered actuator. Actuators can be electric, electro-hydraulic, direct gas, direct hydraulic or pneumatic (using either compressed air or natural gas), gas/hydraulic or gas-over-oil powered. In many cases, actuated valves have an over-ride facility to allow them to be operated manually.

3.22. Electrically powered or controlled actuators will fall under the requirements of the Dangerous Substances Explosive Atmosphere Regulations (DSEAR). These regulations require specific checks on the condition of the electrical equipment to avoid risk of fire or explosion. Actuated valves may also fall under the mechanical requirements of the DSEAR regulations.

3.23. Pneumatically (gas or air) actuated valves may fall under the Pressure Systems Safety Regulations 2000 (PSSR). These regulations impose requirements on the suppliers and operators of such equipment to ensure that it is fit for purpose throughout its lifecycle and specifically a requirement to inspect such equipment in accordance with a Written Scheme of Examination.

3.24. Control of actuated valves can be either from a control panel local to the valve or remotely; typically, from GNCC (via the telemetry system) used to isolate sections of pipeline in case of emergency, a local control system or via an output from a protection system (via a Compressor Station / Unit control system).

Criticality of Valves

3.25. Valves can be categorised as critical or non-critical. Critical valves are those with a specific safety or reliability function and are subject to a more frequent inspection (Annually) and testing regime than non-critical valves (Biennial).

3.26. Critical valves cover all RIVs, PVs and some LAVs, for example, those that are on the other side of Pig Traps which are required to ensure gas is contained during an In-line Inspection (ILI). Critical valves follow a one-year inspection interval. There are circa 1266 critical valves of which 837 are remotely operated.

3.27. The remaining non-critical valves have a two-year inspection interval.

3.28. Historically, NRVs that are only located on compressors/terminals and are non-critical have been subject to a five-yearly interval between intrusive inspections. This is being changed to a more effective duty related inspection regime based on the number of valve operations. This changes the period between inspections to between 3 and 25 years, saving process downtime, inspection and spares turnover, whilst maintaining an acceptable level of risk.

4. Problem Statement

4.1. Over 30% of the valves on the NTS are over 40 years old with original design lives of around 30 years. The number of all the types of defects associated with valves are rising. A proactive intervention programme is required to ensure that unmanageable levels of defects, together with the associated adverse impacts on the safety, operation and availability of the NTS and any potential legislative non-compliance can be avoided.

4.2. The aging population of valves is deteriorating due to age and wear, whereby, many valves cannot achieve the seal required to fulfil their primary function of effective isolation. This is due to leakage through the valve seats where debris has built up, failure of individual components and an inability to lubricate valve seals and components.

4.3. There is also evidence of corrosion on the vent and sealant lines on numerous valves. This results in their inability to be used to maintain the internal valve seals, which allows them to pass gas to atmosphere and leak lubricant from the sealant lines themselves. Internal corrosion on the stem extension is also evident on many valves leading to a false indication of valve travel. In addition, several stem seals on valves are also reaching the end of their lives and are passing gas to atmosphere.

4.4. Various items of equipment ranging from valves to actuators and their associated control systems are now obsolete. This makes spare parts difficult, time consuming and expensive to obtain (often requiring refurbishment of existing parts or 'reverse engineering' spares). This increases both the cost and time to repair in the event of failure.

4.5. Some items of equipment (primarily actuators and their associated control systems) are non-compliant with modern safety or reliability standards. In some cases, these non-compliances can be risk-assessed and deemed acceptable. In other cases, replacement of equipment and systems is required to meet current legislative and other requirements.

4.6. The impact of the increasing defects on valves are:

- Safe isolations are becoming increasingly complex, time consuming and expensive and can impact the resilience of the NTS potentially impacting on customer supplies of gas
- Isolations requiring increasing lengths of the NTS to be vented result in an increased environmental impact
- The continual passing of gas from vent and sealant lines and stem extensions presents a safety hazard as well as the obvious environmental impact
- Increased outage time when failures do occur due to obsolete assets and unavailability of spares potentially impacting on customer supplies of gas.

Drivers for Investment

4.7. The key drivers for investment in the valve assets are:

- Asset Deterioration
- Legislation
- Obsolescence.

4.8. The assets deteriorate over time and with use, leading to an inability to perform their required function. This can also result in them no longer complying with direct legislative requirements. The obsolescence of some of the assets can mean a risk of increased impact when they fail, due to the challenge of implementing an effective spares strategy for obsolete assets.

Asset Deterioration

4.9. Mechanical wear, corrosion and component failure are the causes of increasing defects being identified in valves. The number of defects identified is rising.

4.10. Many of the valves have incurred internal damage to the sealing surfaces (both the nickel-plated ball and the soft seats) over the years. This damage is a result of general wear as well as by the small quantities of liquids and solids that are inevitably present in the pipework. This can cause entrained debris within the valve seats, leading to scoring on the surface of the ball and eventual leakage across the valve seats. See 'Examples of the problem' for information. Damage to the sealing surfaces means that an adequate isolation can no longer be achieved.

4.11. It is possible to remediate some limited damage to the sealing surfaces by flushing the seals and injecting specialist lubricant using the vent and sealant lines that are a part of most valve installations. This can be successful in many applications, but its success cannot be guaranteed. If sealing performance cannot be recovered to a safe level, the only option is usually a complete replacement of the valve.

4.12. Although protected by coatings and cathodic protection systems, the vent and sealant lines that are an inherent part of most large diameter ball valves are showing serious issues with corrosion at the 'wind-water line' (typically the region between the surface of the ground and a depth of about 300mm). This zone is well known as being very susceptible to corrosion. Failure of these lines can result in an uncontrolled escape of gas to atmosphere and prevent flushing and sealant injection to attempt to recover valve performance.

4.13. For a ball valve to seal correctly, it must be positioned very accurately when in the closed position. The positioning is controlled by a series of mechanical stops located on the top of the (buried) valve. These stops can become displaced or obstructed by debris and products of corrosion which get trapped at the bottom of the shaft. Performance of a valve can sometimes be restored by cleaning and repositioning the stops, although this often requires excavation down to the top-works of the valve, removal of the stem extension and associated actuator to attempt a repair.

4.14. All valves which rely on an external shaft (i.e. stem extension) for operation, require this shaft to be sealed against the passage of gas where it connects to the casing of the valve. As the speed of rotation is very low (compared to a compressor running at speed), this seal is usually achieved by means of a simple packed gland (stem seal).

These seals are now reaching the end of their working life and many require replacing to avoid failure and an uncontrolled release of gas to atmosphere.

Legislation

PSSR Legislation

4.15. There are circa 675 Schafer Rotary Valve (Gas Over Oil Actuators fitted with pressure vessels) and 142 pressure relief valves installed within other types of actuator which fall within the remit of the Pressure Systems Safety Regulations (2000). This is existing legislation, which requires the periodic inspection of the equipment in accordance with the Written Scheme of Examination. Inspections are undertaken typically at yearly intervals for pressure relief valves and six yearly for the pressure vessels associated with the gas-over-oil actuators. This can be done more frequently if required by the inspector based on previous inspection results. Failure to comply with the requirements of the PSSR can result in a prohibition notice being served in cases where the condition of the asset is regarded as representing imminent danger. PSSR is concerned with the mechanical integrity of the pressure system. As equipment ages and its condition deteriorates, it is to be expected that additional repair or replacement work may be required.

DSEAR Legislation

4.16. Electrically powered actuators (whether directly or indirectly (e.g. using electro hydraulic actuators) or which have electrically powered components in their control systems fall under the remit of the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR). All sites handling flammable or explosive materials are required to be divided into zones according to the risk of a flammable atmosphere being present. All electrical equipment used within a zoned area is required to be compliant with the applicable standards for design, installation and maintenance for that zone. This is to ensure that the installations are maintained in a satisfactory condition for continued use within a hazardous area. If on testing a failure is found, then interventions will need to take place based on defined response criteria.

4.17. Typically, DSEAR related issues can be either inherent non-compliance in the original installation, or a failure occurring because of deterioration or wear. Examples of deterioration related defects identified as part of DSEAR inspections include seized cable glands, adaptors, entry devices, seized termination lids (excessive painting).

IEC 61508 Functional Safety

4.18. Any valves together with their associated electrical or electronic control and actuation systems that form part of a protective system are subject to the requirements of IEC 61508 “Functional Safety of Electrical / Electronic / Programmable Electronic Safety related systems” and the related IEC61511 “Functional safety – Safety instrumented systems for the process industry sector”. Although compliance with these standards is not a legal requirement, they are de facto standards across a wide range of industries and any non-compliance would be regarded negatively by the [redacted] particularly if non-compliance led to a safety incident.

4.19. IEC61508 requires a Safety Integrity Level (SIL) to be determined based on the risks that the system is protecting against. It must be demonstrated that the system achieves the prescribed SIL based on component reliability and it is then necessary to undertake regular proof tests to confirm that the system is functioning correctly and to undertake remedial action as necessary.

4.20. Remotely operated valves that provide a safety related control function are subject to IEC 61508. National Grid have committed to HSE and Ofgem that these valves will operate within the following parameter:

- 99% performance level i.e. less than 1% fail to operate upon instruction from GNCC

PSR and GSMR

4.21. The legislation for safe shut down systems and emergency procedures for major accident hazard pipelines are included in the Pipeline Safety Regulations (PSR) and Gas Safety (Management) Regulations (GS(M)R).

- The PSR requires all pipeline operators to maintain the pipeline and its isolation valves, where Regulation 6 states: "The operator shall ensure that no fluid is conveyed in a pipeline unless it has been provided with such safety systems as are necessary for securing that, so far as reasonably practicable, persons are protected from risk to their health and safety."

- The Gas Safety (Management) Regulation 7.4 states: "Where any gas escapes from a network the persons conveying the gas in the part of the network from which the gas escapes shall, as soon as is reasonably practicable after being so informed of the escape, attend the place where the gas is escaping and within 12 hours of being so informed of the escape, he shall prevent the gas escaping."

HSG253 Safe Isolation

4.22. In addition to the requirements of GS(M)R and PSR, the HSE document 'HSG253' (The safe isolation of plant and equipment) sets out requirements for the safe isolation of plant and equipment to allow work to be undertaken. These requirements are a function of line size, operating pressure, materials being handled and the type and duration of the work being undertaken. The requirements of HSG253 specific to the gas transmission system have been translated into a National Grid document (T/PM/TR/17 – Management Procedure for the Isolation of Above 2 Bar Plant and Equipment), which defines the various isolation requirements across the NTS.

Obsolescence

4.23. There are several manufacturers/models of actuator that are approaching or exceeding their original design life and are now becoming obsolete. Manufacturers are no longer supporting or providing spares for the following assets:

- Pre-1983 Shafer (gas-over-oil) actuator handpumps – population of circa 600
- Rotork (A-Range Electric and Gas/Hydraulic) actuators – population of 778
- Ledeen (Gas/Hydraulic) actuators – population of 107
- Cort (Gas/Hydraulic) actuators – population of 90

4.24. We operate a strategy by which assets that are removed from service are stored and reused as far as possible. This mitigates the issue of obsolescence to some extent and extends the useful life of assets for as long as practicable.

4.25. However, spares are not limitless or fully comprehensive. Therefore, where an asset is obsolete and no spare is available, the repair time for any failure is increased. In the case of critical valves this can increase the likelihood of short-term loss of supply, operational restrictions and not being able to isolate the NTS pipeline following an incident.

Impact of No Investment

4.26. A failure to invest in valves and their associated control systems will result in the performance of the valves continuing to deteriorate due to mechanical wear, component failure, corrosion and electrical failure. This deterioration will increase with duty and as the assets age. Elements of valves, such as actuators, will be subject to increasing obsolescence, the impact of which, will be magnified as existing spares stocks are used.

4.27. Therefore, without the appropriate level of routine maintenance and investment they will not be able to operate, seal gas flow as designed and will fail to conform to the legislative requirements of PSSR, PSR, GS(M)R, DSEAR, safety standards as agreed with Ofgem and HSE (IEC 61508).

4.28. A failure to invest in valves and their associated control systems will have the following effects:

- An increase in operational and safety risks across the network leading ultimately to sections of the network having to be taken out of service with potential consequential impacts on customer gas supplies.
- Increased time and cost and disruption to customers for providing access for maintenance or modifications across the network.
- Environmental impacts from an increased amount of gas released to atmosphere.

Impact on operational, availability and safety risks

4.29. Any failure to replace obsolete and unsupportable assets will decrease the ability to provide safe and effective isolations. In an emergency (e.g. a remotely operable valve fails to a close command), it will take substantially longer to isolate the affected section of feeder potentially increasing the severity and prolonging the duration of any incident. For planned isolations, issues with obsolete systems may result in additional costs and operational restrictions and the need to vent larger quantities of natural gas to atmosphere than would otherwise be necessary.

4.30. Any increase in time to repair because of obsolescence will result in assets (e.g. compressors) being unavailable for longer. This requires additional assets to be retained ready to be put into service as cover for extended maintenance outages to ensure the resilience of the NTS and prevent customer impacts.

4.31. If spares and know-how are unavailable or difficult and time-consuming to obtain, there is an increasing risk of degraded operation resulting from the re-use of recovered parts. Whilst these will have been deemed fit for purpose there is still an increased risk over and above using new parts. If this impacts operation of a safety related system, this could have a direct impact on safety of staff or the public and security of supply.

Increased time, cost and disruption providing access for maintenance

4.32. Failure to invest in replacement of obsolete assets is likely to result in an increase in the time, cost and level of disruption across the network when providing access for maintenance.

4.33. If valves cannot be repaired, their impaired operation may prevent effective isolations being obtained requiring use of additional valves decreasing availability of the network.

Increasing release of gas to atmosphere

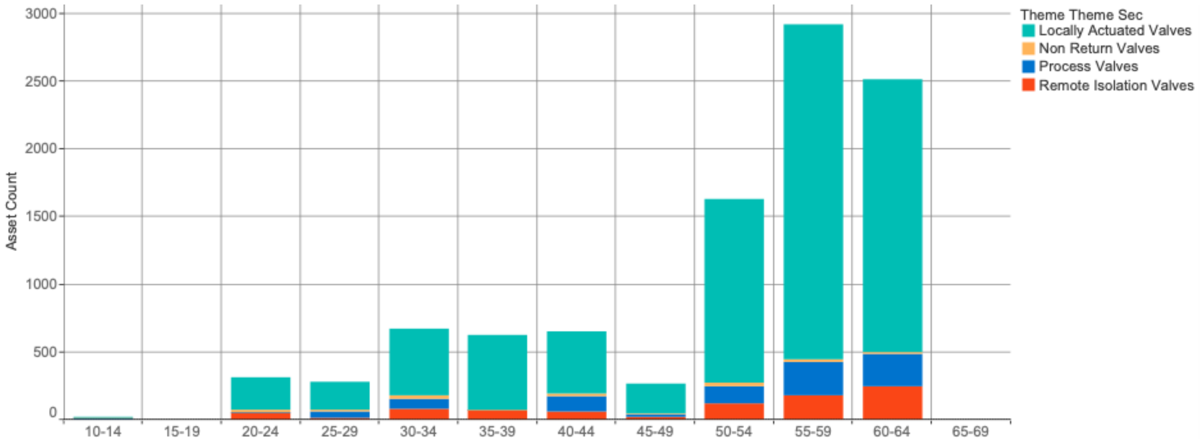
4.34. The issues leading to continual minor leakage of gas to atmosphere or more significant loss of containment leading to uncontrolled escapes of gas to atmosphere will increase. Any failure of a valve to reliably and fully isolate in the event of an emergency could result in a substantial increase in the volume of gas lost to atmosphere. All gas powered pneumatic actuators vent natural gas to atmosphere whenever changing state.

4.35. Without the proposed investment, the valve assets and their performance will continue to deteriorate.

Age Profile

4.36. Over 68% of the valves, of 4" diameter and above, on the NTS are over 40 years old with original design lives of around 30 years. This will increase to over 81% by 2031 as shown in the figure below.

Age profile of Valves by end of RIIO-3 with no investment

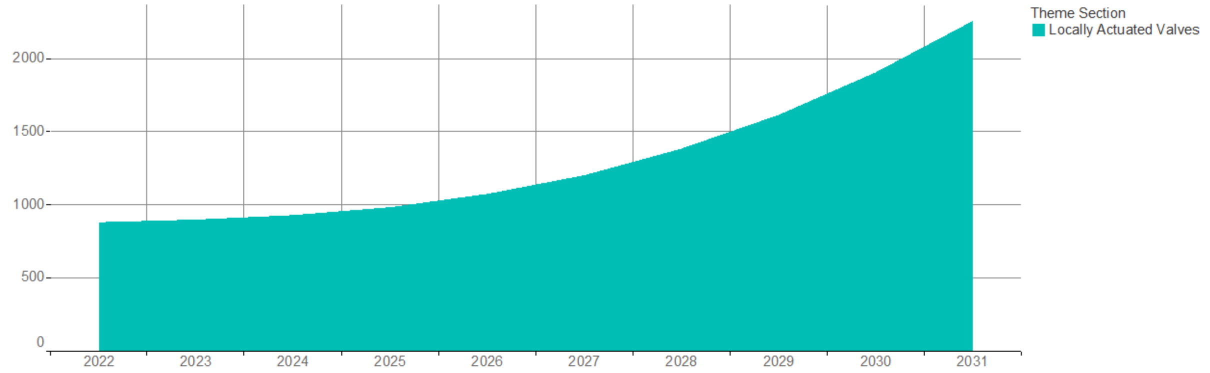


Defects

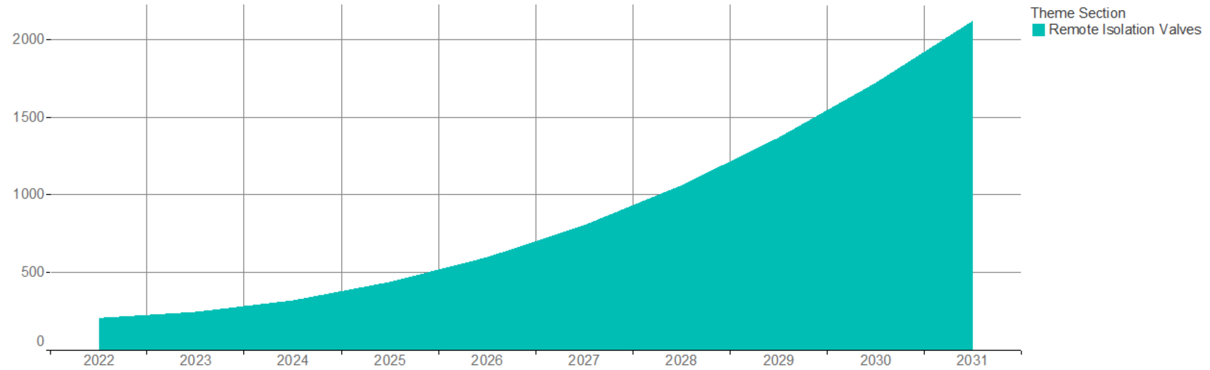
4.37. The currently identified 1,700 valve defects will remain unresolved and are forecast to rise to 2,700 by the end of 2026 and up to 6,600 by the end of 2031.

4.38. The charts below show the number of defects by valve type starting from current levels captured in Ellipse work order data and predicted for future years using the equipment failure deterioration models in our NOMs methodology developed in 2017.

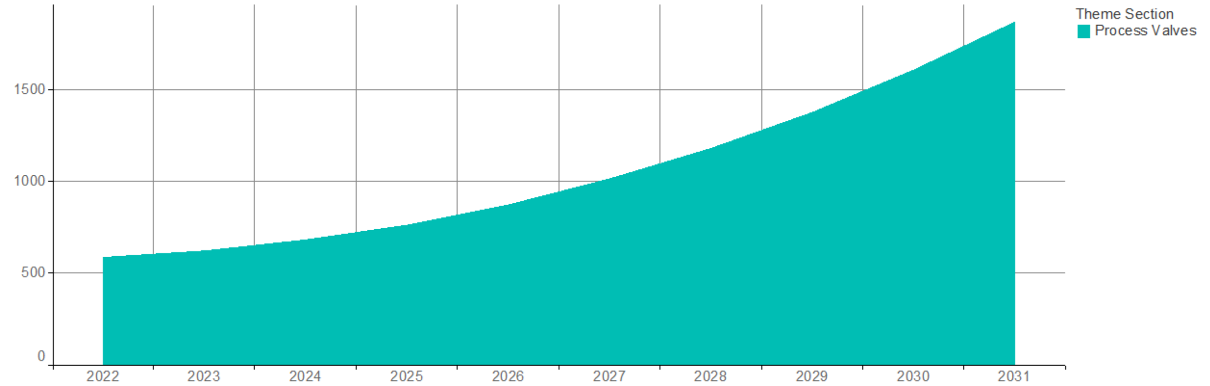
Locally Actuated Valves - Predicted defects – No investment



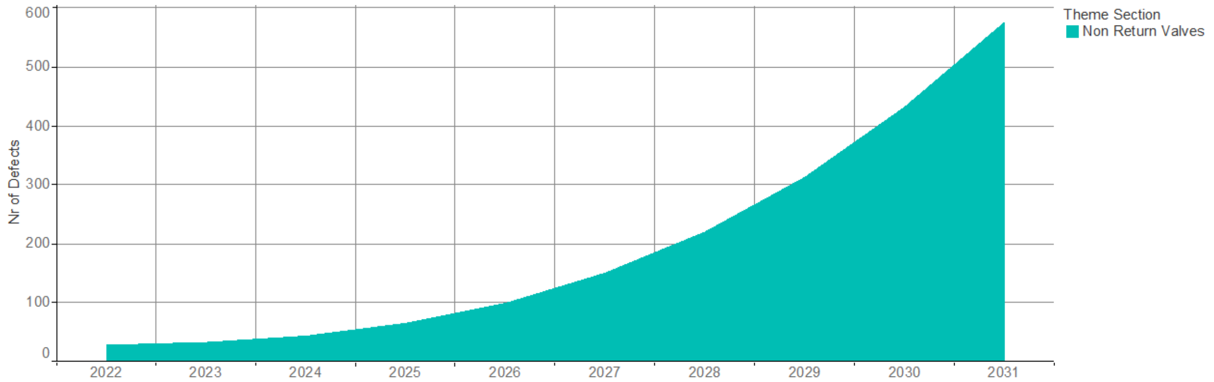
Remote Isolation Valves - Predicted defects – No investment



Process Valves - Predicted defects – No investment



Non Return Valves - Predicted defects – No investment



Obsolete Assets

4.39. Up to 1,575 obsolete assets will remain unsupported with extended outage implications. 56% are critical valves that will have significant implications for safety or supply.

DSEAR

4.40. The current DSEAR inspection identified defects will remain unresolved and increase at a predicted rate of 12 per year.

Desired Outcomes

4.41. The desired outcome of the investment during the period is to:

- Ensure that all valves comply with legal requirements and agreed safety standards;
- Have valves that will operate and perform their function when required to do so, particularly in an emergency, to contain the bulk flow of gas in a safe manner;
- Ensure that valves are fully supportable such that any unexpected defects can be remediated without significant impact on the availability of the NTS;
- Drive continued environmental improvements by reducing planned and unplanned emissions of methane to atmosphere; and
- Safely remove assets that are no longer required, to manage overall whole life cost and risk.

Examples of the Problem

4.42. The sections below provide typical examples of the common problems that are being experienced with valves across the NTS.

Diss Compressor Unit 'B' failed isolation valve replacement

4.43. Whilst undertaking routine 'Unit B' compressor function proof testing the suction valve (Cort 3-piece bolted body and welded in-line) designated MV2202 failed to provide an effective closure and isolation. As this valve delivers a primary 'Emergency Shut Down' (ESD) function the machine was declared unavailable until a repair could be achieved. Multiple repair attempts were conducted which were unsuccessful in achieving a seal and the valve was replaced.

Old valve removed

4.44. The picture below shows the old valve upon internal inspection, showing extensive debris entrained within the seat rings.

View of old valve showing debris

4.45. The figure below shows the valve following strip down and inspection. These pictures show the effects of entrained debris within the seat rings leading to electro-nickel plating degradation on the surface of the ball. This degradation therefore did not allow the seat rings to engage with the surface of the ball and provide a safe/efficient seal.

Effects of entrained debris

2.1. The figure below, in comparison shows a ball valve that is in good condition.

A ball in good condition

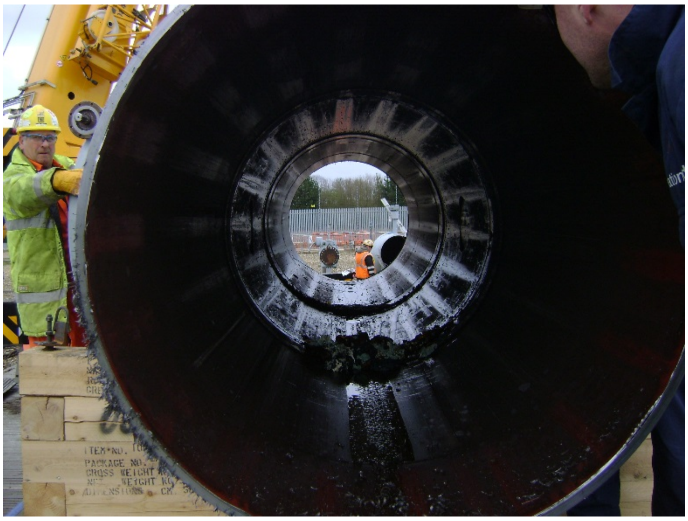
Peterborough Compressor Tee AGI Valve 18 replacement

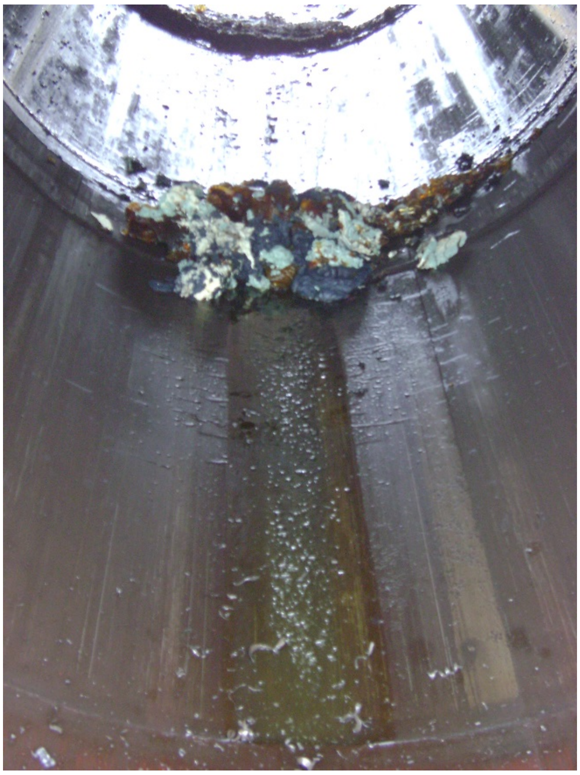
4.46. The condition of the original valve had deteriorated to such an extent that it was no longer able to provide an adequate seal to allow work to be carried out safely on the pig trap. Even with three additional body vents installed and open, there was a large amount of gas passing the valve seats. Over two years, several attempts had been made to repair the valve with no success. This included work by specialist contractors who attempted valve recovery using a series of heavier grades of sealant, again this was without success.

4.47. Given the age, condition and performance of both valve and actuator, the decision was taken to replace both at the same time.

4.48. The pictures show degradation of the valve seats, which have required several attempts of sealant injection, including flushing and introduction of heavier grades of sealant (depicted in the different colours in the second photograph).

Degradation of valve seats





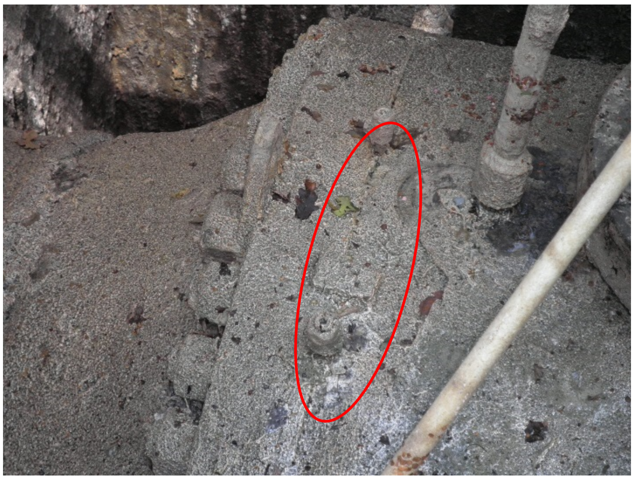
Helpston Block Valve Removal and pipe through

4.49. A 36" Locally Actuated 'Cort' Ball Valve (123501) at Helpston BV had failed in service, causing it to leak to atmosphere from the 3-piece bolted body arrangement, e.g. failure of the closure O-rings. Addressing the leak was required on the grounds of safety. Replacing the valve with a new modern equivalent was not the most cost-effective solution, as the next available strategic main line isolation valve was situated only 3km away at Peterborough Compressor Station, therefore the block valve was deemed not to be required.

4.50. Some years previously, National Grid in conjunction with specialist contractors, [redacted], attempted to repair the valve by drilling the body in three locations around its circumference. This was to inject a grout type material into the

'O' ring cavity to affect a repair. This was successful at the time but was only seen to be a temporary repair with an expected life of 5/6 years. The figures below show these valves.

Valve before removal alongside picture showing intervention applied by Furmanite



4.51. The repaired valve was regularly monitored, whereby the LEL (Lower Explosive Limit) readings and 'bubble/leak rate' had remained constant. This was continued until an increase in leak rate had been recorded which warranted further investigation/intervention.

4.52. This investment removed a leaking ball valve asset from the NTS and replaced it with a section of line-pipe, therefore removing Helpston BV from the No. 2 Feeder between Duddington MJ and Peterborough Compressor Station.

4.53. Following valve removal, further research and development was undertaken to identify failure modes, shown in the figure below.

Picture showing failure of internal O-ring in valve closure and attempts to inject sealant into valve to repair leak.

Wold Newton Block Valve – Vent and Sealant Line Corrosion and Safe Working Risks

4.54. The investment re-lifed the Wold Newton Block Valve (BV) installation and was split into 2 Phases of work:

- Phase 1 removed the immediate risks associated with the severely corroded vent & sealant lines. This included additional costs of £0.494m for activities, such as, a pipeline section shutdown, excavation of the block valve, mechanical works to replace vent and sealant lines, backfill and recompression.

- Phase 2 removed the following inherent risks of confined space working and their associated hazards. It also raised the routine maintenance of the valves to an above ground 'safety by design' layout.

Extent of sealant line corrosion

4.55. This work also removed the risk of Ermeto fittings installed on the vent and sealant lines which are no longer approved fittings for use within National Grid. These are known to have caused injury and require replacing as per the safety bulletin SB/324.

4.56. Successful delivery of the investment returned the valves to good or serviceable condition which will enable the safe isolation of the No.6 Feeder in the event of a pipeline emergency.

Views of site before and after works

Site before works

Site after works

Spend Boundaries

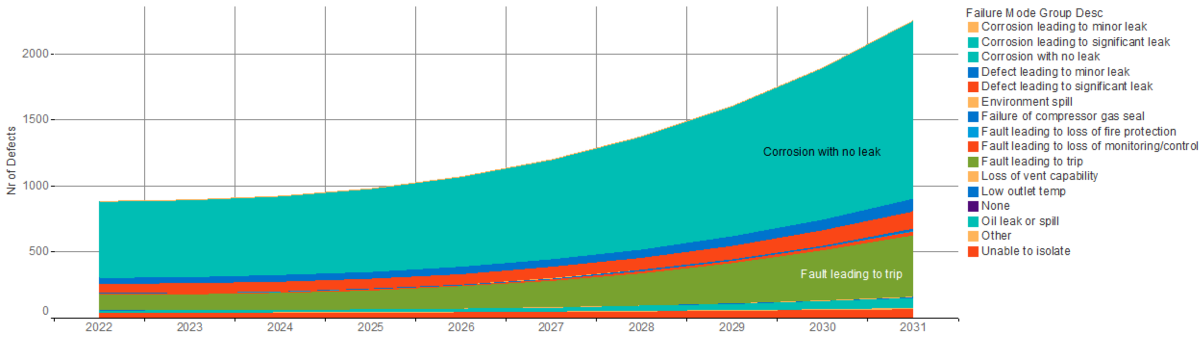
4.57. The proposed investment includes all valve assets installed on the NTS, including any ‘no-regrets’ site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

4.58. All small valves are excluded as component parts of other Plant and Equipment, these are included in the justification report for Plant and Equipment.

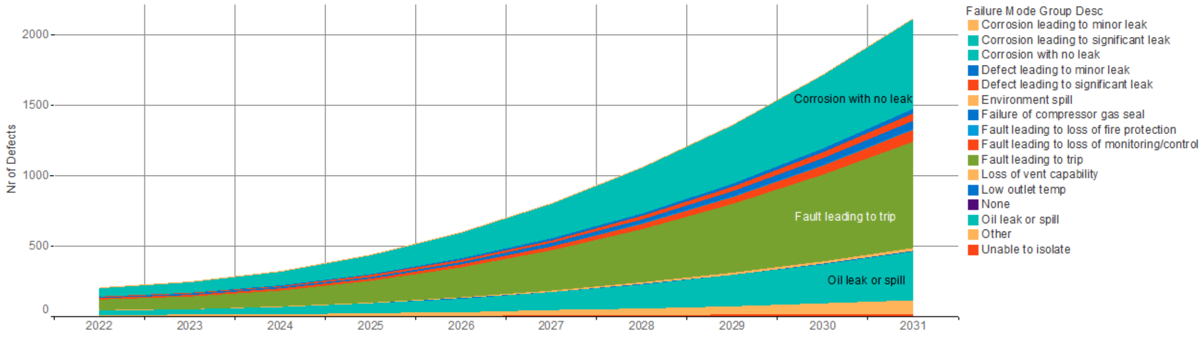
5. Probability of Failure

5.1. The probability of failure is modelled using our NOMs methodology. The charts shown below show the predicted frequency of defects split by failure mode.

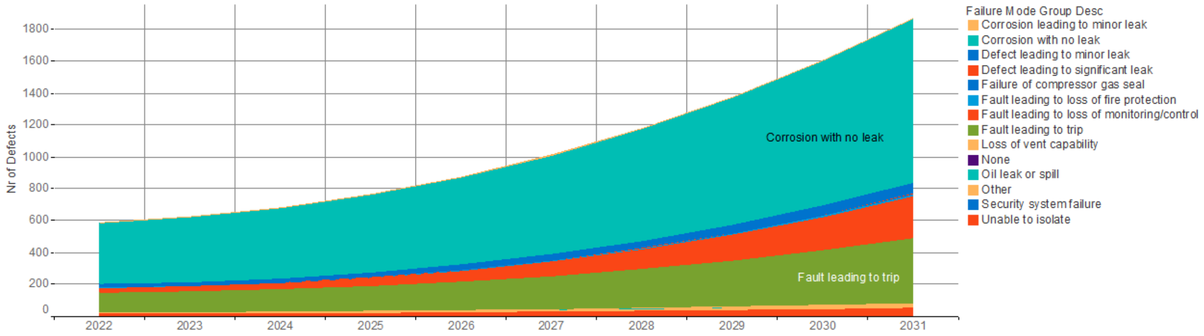
Locally Actuated Valves - Predicted defects by Failure mode – No investment



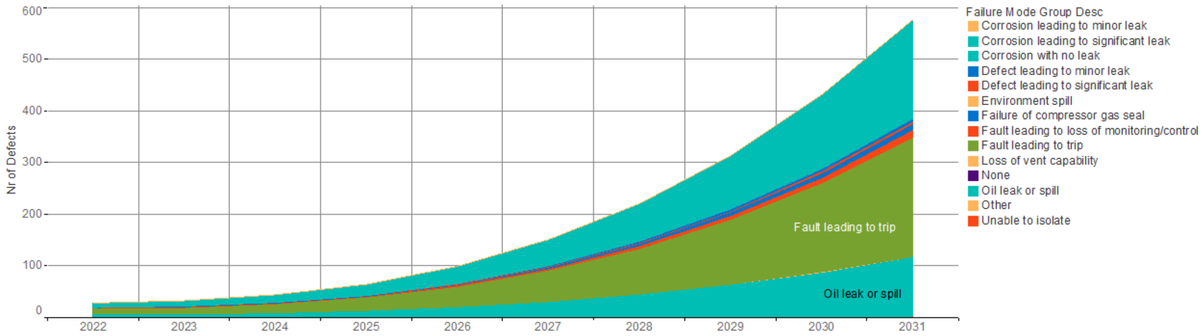
Remote Isolation Valves - Predicted defects by Failure mode – No investment



Process Valves - Predicted defects by Failure mode – No investment



Non-Return Valves - Predicted defects by Failure mode – No investment



5.2. For valves, the charts indicate that the failure modes that contribute most to the probability of failure are:

- Corrosion no leak;
- Mechanical or electrical fault leading to trip;
- Significant gas leak;
- Oil leak or spill from actuator;
- Inability to isolate – locally; &
- Inability to isolate – remotely.

Probability of Failure

5.3. The table below shows the type of valve investments that are driven by the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

Types of Valve investment driven by PoF

NARMs Asset Intervention Categories	Secondary Asset Class
Asset Disposals (not part of replace or refurb) Includes Asset Removals	Locally actuated valves
	Remote Isolation Valves
Extension of Expected Asset Life Includes Minor Refurbishments	Locally actuated valves
	Remote Isolation Valves
	Process valves
Asset Replacement (PoF Driven) Includes Asset Replacements	Locally actuated valves
	Remote Isolation Valves
	Process valves
	Non-Return Valve
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Locally actuated valves
	Remote Isolation Valves
	Process valves
	Non-Return Valve

5.4. These intervention categories are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this Justification Report.

Consequence of Failure (CoF)

5.5. All Valve interventions are justified through a PoF driver (or through Removal), as defined above.

Valve Interventions

Valve interventions

Intervention	SAC	Intervention Category
A22.14.1.1 / Locally Actuated Valve - Block Valve Replacement	Locally actuated valves	Replacement
A22.14.1.10 / NRV Major Overhaul - 36" NRV	Non Return Valve	Major Refurbishment
A22.14.1.11 / NRV Replacement - 8" NRV	Non Return Valve	Replacement
A22.14.1.13 / Process Valve Actuator Replacement	Process valves	Major Refurbishment
A22.14.1.14 / Process Valve Replacement	Process valves	Replacement
A22.14.1.15 / Process Valve Stem Seal Replacement	Process valves	Replacement
A22.14.1.16 / Process Valve Vent & Sealant Line Major Refurb	Process valves	Major Refurbishment
A22.14.1.17 / Process Valve Vent & Sealant Line Replacement	Process valves	Major Refurbishment
A22.14.1.18 / Remote Isolation Valve - DSEAR Actuator Replacement	Remote Isolation Valves	Major Refurbishment
A22.14.1.2 / Locally Actuated Valve - DSEAR Actuator Replacement	Locally actuated valves	Major Refurbishment
A22.14.1.20 / Remote Isolation Valve Actuator Replacement	Remote Isolation Valves	Major Refurbishment
A22.14.1.21 / Remote Isolation Valve Removal	Remote Isolation Valves	Removal
A22.14.1.22 / Remote Isolation Valve Replacement	Remote Isolation Valves	Replacement
A22.14.1.23 / Remote Isolation Valve Stem Seal Replacement	Remote Isolation Valves	Replacement
A22.14.1.25 / Remote Isolation Valve Vent & Sealant Line Replacement	Remote Isolation Valves	Major Refurbishment
A22.14.1.4 / Locally Actuated Valve Actuator Replacement	Locally actuated valves	Major Refurbishment
A22.14.1.5 / Locally Actuated Valve Replacement	Locally actuated valves	Replacement
A22.14.1.6 / Locally Actuated Valve Stem Seal Replacement	Locally actuated valves	Replacement
A22.14.1.7 / Locally Actuated Valve Vent & Sealant Line Minor Refurbishment	Locally actuated valves	Minor Refurbishment
A22.14.1.8 / Locally Actuated Valve Vent & Sealant Line Replacement	Locally actuated valves	Replacement
A22.14.1.9 / Locally Actuated Valves - Block Valve Removal	Locally actuated valves	Removal
A22.22.6.1 / Locally Actuated Valve Replacement (St. Fergus)	Locally actuated valves	Replacement

Intervention	SAC	Intervention Category
A22.22.6.10 / Remote Isolation Valve Stem Seal Replacement (St. Fergus)	Remote Isolation Valves	Replacement
A22.22.6.11 / Remote Isolation Valve Vent & Sealant Line Replacement (St. Fergus)	Remote Isolation Valves	Major Refurbishment
A22.22.6.12 / Remote Isolation Valve Actuator Replacement (St. Fergus)	Remote Isolation Valves	Major Refurbishment
A22.22.6.14 / NRV Replacement - 8" NRV (St. Fergus)	Non Return Valve	Replacement
A22.22.6.2 / Locally Actuated Valve Vent & Sealant Line Replacement (St. Fergus)	Locally actuated valves	Major Refurbishment
A22.22.6.3 / Locally Actuated Valve Actuator Replacementment (St. Fergus)	Locally actuated valves	Major Refurbishment
A22.22.6.4 / NRV Major Overhaul - 36" NRV (St. Fergus)	Non Return Valve	Major Refurbishment
A22.22.6.5 / Process Valve Replacement (St. Fergus)	Process valves	Replacement
A22.22.6.6 / Process Valve Stem Seal Replacement (St. Fergus)	Process valves	Replacement
A22.22.6.7 / Process Valve Vent & Sealant Line Replacement (St. Fergus)	Process valves	Major Refurbishment
A22.22.6.8 / Process Valve Actuator Replacement (St. Fergus)	Process valves	Major Refurbishment
A22.22.6.9 / Remote Isolation Valve Replacement (St. Fergus)	Remote Isolation Valves	Replacement

Data Assurance

5.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

5.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

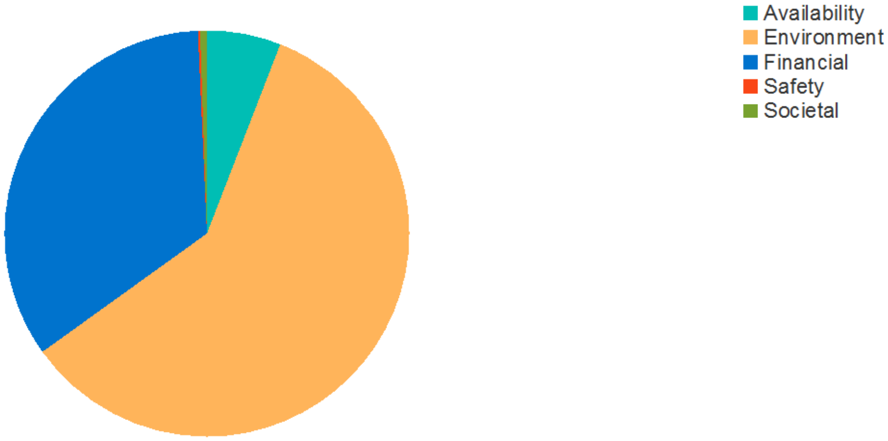
5.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change will be progressed to restate our RIIO-1 targets in terms of monetised risk.

6. Consequence of Failure

6.1. The chart below shows the expected stakeholder impacts because of failure occurring on each type of valve asset. The charts show the relative numbers of consequence events, not relative monetised risk.

Locally Actuated Valves

Stakeholder Impacts – failure of locally actuated valves

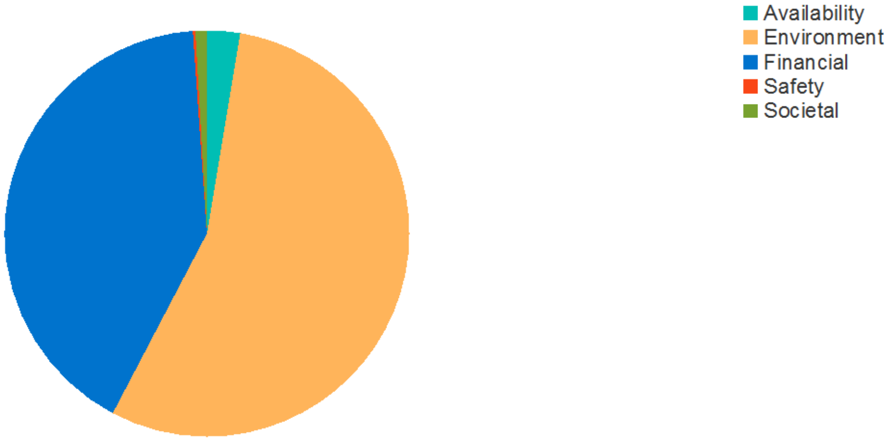


6.2. The contribution of individual service risk measures towards the overall risk for Locally Actuated Valves can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas through the inability to seal, small leaks and vents
- **Financial risk** is mostly associated with the reactive costs of operating and maintaining the network at the current level of risk
- **Availability risk** is associated with the potential outages associated with the inability to isolate the network in the event of asset failure. It is relatively small due to the degree of resilience in the NTS. However, there are real examples where the inability to isolate the network due to non-operational valves has demonstrated the potential for customer outages.
- **Societal risk** is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, overall the overall societal risk associated with valve asset failure is small.
- **Safety risk** is associated with the potential for fires or explosions arising from a valve leak. The likelihood of a gas ignition causing a fire (or explosion in a confined space) is low and the likelihood or an employee or member of the public being close enough to the fire/explosion to be killed or injured is also very low. Therefore, the modelled Safety risk associated with valve asset failure is small.

Non-Return Valves

Stakeholder impacts – failure of non-return valves



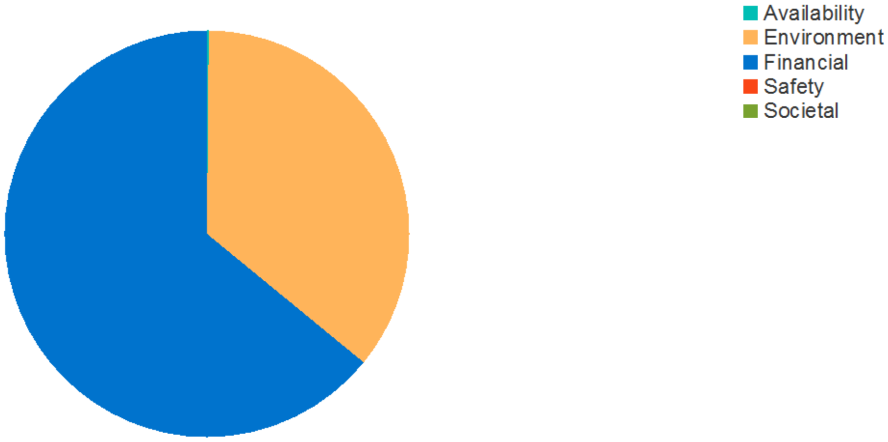
6.3. The contribution of individual service risk measures towards the overall risk for Non-Return Valves can be explained as follows, in order of significance:

- **Environmental risk** is associated with the loss of gas through the inability to seal, small leaks and vents
- **Financial risk** is mostly associated with the reactive costs of operating and maintaining the network at the current level of risk
- **Availability risk** is associated with the potential outages associated with the inability to isolate the network in the event of asset failure.

6.4. The risk associated with other service risk measures for Non-Return Valves is negligible, based on the assigned failure modes.

Process Valves

Stakeholder impacts – failure of Process valves



6.5. The contribution of individual service risk measures towards the overall risk for Process Valves can be explained as follows, in order of significance:

- **Financial risk** is mostly associated with the reactive costs of operating and maintaining the network at the current level of risk

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas through the inability to seal, small leaks and vents

6.6. The risk associated with other service risk measures for Process Valves is negligible, based on the assigned failure modes.

Remote Isolation Valves

Stakeholder impacts – failure of remote Isolation valves

6.7. The contribution of individual service risk measures towards the overall risk for Remotely Actuated Valves can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas through the inability to seal, small leaks and vents
- **Financial risk** is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk
- **Availability risk** is associated with the potential outages associated with the inability to isolate the network in the event of asset failure. However, there are real examples where the inability to isolate the network due to non-operational valves has demonstrated the potential for customer outages
- **Societal risk** is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, overall the overall societal risk associated with valve asset failure is small.
- **Safety risk** is associated with the potential for fires or explosions arising from a valve leak. The likelihood of a gas ignition causing a fire (or explosion in a confined space) is low and the likelihood or an employee or member of the public being close enough to the fire/explosion to be killed or injured is also very low. Therefore, the modelled Safety risk associated with valve asset failure is small.

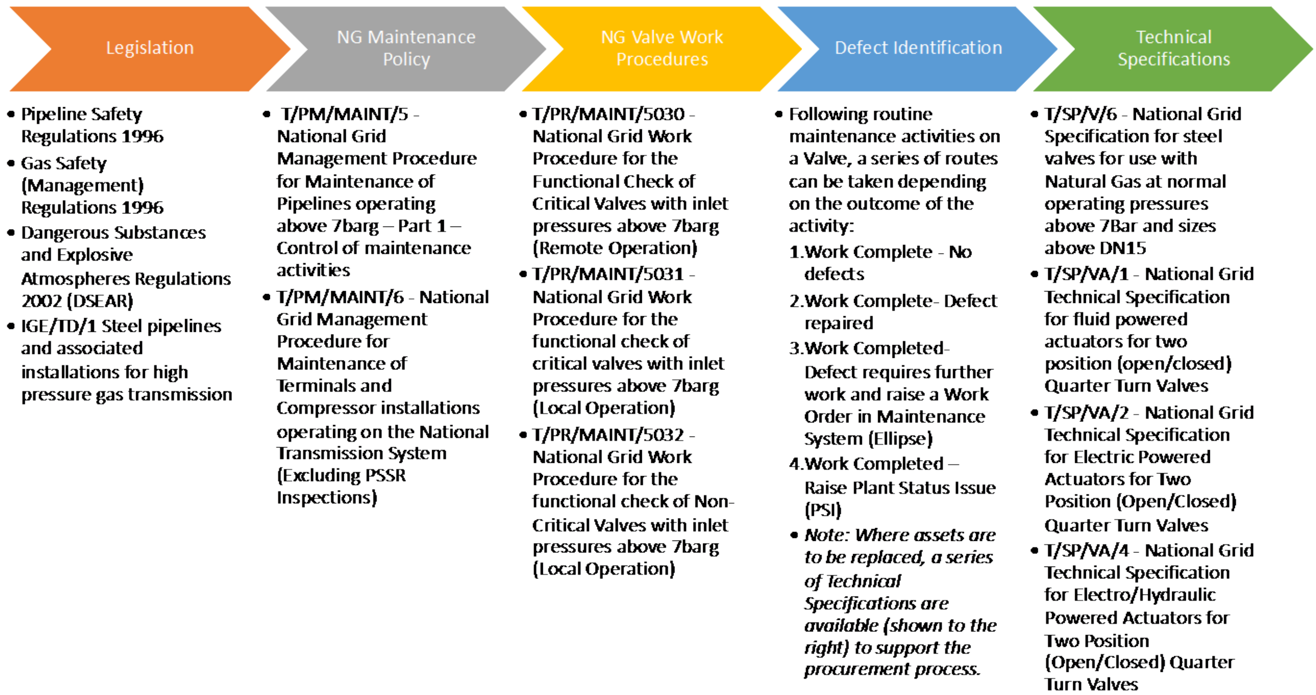
7. Options Considered

Potential Intervention Category Options

7.1. Intervention on the valve assets is only undertaken when defects have been identified during routine maintenance.

7.2. We undertake inspections and maintenance of valves in accordance with our policies and standards that reflect and address the requirements set out in legislation (e.g. PSR, GS(M)R, DSEAR, IEC 61508) and in gas industry accepted standards (e.g. IGEM technical standards IGE/TD/1). This is illustrated in the diagram below:

Policies and Standards for inspection and maintenance



7.3. Inspections are undertaken on a regular basis (in accordance with those Policies listed above) based on and to consider the type of valve and its criticality. These inspections identify defects, faults or non-compliances which require remediation. In some cases, the issue can be remediated on the day e.g. minor repair. If this is not possible, then the asset is registered for further investigation, enhanced maintenance and/or intervention. The type of intervention is determined based upon the type of issue found and the results of any investigation or enhanced maintenance.

7.4. The following intervention categories apply to the Valve assets:

Actuator Repair or Replacement (incl. Gearbox Replacement)

7.5. If during routine maintenance, it is determined that the actuator does not operate correctly and may show signs of the following typical failure modes:

7.6. Gas/Hydraulic or Gas-Over-Oil types

- gas passing internal seals of the actuator piston
- oil passing the internal seals of the actuator piston/vane
- manual handpump failure

- gas or oil control cabinet component failure, i.e. regulator, solenoids or relief valve etc.
- small-bore pipework failure
- corrosion, i.e. internal cylinder, external cylinder tie-bars or control cabinet
- oil seal failure
- water ingress.

7.7. Electric types

- oil seal failure
- water ingress
- relays, electric motor or switch failure
- drive shaft pin failure
- drive bush failure.

7.8. Minor intervention is then attempted to affect a remediation, this is sometimes with the support of the manufacturer where the actuator type is not obsolete. If the minor interventions do not improve the actuator performance to within an acceptable standard, then either of the following interventions are undertaken.

- **Actuator Repair:** This intervention repairs components of the actuator or gearbox and does not re-life the actuator, only extends the useable life of the actuator. Where the actuator is obsolete, this may be remediated using refurbished components.
- **Actuator Replacement:** This replaces the existing actuator with a new modern equivalent actuator or gearbox on the NTS and resets the asset life for this asset.

7.9. As most actuators are located above ground, these interventions apply predominantly to above ground assets, with small exceptions where actuators are mounted within pits.

7.10. Other technologies have been employed to support this intervention, see Portable Valve Actuation in Innovation section and Electro Hydraulic Valve Actuator (ref: Specification T/SP/VA/4).

DSEAR Actuator Replacement

7.11. This intervention follows the same rationale as the “Actuator Repair or Replacement”.

7.12. During routine maintenance, it is determined that the actuator does not operate correctly and may show signs of the following typical DSEAR related failure modes:

- Seized Cable Glands, Adaptors, Entry Devices
- Seized Termination lids (excessive painting/seized)
- Scratched Flamepaths
- Unauthorised Modification to equipment (invalidating certification)
- Uncertified Equipment

- Unidentifiable equipment (unable to confirm certification)
- Damaged units

7.13. This replaces the existing actuator with a new modern equivalent actuator on the NTS and resets the asset life for this asset.

7.14. The actuators are predominantly located above ground, with small exceptions where actuators are mounted within pits.

Valve Vent & Sealant Line (V&SL) Repair or Replacement

7.15. During maintenance, it is determined that the vent and sealant line has any of the following failure modes:

- Valve suffers from stiction or is stiff to operate, which could be caused by blocked V&SL. In the case of a blocked V&SL enhanced maintenance is undertaken to solve the issue i.e. flush valve sealant lines / valve seats and re-inject lubricant together with operation of the valve. (Note: This could also require an Actuator intervention, see below)
- Single failure of V&SL fittings, i.e. small bore valves, button-heads etc.
- Corrosion defects categorised in accordance with T/PM/P/20 (Management Procedure for Inspection Assessment and Repair of damaged (non-leaking) steel pipelines and pipework up to 150mm nominal diameter designed to operate at pressure of greater than 2bar). This Management Procedure includes Vent and sealant pipe on ball valves associated with the control of gas at pressures above 2 bar.
- Check if Ermeto fittings are present on the V&SL. Ermeto fittings are no longer approved fittings for use within National Grid and require replacing as per the safety bulletin SB/324

7.16. Depending upon the severity of the failure and the success of any enhanced maintenance the V&SL are either repaired or replaced:

V&SL Repair

7.17. This intervention repairs the existing defective vent & sealant lines on the valve. It ensures that future lubrication of valve seats and cavity venting can be conducted safely to ensure no future leak path of gas via the valve seats on operation. This intervention also repairs any corrosion defects. As this only replaces a single element of the valve it does not extend the life of the valve asset.

7.18. This intervention predominantly can be conducted above ground. However, use of the new innovative 'shallow dig' technology currently employed at St. Fergus has been used.

V&SL Replacement

7.19. This intervention fully replaces the existing defective vent & sealant lines and fittings (see SB/324) on the valve. This allows future lubrication of valve seats and cavity venting can be conducted safely to ensure no future leak path of gas via the valve seats on operation.

7.20. This intervention could apply to either above ground or below ground valves. Where below ground, this requires full excavation of the valve body. This does not re-life the valve, only extends the asset life of the valve.

Valve Stem Seal Replacement

7.21. During maintenance, it is determined that the valve does not provide a satisfactory stem seal, i.e. gas passing the stem seal of valve and leaking to atmosphere.

7.22. The existing defective valve stem seal is replaced with a new valve stem seal to ensure no future leak path of gas via the valve stem. As this only replaces a single element of the valve it does not extend the life of the valve.

7.23. This intervention applies to either above ground or below ground valves. Where the valve is below ground, this requires full excavation down to the valve 'bonnet' (top works) of the valve.

Valve Replacement or Removal

7.24. Valve replacement or removal is only considered after defects have been identified and extensive enhanced maintenance has been undertaken.

7.25. Routine valve maintenance is undertaken in accordance with the maintenance procedures and work instructions. During maintenance, it is determined that the valve does not provide a satisfactory seal, or has any of the following failure modes:

- gas passing seats of valve, but stays within network
- gas passing stem seal of valve and leaks to atmosphere
- gas leaking through body of valve and leaks to atmosphere
- vent and sealant lines have failed
- vent and sealant lines are blocked
- vent and sealant lines not present

7.26. In this case a repair is attempted by injecting lubricant into the valve and operating, the sealing capability is then retested. If there no increase in sealing capability, then further investigation and use of 'enhanced valve maintenance' techniques are undertaken. This includes flushing of the valve sealant lines / valve seats and re-injection of lubricant together with operation of the valve. If there is still no sealing capability, then the valve is considered for replacement or removal.

7.27. A full assessment for the requirement of the valve is undertaken with relevant stakeholders across NG and specific customers if required. If the valve is no longer required for isolation, then a risk assessment is carried out to support that the valve does not provide any operational purpose. If this is the case, then the valve is removed otherwise it is replaced.

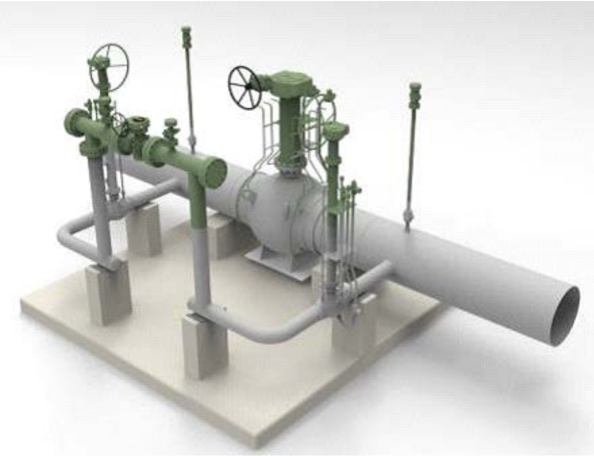
- **Removal** – the valve is removed and replaced with a section of pipe.
- **Replacement** – the valve is removed and replaced with a new valve.

7.28. These interventions apply to either above ground or below ground valves. Where below ground, this requires full excavation of the valve and pipe to enable the removal or replacement of the valve.

Block Valve Replacement

7.29. Block Valve Replacement is based on a similar rationale as the "Valve Replacement or Removal" option. However, this option not only considers the volume of valve / actuator defects, but defects on other asset classes, such as Civils, Security, Electrical etc. Whereby, a 'Campaign' approach can be employed to remove these risks and install a new Block Valve site that is fit for purpose i.e. safety by design (as in the case of the Wold Newton example, in the section on Examples of the Problem). This approach has been used within the ongoing National AGI Renovation Campaign (NARC) and allowed the business to embed some of the Innovation/Best Practices, such as the modular block valve design.

Modular Block Valve design



Block Valve Removal

7.30. Block Valve Removal is based on a similar rationale as the "Valve Replacement or Removal" option. This option, like the Block Valve replacement option, will also consider volumes of defects. However, instead of replacing the Block Valve, if the site is no longer required for isolation, then a full pipeline specific risk assessment is carried out with stakeholders to support that the valve does not provide any operational purpose. If this is the case, then the block valve site is removed and piped through.

8" Non-Return Valve (NRV) replacement

7.31. Non-Return Valve replacement is only considered after defects have been identified and extensive enhanced maintenance has been undertaken.

7.32. Non-Return Valve routine maintenance is undertaken in accordance with the maintenance procedures and work instructions. During maintenance, NRV replacement is considered if it is determined that the valve does not provide a satisfactory seal, or has any of the following failure modes:

- Indication failure
- Seal failure
- Seat failure
- Internal component wear, i.e. metal fatigue, spring degradation, bearings, stop pins etc.

- Damper failure

7.33. This replaces the existing NRV with a new modern equivalent on the NTS and resets the asset life for this asset. This intervention applies predominantly to above ground assets.

7.34. Due to the relatively low volume and unit cost to replace this asset, it is considered practical to replace this asset, rather than attempt to carry out a major overhaul or re-life.

36" Non-Return Valve (NRV) re-life (incl. OEM major overhaul)

7.35. 36” NRV re-life is based on a similar rationale as the 8” NRV replacement option above. This option undertakes a major overhaul of the existing NRV and resets the asset life for this asset. The NRVs are predominantly below ground assets that are situated within pits.

7.36. Due to the relatively high volume and unit cost to re-life this asset and based on the ongoing availability of support from the OEM’s, it is considered practical to continue to re-life, rather than attempt to replace these assets.

ROV Strategy

7.37. Cyber security risks are increasing. The current design of the gas transmission network has not been developed with cyber security in mind.

7.38. An investment programme shall be initiated to remove or inhibit remote connections to the identified ROV’s prioritised by criticality. The work will include installation of a locally operated manual gearbox, modifications to the system wiring, SCADA configuration, graphics, drawings and documentation.

7.39. This cost-effective approach will reduce the risk of third-party interference, limit the ability of a cyber-attacker to disrupt UK gas supplies and ensure a continued safe and secure network.

7.40. There may be opportunities to realise some unit cost efficiencies when combining the programmes of work, however, this is currently unknown and subject to a detailed work plan being derived. Intervention volumes would however, remain unchanged. Please refer to the Cyber Resilience Plan (A23.07) for further details.

Intervention Unit Costs

7.41. The total RIIO-2 investment for Valves is £63.1m, which represents the entire investment theme. The unit costs that support the valves investment have been developed using a significant number of historical outturn cost data points, and where this has not been possible other estimation methods have been applied.

7.42. 91% of costs for Valves are supported by historical outturn information from over 30 sanction papers. This includes evidence from replacement of remote isolation, process and locally actuated valves as part of our National AGI Renovation Campaign (NARC) which has focused on delivering asset health works efficiencies during RIIO-1.

7.43. The remaining 9% of costs for Valves have been developed using other estimation methods. The minor refurbishment of vent & sealant lines is based on a new flow stopping technique using a ‘mini grouted tee’. This methodology, in some instances, negates the need for a full replacement and a costlier intervention on the vent & sealant line. The technique however has only recently been approved and is not currently available for all small-bore diameters and therefore the unit costs have been estimated from field trial information provided by PMC.

Outturn costs for actuator replacements have not been possible to extract from projects analysed so far and therefore unit costs have been taken from the NARC unit cost book and assumed to be VA/2 electric actuator replacements.

7.44. The table below provides the unit costs for all potential Valves interventions.

Intervention Unit Costs

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Valves					
Locally Actuated Valve					
A22.14.1.1 / Locally Actuated Valve - Block Valve Replacement	[redacted]	Per asset	Outturn	1	[redacted]
A22.14.1.2 / Locally Actuated Valve - DSEAR Actuator Replacement	[redacted]	Per asset	Estimated - Other	0	[redacted]
A22.14.1.4 / Locally Actuated Valve Actuator Replacement	[redacted]	Per asset	Outturn	5	[redacted]
A22.14.1.5 / Locally Actuated Valve Replacement	[redacted]	Per asset	Outturn	8	[redacted]
A22.14.1.6 / Locally Actuated Valve Stem Seal Replacement	[redacted]	Per asset	Outturn	4	[redacted]
A22.14.1.7 / Locally Actuated Valve Vent & Sealant Line Minor Refurbishment	[redacted]	Per asset	Estimated - Other	0	[redacted]
A22.14.1.8 / Locally Actuated Valve Vent & Sealant Line Replacement	[redacted]	Per asset	Outturn	4	[redacted]
A22.14.1.9 / Locally Actuated Valves - Block Valve Removal	[redacted]	Per asset	Outturn	4	[redacted]
A22.22.6.1 / Locally Actuated Valve Replacement (St. Fergus)	[redacted]	Per asset	Outturn	8	[redacted]
A22.22.6.2 / Locally Actuated Valve Vent & Sealant Line Replacement (St. Fergus)	[redacted]	Per asset	Outturn	4	[redacted]
A22.22.6.3 / Locally Actuated Valve Actuator Replacement (St. Fergus)	[redacted]	Per asset	Outturn	1	[redacted]
Non-Return Valve					[redacted]
A22.14.1.10 / NRV Major Overhaul - 36" NRV	[redacted]	Per Asset	Outturn	1	[redacted]
A22.14.1.11 / NRV Replacement - 8" NRV	[redacted]	Per Asset	Outturn	1	[redacted]
A22.22.6.14 / NRV Replacement - 8" NRV (St. Fergus)	[redacted]	Per Asset	Outturn	1	[redacted]
A22.22.6.4 / NRV Major Overhaul - 36" NRV (St. Fergus)	[redacted]	Per Asset	Outturn	1	[redacted]
Process Valves					[redacted]
A22.14.1.15 / Process Valve Stem Seal Replacement	[redacted]	Per Asset	Outturn	4	[redacted]
A22.14.1.16 / Process Valve Vent & Sealant Line Major Refurb	[redacted]	Per Asset	Estimated - Other	0	[redacted]
A22.14.1.17 / Process Valve Vent & Sealant Line Replacement	[redacted]	Per Asset	Outturn	4	[redacted]
A22.14.1.13 / Process Valve Actuator Replacement	[redacted]	Per Asset	Outturn	5	[redacted]

A22.14.1.14 / Process Valve Replacement	[redacted]	Per Asset	Outturn	8	[redacted]
A22.22.6.5 / Process Valve Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	8	[redacted]
A22.22.6.6 / Process Valve Stem Seal Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	1	[redacted]
A22.22.6.7 / Process Valve Vent & Sealant Line Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	4	[redacted]
A22.22.6.8 / Process Valve Actuator Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	1	[redacted]
Remote Isolation Valves					[redacted]
A22.14.1.18 / Remote Isolation Valve - DSEAR Actuator Replacement	[redacted]	Per Asset	Estimated - Other	0	[redacted]
A22.14.1.20 / Remote Isolation Valve Actuator Replacement	[redacted]	Per Asset	Outturn	5	[redacted]
A22.14.1.21 / Remote Isolation Valve Removal	[redacted]	Per Asset	Outturn	1	[redacted]
A22.14.1.22 / Remote Isolation Valve Replacement	[redacted]	Per Asset	Outturn	8	[redacted]
A22.14.1.23 / Remote Isolation Valve Stem Seal Replacement	[redacted]	Per Asset	Outturn	4	[redacted]
A22.14.1.25 / Remote Isolation Valve Vent & Sealant Line Replacement	[redacted]	Per Asset	Outturn	4	[redacted]
A22.22.6.10 / Remote Isolation Valve Stem Seal Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	4	[redacted]
A22.22.6.11 / Remote Isolation Valve Vent & Sealant Line Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	4	[redacted]
A22.22.6.12 / Remote Isolation Valve Actuator Replacement (St. Fergus)	[redacted]	Per Asset	Outturn	1	[redacted]
A22.22.6.9 / Remote Isolation Valve Replacement	[redacted]	Per Asset	Outturn	8	[redacted]

Unit Cost Sensitivity

7.45. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. The graph below shows the results of this compared to the preferred option.

Net Benefits of Upper and Lower Unit Cost Sensitivity

7.46. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs.

Innovation

7.47. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

7.48. In the Valves investment theme, we have developed and implemented several projects in the RIIO-1 period which will be brought forward into this investment period:

- **Valve Sealant Line Grouted Tee**, in which we developed a small grouted tee connection, which can be attached to the vent & sealant pipework. Once the stopple is removed, maintenance can take place on the valve vent and sealant line while the gas remains live. This has been used three times in the RIIO-1 period to date, yielding £817,000 in savings, as it mitigated the need to replace the valves and is more efficient. This technique allows the pipe to be worked while it is live, so avoids the need for outages, recompression and venting, with the customer benefitting from fewer outages during maintenance.
- **Portable Valve Actuation** project's aim was to assess the practicality, operational benefit and whole life cost benefit associated with replacing the powered actuation on non-critical locally actuated valves with aged gearboxes with high performance gearboxes and a portable form of actuation which could be attached by operatives as required. This solution negates the need for the electrical infrastructure and attendant maintenance of powered valves, with the new gearbox valves delivering quicker and more efficient valve operation. Maintenance efficiencies also realise a saving for each gearbox. There is also an environmental benefit from changing the valve actuators as previously actuators use high pressure gas to provide the energy needed to power the hydraulics and release some of this gas on every operation. Over the lifetime of a single actuator gas equating to 5.5 tonnes of CO2 was released. Twenty of these have been installed to date in the RIIO-1 period yielding a saving of £40,000 per valve.
- **The Optimisation of Severe Winter Strategy for Pipeline Isolation Valves** project, assessing the reliability of valves in extreme weather will be implemented in the business moving forward for future weather events. There is potential to utilise this project in conjunction with the portable valve actuation project to ensure greater reliability of valves.

7.49. We are also looking to continue to develop the following project and deliver benefit from it in this investment period:

- **Valve Care Toolbox**, which is aiming to develop a toolbox of techniques and methods for addressing the condition-based maintenance of valves. It allows for work to be done to maintain/improve the condition and extend lifetime on a case by case basis. It mitigates the replacement of the valve, its components and/or the venting of a section of pipeline. The future savings from the project are also yet to be determined.

8. Programme Options

8.1. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders. Hence, we have considered a range of options from the do nothing position through to reductions in risk across all measures. These have been used to explore the credible options for varying the investment and appraising the impact on our legal compliance, risk position and stakeholders.

8.2. In developing our plan, the following options have been considered for investment in the Valves and associated assets. Please note that all programme options include any fixed ‘no-regrets’ investments associated with the Bacton and St Fergus sites.

Baseline – Do Nothing

8.3. The impact of no investment in our Valve assets increases service risk over a 10-year period, the most significant impact being a doubling in the volume of gas released to atmosphere every year through the inability to seal, small leaks and vents. There is also a corresponding increase in the number of potential outages every year caused by Valve failures resulting in isolations on the NTS. This option includes the reactive only investment across all the Valve types and is the option against which all the other options are compared.

Programme Option 1 – Maintain Risk

8.4. This option undertakes a mix of replacement, refurbishment and reactive repairs to maintain the current levels of risk. Obsolete actuators are replaced.

Programme Option 2 – Minimal Replacement

8.5. This option reduces the investment in all valves to that required to manage short term risk including minimal replacement of actuators and valves, only replacing on significant safety grounds or DSEAR compliance with all other assets on fix on fail. The rationale for each asset type is:

- LAVs - do not replace and leave open wherever possible.
- PVs - swap Actuators on LAV and PV's
- RIVs – declassify RIV and make local
- NRVs – no credible option to reduce replacement due to impact on compressor availability or metering
- DSEAR actuator replacement – no credible option to reduce – required to maintain compliance and operation

Programme Option 3 – Vent and Sealant Line – Repair Only

8.6. This option undertakes only minimal reactive interventions to vent and sealant lines - there is no replacement.

Programme Option 4 – Stem Seal – Repair Only

8.7. This option undertakes only minimal reactive interventions to stem seals - there is no replacement.

Programme Option 5 - Minimal Investment

8.8. This option is a combination of Options 2, 3 and 4.

Programme Option 6 – Increased Proactive Investment

8.9. This option reduces risks through more proactive replacement of non DSEAR actuators and replaces vent and sealant lines and stem seals rather than refurbishing or repairing them.

Programme Options Summary

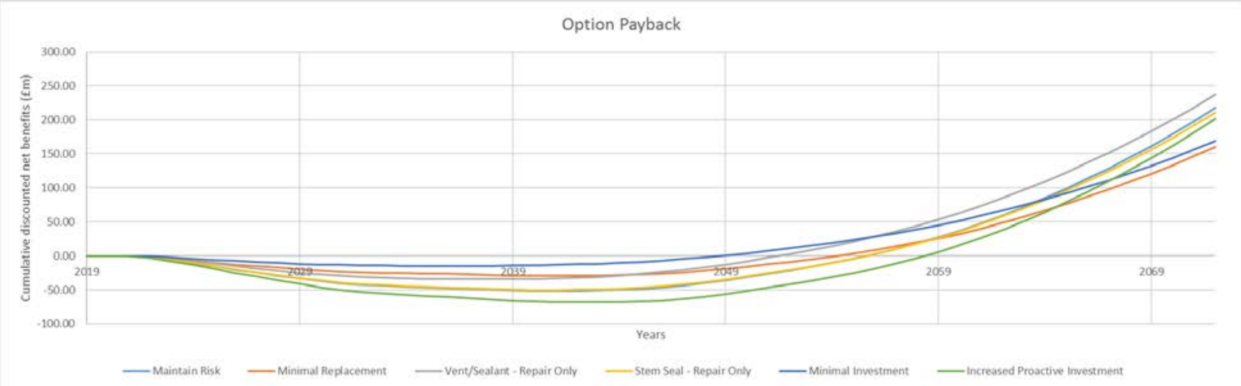
8.10. In considering the CBA for each of the programme options, a summary of all the potential programme options is provided in the table below.

Potential Programme Options

Option	RIIO-2 Invest' £ m.	RIIO-3 Invest' £ m	PV Costs £ m	PV benefits £ m	Net NPV £ m	CB Ratio	Payback Period (years)
1 - Maintain Risk	£63.15	£61.29	£147.39	£261.53	£114.15	1.77	34
2- Minimal Replacement	£38.44	£33.69	£96.66	£184.07	£87.41	1.90	33
3 - Vent/Sealant Repair	£47.91	£47.33	£106.63	£243.83	£137.20	2.29	30
4 - Stem Seal Repair	£61.74	£59.88	£143.53	£254.22	£110.69	1.77	34
5 - Minimal Investment	£23.40	£21.67	£60.00	£161.82	£101.81	2.70	27
6 - Increased Proactive	£77.62	£74.80	£183.55	£278.44	£94.89	1.52	37

8.11. The graph shows the cumulative discounted NPV of the net benefit for each of the investment options.

Option Payback – Net NPV



Programme Options Selection

8.12. All the potential options are cost beneficial over the 45-year analysis period. The selection of the preferred option has therefore been based on an assessment of the level of risk, maintaining our compliance with legislation and delivering value for consumers and stakeholders. The outcomes associated with each option are provided below:

Programme Option 1 – Maintain Risk

8.13. This option maintains all risk at current levels, utilising the current strategy of inspection, and when problems are identified on individual valves, a staged and increasing level of intervention until the performance of the valve is returned. This approach has proved very effective during RIIO-1. This represents the lowest whole life cost to maintain the level of risk across the valve assets.

Programme Option 2 – Minimal Replacement

8.14. The impact on the performance of each valve type in the minimal replacement option is shown below:

- LAV - Impacts ability of individual valves to achieve successful isolation. This gives rise to increased response time for isolating in an emergency and larger sections of the NTS requiring to be isolated to undertake planned or emergency work. The environmental impact of isolation will be increased, as longer sections of feeder require isolation with increased vent volumes.

- PV - To swap actuators from the PV to the LAV, logic controllers need modification. The lack of bridle around the resulting PV leads to increased venting and associated environmental impact, as well as significant operability issues.

- RIV - Making the RIV local operation only, significantly reduces the speed of response to isolate. There is potential to be non-compliant with PSR and GS(M)R. Local operation of these valves will also increase the costs of call outs, requiring individuals to be dispatched to site to operate the valves.

Programme Option 3 – Vent and Sealant Line – Repair Only

8.15. This option leads to increased minor reactive intervention on these assets. The condition and associated performance of these assets will deteriorate over the period and there will be an increased risk of losing gas, and the associated environmental and safety impacts.

Programme Option 4 – Stem Seal – Repair Only

8.16. This option results in increased minor reactive intervention (i.e. fix on fail) across all valve types. Due to an increase in unplanned interventions, there is a potential increase in feeder outages and the associated vent volumes related would increase environmental impacts.

Programme Option 5 - Minimal Investment

8.17. This option is a combination of Options 2, 3 and 4, with all the associated disbenefits of each of these options.

Programme Option 6 – Increased Proactive Investment

8.18. This option utilises increased proactive replacement of valves and therefore predominantly further reduces the risk on the valve assets, below the point at the start of RIIO-2 with an associated increase in investment. There is no support for such a reduction in risk from stakeholders.

Preferred Option

8.19. Our preferred option is Option 1 to maintain the current level of risk. Even though some of the other options require less investment and are modelled to be more cost beneficial, they do not meet the required outcomes. The modelling makes some assumptions that we do not think provide a fair comparison between the options, as discussed below.

8.20. Options 2,3 4 and 5 include assumptions that valve performance can be restored through ongoing reactive minor interventions. Our experience during RIIO-1 does not support this and we think this undermines the CBA figures for these options. A level of valve replacement will always be required to maintain the risk and performance of the NTS. Our strategy of increasing the scale of intervention to restore performance on individual valves when issues are identified, has proven very cost effective during RIIO-1.

8.21. Maintaining the current level of risk is consistent with the feedback from stakeholders, who want at least the current level of risk maintained. Our chosen option meets the desired outcomes at least whole life cost, across the all valve assets.

8.22. A complete explanation of the selected option is provided in the next section.

9. Business Case Outline and Discussion

9.1. In this section, we set out our overall investment plan for valves. This section demonstrates why the proposed investment levels for valves are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

9.2. Valve assets deteriorate over time and with use. This in turn prevents them from performing their required functions and can also result in them no longer complying with current and future legislative requirements. In addition, the obsolescence of some actuators can mean, despite our robust spares strategy, there is a risk of increased impact when they fail.

9.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment on valve assets:

- Asset deterioration, linked to our ageing asset base
- Legislative changes
- Asset obsolescence

9.4. Considering these drivers ensures that we develop plans that meet our legal obligations to intervene, allows us to manage obsolescence effectively, and ensures we prioritise the right assets for investment.

Business Case Summary

Outcomes delivered

9.5. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- **Environmental risk** - the largest proportion of overall service risk and is associated with the loss of gas through the inability to seal, small leaks and vents
- **Financial risk** - associated with the reactive costs of operating and maintaining the network at the current level of risk
- **Availability risk** - associated with the potential outages associated with the inability to isolate the network in the event of asset failure. This risk is relatively small due to the degree of resilience in the NTS
- **Societal risk** is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, overall the overall societal risk associated with valve asset failure is small.
- **Safety risk** is associated with the potential for fires or explosions arising from a valve leak. The likelihood of a gas ignition causing a fire (or explosion in a confined space) is low and the likelihood or an employee or member of the public being close enough to the fire/explosion to be killed or injured is also very low. Therefore, the modelled Safety risk associated with valve asset failure is small.

9.6. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability. Specific outcomes associated with this investment are:

- Meet legal requirements and agreed safety standards
- Ensure valves and perform their function continually and reliably, particularly in an emergency, to contain the bulk flow of gas in a safe manner
- Manage obsolescence effectively ensuring all valves are supportable with spare parts and technical knowledge
- Decommission and remove assets that are no longer required to manage overall whole life cost and risk
- Reducing the environmental risk of emissions

9.7. Our proposed investment in the valve assets will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

9.8. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions revealed that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it a challenge to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' [Chapter 14 of the GT submission].

Interventions Scope

9.9. To deliver the outcomes for the investment period, the valve assets require the right mixture of the intervention categories (defined in the Options section above) to deliver acceptable and affordable outcomes for our stakeholders.

9.10. We have considered options around the mix of interventions. More specifically, the decision on the volume of each of the interventions required on the valve assets during the investment period has been determined by:

- An asset specific risk-based review of the results of routine inspections, maintenance and investigations already undertaken.
- Forecast of the valve defects and associated risks to arise following the routine inspections, maintenance and investigations to be carried out during the investment period
- Results of the complete DSEAR assessment survey undertaken during RIIO-1 to identify and assess non-conformances to the standard
- Knowledge of the volumes of assets that are currently obsolete, or forecast to be obsolete during the investment period, and that cannot be effectively managed with spares recovered from decommissioned assets

- A site-specific review (including associated pipeline specific risk assessment) of the Block Valves sites to determine which of those need to be retained or could be decommissioned (i.e. piped through)

9.11. No intervention is undertaken on a valve without first gathering inspections and investigations evidence that an intervention is required and defining the most effective type of intervention option to resolve the issue found.

9.12. The investment proposed in the period is to:

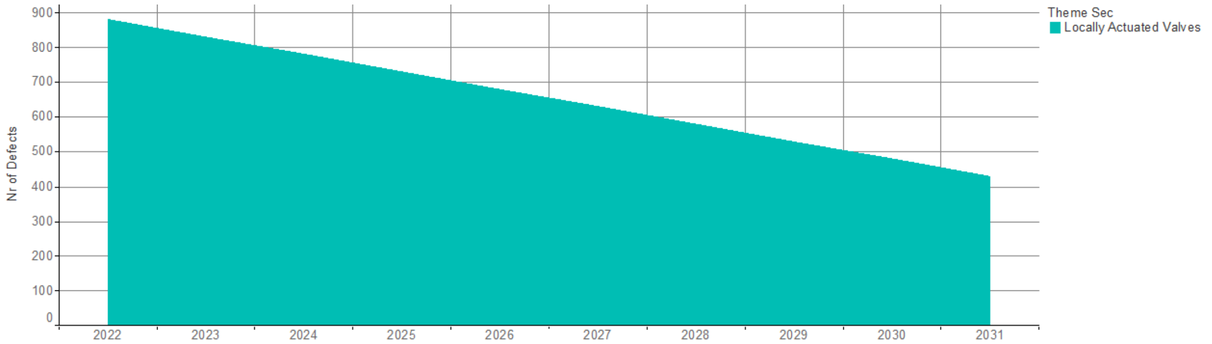
- Maintain the current risk profile across the network by remediating the highest risk currently identified valve defects together with those which are forecast to be identified during scheduled routine inspection and maintenance activities
- Avoid unnecessary costs and risks to both network and people by ensuring that valves seal reliably when required
- Manage obsolescence issues across the network to ensure that the operational and safety risk associated with obsolete systems and equipment is maintained within acceptable limits
- Drive continued environmental improvements by reducing planned and unplanned emissions of methane to atmosphere
- Ensure compliance with legal requirements and all relevant regulations and approved codes of practice

9.13. During the investment period, we will avoid unnecessary investment by rationalisation of valves and their associated systems whilst maintaining compliance with safety and reliability standards.

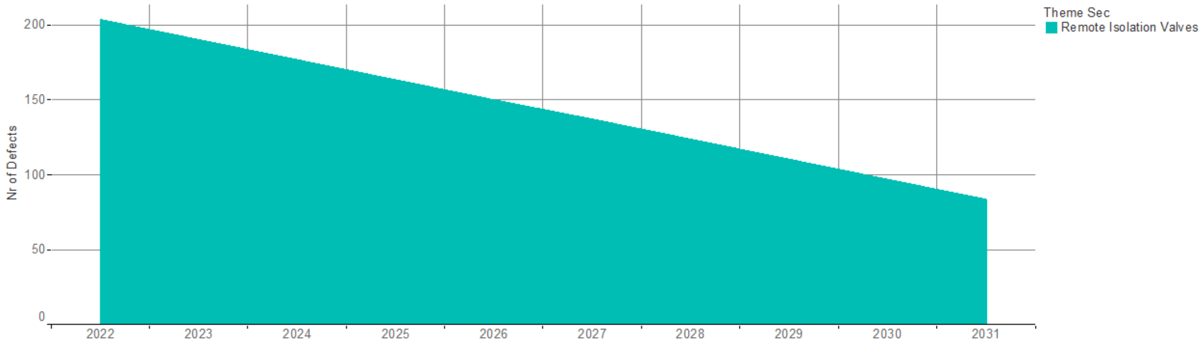
Defects

9.14. The currently identified 1,700 valve defects are predicted to be below 800 by the end of 2031. This compares with a forecast increase to 2,700 by the end of 2026 and an increase to 6,600 by the end of 2031 without investment. The chart below shows the predicted defects following the preferred programme of investment for valves by valve type.

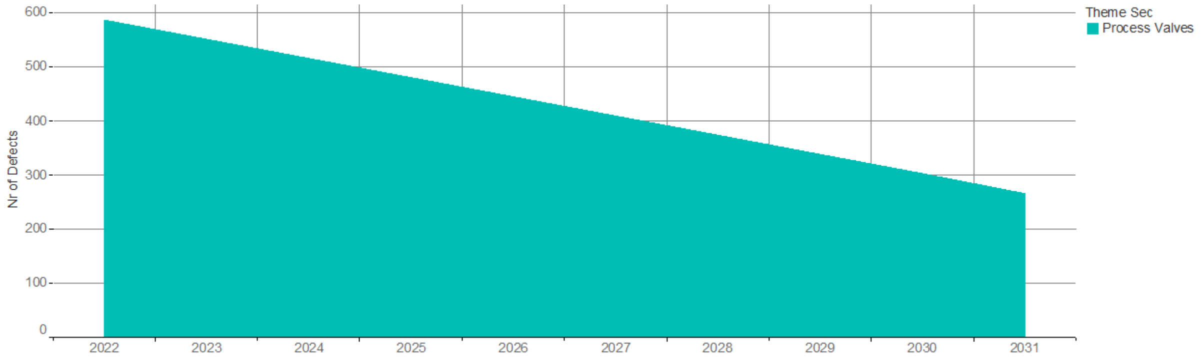
Locally Actuated Valves - Predicted defects with Preferred Investment Option



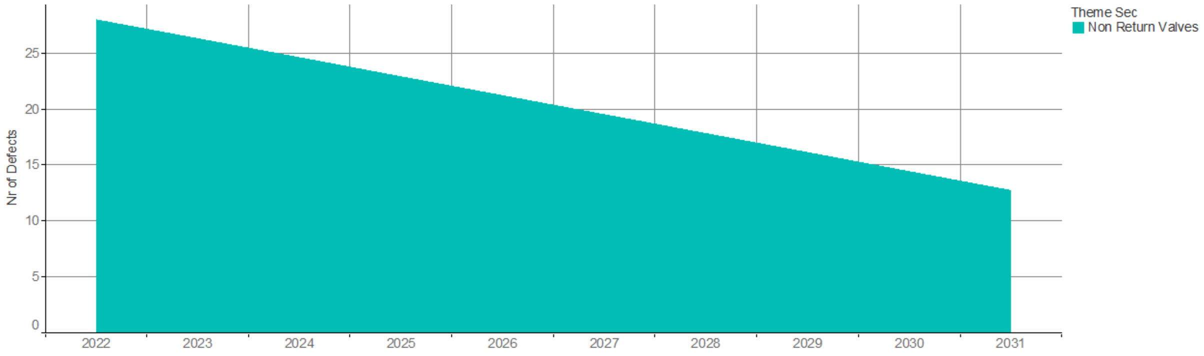
Remote Isolation Valves - Predicted defects with Preferred Investment Option



Process Valves - Predicted defects with Preferred Investment Option



Non-Return Valves - Predicted defects with Preferred Investment Option



Obsolete Assets

9.15. Up to 884 obsolete assets will be replaced to mitigate the extended outage implications.

Remote Isolation Valve Defects

9.16. Remote isolation valves defects that contravene IEC 61508 and commitment to HSE/Ofgem will be reduced.

DSEAR

9.17. DSEAR inspection identified defects will be reduced.

Intervention Volumes

9.18. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the valve assets in the investment period. [redacted]:

Volumes of each Intervention

[redacted]

** The volumes quoted (in JR and Data Tables) relate to the **equivalent** number of valves delivered (based on the assigned unit cost). The numbers in the CBA are correct as they relate to the **actual** numbers of outputs delivered in RIIO-2.*

Asset Health Spend Profile

9.19. The profile of investment in the valve assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

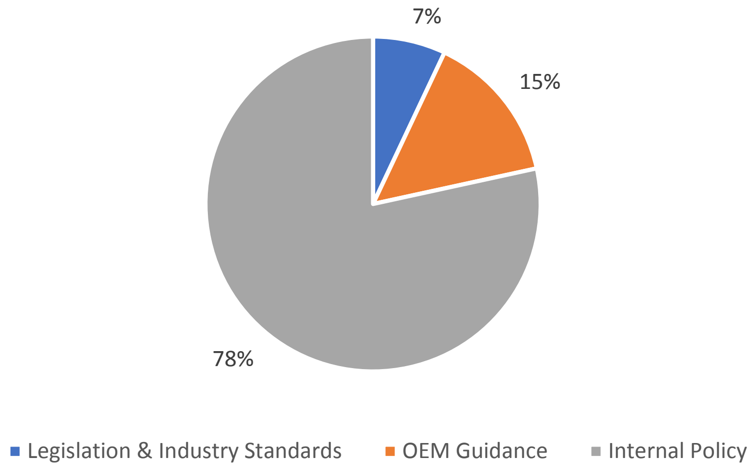
Profile of Investment in Valve assets

Valve Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Locally actuated valves	1,848	5,624	6,266	6,382	7,288	7,786	7,151	8,103	6,607	6,185
Non-return Valve	1,219	2,630	1,621	2,150	1,581	2,168	3,546	1,523	1,175	927
Process valves	2,689	2,982	4,357	1,763	2,532	1,935	1,852	1,256	754	241
Remote Isolation Valves	605	2,638	2,363	3,653	2,953	3,018	2,534	2,547	1,170	808
Total	6,361	13,875	14,608	13,948	14,355	14,907	15,083	13,429	9,706	8,161
	63,146					**61,286**				

Intervention Drivers

9.20. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that the majority of the investment consists of interventions that are based on internal policy, with the remainder meeting legislative requirements and OEM Guidance.

RIIO-2 Valves Intervention Drivers[2]



[2] See Appendix D for intervention driver category definitions

Selected Programme CBA

9.21. We are targeting an appropriate level of asset health investment in valves to mitigate the reliability, safety, environmental and societal risks from the ageing valves asset base.

9.22. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in valves is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

9.23. The CBA for valve investments is cost beneficial over the 45-year period. This investment pays back in 34 years, and over 45 years is significantly cost beneficial. This is shown below.

Cost Benefit Summary – Valves investment[3]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£46.33	£79.04	£107.10	£147.39
Present Value H&S benefits (£m)	£0.02	£0.15	£0.53	£2.00
Present Value non H&S benefits (£m)	£6.10	£27.74	£80.62	£259.54
Net Present Value (£m)	£(40.21)	£(51.14)	£(25.96)	£114.15

9.24. We have challenged whether this is the right programme of work. In developing our plans and making our decision we have been fully cognisant of the need to develop plans that are value for money, acceptable, affordable and deliverable.

9.25. All the programme options that were developed and considered are cost beneficial over the 45-year period. The selected option is 'Maintain Risk', which focusses on those valves that have the most impact on risk and undertakes the lowest whole life interventions. Whilst this is not the most cost-beneficial option it is the lowest whole life cost option to deliver the desired outcomes:

- Meeting legislative requirements and agreed safety standards
- Ensuring valves perform their function continually and reliably, particularly in an emergency
- Managing obsolescence effectively
- Reducing the environmental risk of emissions
- Maintaining reliable energy supplies across the NTS
- Meeting the expectations of our customers and stakeholders and keeping risk stable.

9.26. We have assessed the sensitivity of the Cost Benefit Analysis to the full range of unit costs. The results of this analysis are presented in the Unit Cost section above.

9.27. This level of investment will ensure we successfully manage asset deterioration and obsolescence, whilst meeting our legal obligations. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

[3] A14.15.1 Valves CBA

9.28. Based on our robust CBA assessment, and reviewing the programme against the drivers for investment and outcomes delivered, we are confident that our plans are value for money and in line with stakeholder views.

10. Preferred Option Scope and Project Plan

10.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred option

10.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the valve assets in the investment period. [redacted]:

Volumes of each Intervention by period

[redacted]

[redacted]

Asset Health Spend Profile

10.3. The profile of investment in the valve assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Investment profile – Valve assets

Valve Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Locally actuated Valves	1,848	5,624	6,266	6,382	7,288	7,786	7,151	8,103	6,607	6,185
Non-Return Valve	1,219	2,630	1,621	2,150	1,581	2,168	3,546	1,523	1,175	927
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Total	6,361	13,875	14,608	13,948	14,355	14,907	15,083	13,429	9,706	8,161
	63,146					**61,286**				

Delivery

10.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change, and provide an opportunity to reconsider the efficient timing of delivery.

10.5. We recognise that many of our asset classes are co-located across the NTS pipeline network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets, sites and/or work places simultaneously. To achieve this, the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention which could be for a period of 25 years. Reliable operation of what may be infrequently used valves is therefore also a critical factor for delivery. The cost of recompression for a large section of the network once the work is complete could be up to £0.25m. A systematic approach therefore maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads. Further, reliability of valves is critical to achieving the necessary isolations and outages.

10.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

10.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

10.8. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

10.9. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

Appendix A – Locally Actuated, Remote Isolation and Process Valves

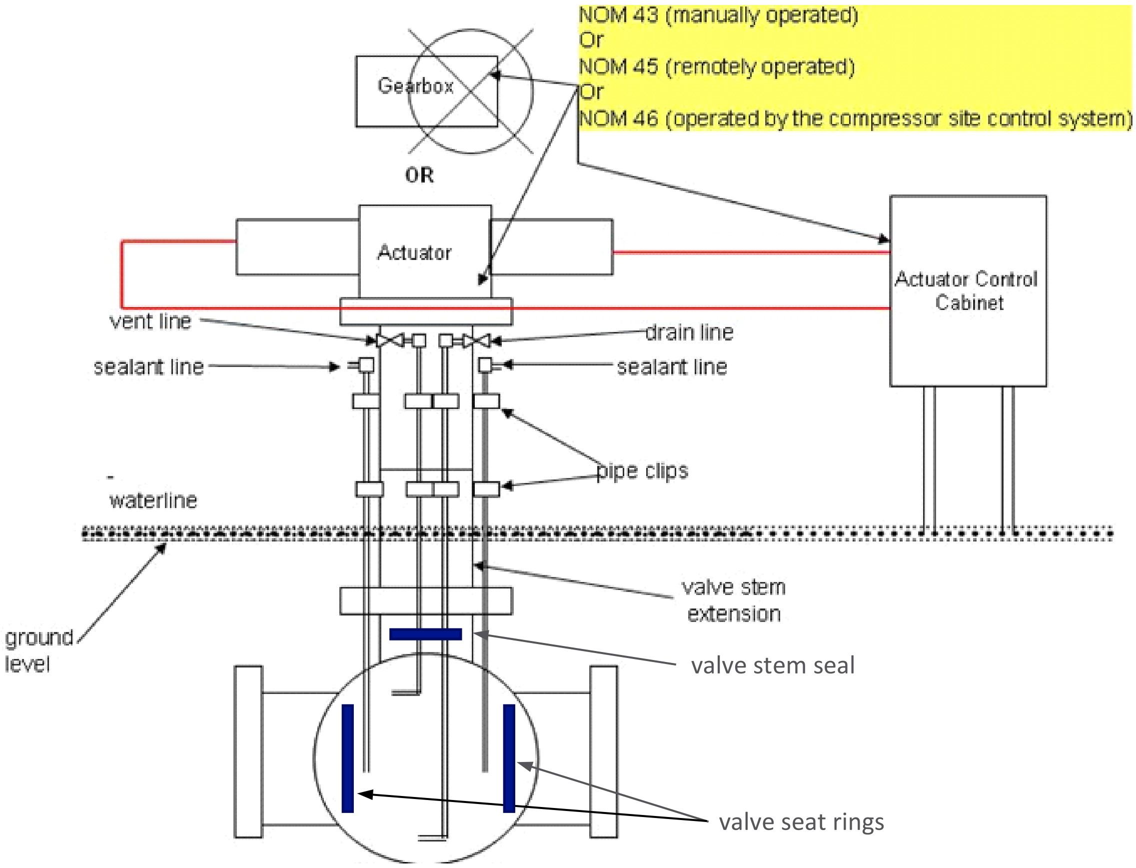
Valve Overview

A general overview of a typical valve arrangement is shown in the figure below which highlights all the typical sub-components that are associated with each of the Valve Body and associated fittings, e.g. Vent & Sealant lines, Seat rings etc.

Valve Stem Extension;

- Valve Stem Seal;
- Valve Operator (Gearbox or Actuator), associated fittings and actuating medium storage vessels;
- Actuating medium up to the point of isolation or distribution point. e.g. actuating gas isolation point or electrical junction point;
- Instrumentation inherent to the actuator unit.
- Control cabinets inclusive of all contents e.g. hand/electric pumps, regulators and relief valves;
- Applies to all valves of size 100mm to 1200mm

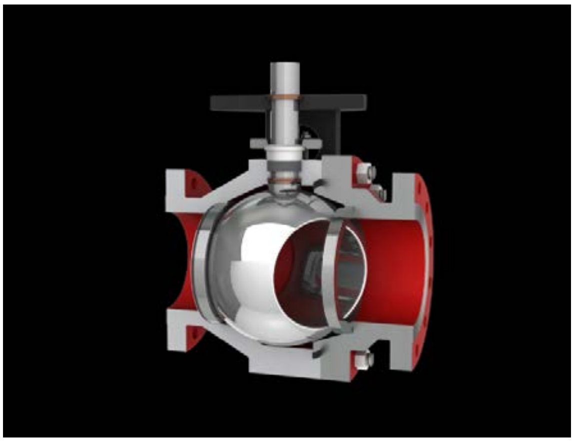
General Ball Valve Overview



Valve Sub-Assemblies

As part of the overall valve assembly there are further sub-assemblies thus:

Valve Body (including seat rings and stem seal)



The valve body serves as the main element of a valve assembly because it is the framework that holds all the parts together. The valve body ends are designed to connect the valve to the piping by different types of end connections, such as butt or socket welded, threaded or flanged. Valve bodies are cast or forged in a variety of forms and each component have a specific function and constructed in a material suitable for that function.

The seat or seal rings provide the seating surface for the ball or plug. A valve may have one or more seats. In the case of a plug or a non-return valve, there is usually one seat, which forms a seal with the disc or plug to stop the flow. In the case of a ball valve, there are two seats; one on the upstream side and the other on the downstream side, which forms a seal with the surface of the ball to stop the flow.

The stem seal is required to provide a reliable seal between the stem and the valve body and is made up of a series of glands, packing rings and lubricant. An important aspect of the life time of a valve is the sealing assembly, whereby the stem seal must be properly maintained to prevent damage to the stem and potential for gas leakage to atmosphere.

Valve Stem Extension (including vent and sealant lines)

The valve stem extension serves as the primary means to extend the valve stem from below ground when buried, to above ground, to enable routine valve operations to take place. This will generally have the valve ancillary pipework (i.e. vent and sealant lines) attached to it to enable the valve cavity to be vented and lubricant to be injected into the set rings or stem seal.

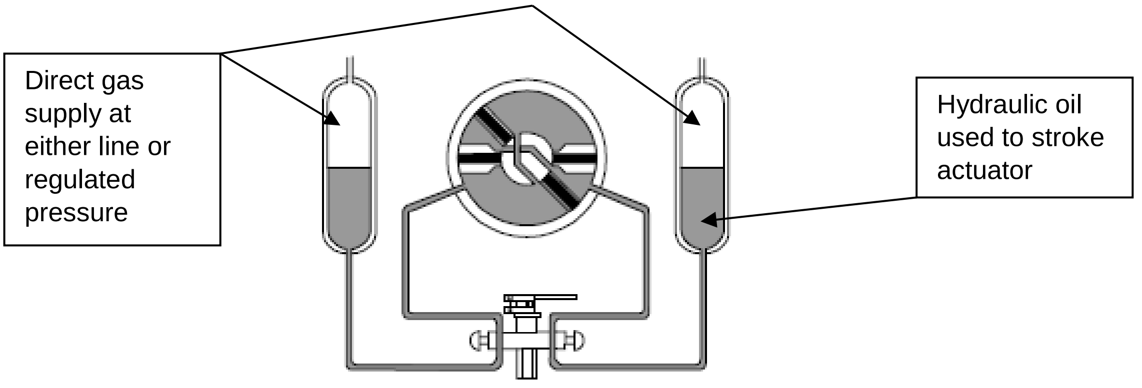
Valve Actuator

The valve actuator serves as a device that produces linear and rotary motion (quarter-turn) using a source of power (see list below) under the action of a source of control (control cabinet) and are used to fully open or close the valve. Within National Grid there are several powered variants applicable to the actuator that is providing the primary force to operate the valve, these being:

- Direct Gas
- Gas/Hydraulic
- Gas-Over-Oil
- Hydraulic
- Electric
- Air/Spring return
- Electro/Hydraulic

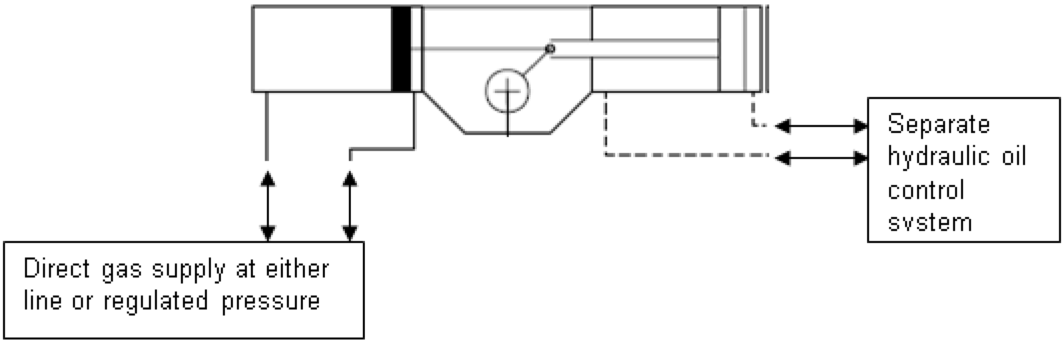
By way of an example for two of these actuator types, please see below:

Gas over Oil operation



This method applies direct gas pressure onto the oil being stored in the reservoirs, therefore, forcing the oil through the actuator controls to stroke the actuator. This system will also incorporate a manual override, in the form of a manual handpump installed in the normal hydraulic circuit. Some systems have a 3rd reservoir, which is used only for storing gas pressure, in the event of a gas supply being lost.

Direct Gas with manual override operation



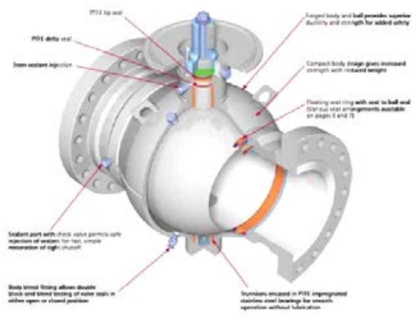
This method only applies direct gas pressure onto the pneumatic cylinder side of the actuator to stroke the actuator. This method of operation is used during normal modes of operation. However, there is a separate hydraulic manual override control system that will, in the event of gas pressure being lost, provide an alternative method of stroking the actuator.

Ball Valves and Plug Valves

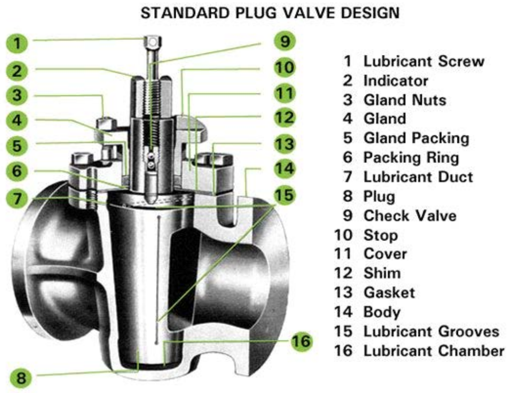
Whilst there are four main different valve purposes, only two types of valve are used on the Gas National Transmission System (NTS), these can be in the form of Ball or Plug Valves.

Ball Valves have two seals and an inner cavity which can be vented to create a double block and bleed, whilst a plug valve has a single seal.

Typical Ball Valve



Typical Plug Valve



Many maintenance tasks can be performed downstream of a closed ball valve with a cavity vent, however the use of plug valves to form an isolation would typically require two valves and a vent to ensure the downstream plant is isolated, as there is no cavity.

Whilst there are several safety and efficiency benefits to a ball valve, they operate more complex technologies and have additional modes of failure.

Such as:

<u>Bolted Body Ball Valve types only, i.e. Cort-CB5</u>

- Valve Closure 'O'-Ring seal failing (with instances of external repairs (drilled interventions) being undertaken to inject a sealing agent, with little success).
- Failure of Anchor Pins due to early design configurations

<u>All types of Ball Valve body</u>

- A general reduction in tensile strength of the elastomers ('O'-Rings) within the valve.
- Break down of the Electro-Nickle Plating on the surface of the ball
- Heavy deposits found in the seat ring
- Deposits found behind the seat ring and entrained within the backing ring and spring pockets that support the seat ring
- Damage to the seat ring (heavy scores/scratches)
- Deposits of hard sealant found within the sealant lines and seat rings, due to historic use of Val-Tex over several years which sets like concrete. This has organophilic clays within the product, which, when the product 'dries out' will set/cure hard.
- Buildup of debris against the valve end stops within quadrant.

- Stem seal damage, due to moisture and debris ingress.

All types of Plug Valve

- Stem seal damage, due to moisture and debris ingress.
- Friction on attempting to operate valve. This is due to a 'metal-to-metal' seat design and requires lubrication before operation.

All types of Non-Return Valve

- Indication failure
- Seal failure
- Seat failure
- Internal component wear, i.e. metal fatigue, spring degradation, bearings, stop pins etc.
- Damper failure

In addition to the valve body assembly, there is also a range of typical failure modes associated with:

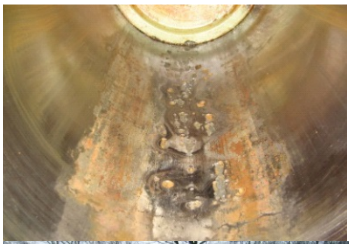
Valve Stem Extension (including vent and sealant lines)

- Internal corrosion of stem extension, with corrosion deposits & water around the valve top works
- Corrosion deposits finding their way into valve quadrant, giving a false indication of valve travel.
- Water ingress into valve top works & quadrant, showing the stem extension 'seal' is just copper slip.
- Corrosion on vent and sealant lines at interface of 'wind and water line' and behind pipe clips.
- Corrosion on sealant line 'button-head'.

Valve Actuator

Obsolescence

- Pre-1983 Shafer (gas-over-oil) actuator handpumps are obsolete
- Rotork (A-Range Electric and Gas/Hydraulic) actuators are obsolete
- Ledeen (Gas/Hydraulic) actuators are obsolete



Corrosion

- Internal actuator cylinder corrosion
- External cylinder tie-bar corrosion
- Control cabinet corrosion.

Component failure

- Relays and switch failure
- Oil seal failure
- Drive shaft pin failure
- Drive bush failure.

In addition to the above-mentioned typical failure modes, all types of Ball or Plug Valve assemblies have the ‘potential’ to leak to atmosphere via the following sub-components:

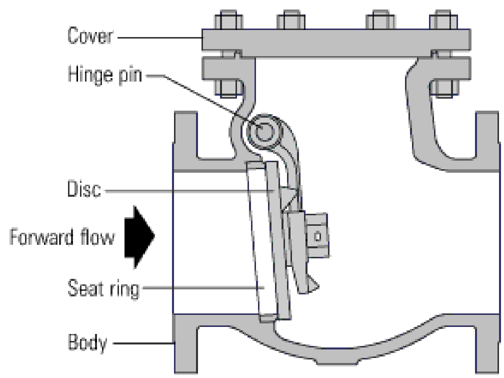
- Stem Seal – This is the seal for the valve stem and comprises of a series of elastomer ‘O’ rings.
- Vent & Sealant Lines – These small-bore fittings are used as the primary means to inject lubricant into the valve seats and to enable the valve cavity to be vented, to test the valve seats situated within the main body of the valve.
- Operator (Actuator or Gearbox) – This is the primary means to operate the valve, which when gas powered, can be in the form of Direct Gas, Gas/Hydraulic or Gas-Over-Oil operated.
- Actuator Control Cabinets – This is the primary means to supply and control the gas pressure to the operator.

Appendix B – Non-Return Valves

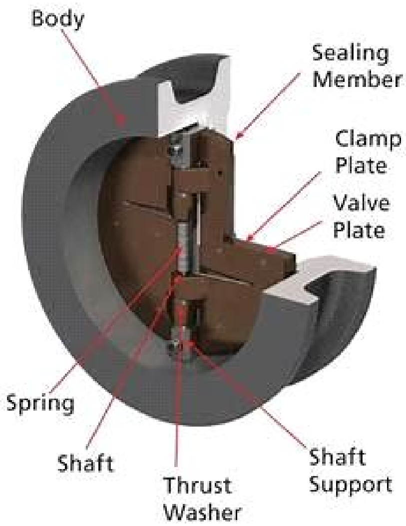
Non-return valves (NRV) - ensure process gas flows in the desired direction whilst preventing reverse flow and segregating pressure between systems. NRV are used for flow direction control and on the main station by-pass to control station discharge flow when on-line, allowing flow onto the NTS in the desired direction only. NRV's are also positioned to suit either series and/or parallel unit operation when multiple machines are designed to run together.

Non-return valves rely on mechanical action (spring or deadweight) alone. The mechanical forces exerted on the internal components of a non-return valve in operation result in progressive damage to the soft and hard parts. Most non-return valves can be accessed internally for overhaul although many of the valves currently in use are obsolete requiring parts to be reverse engineered.

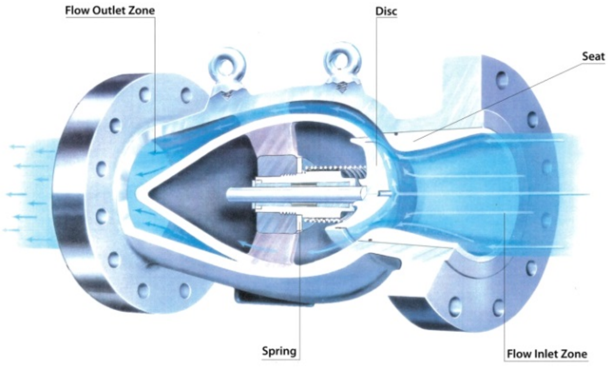
Examples of typical NRV used on the NTS are shown below:



Swing Check NRV



Wafer Check NRV

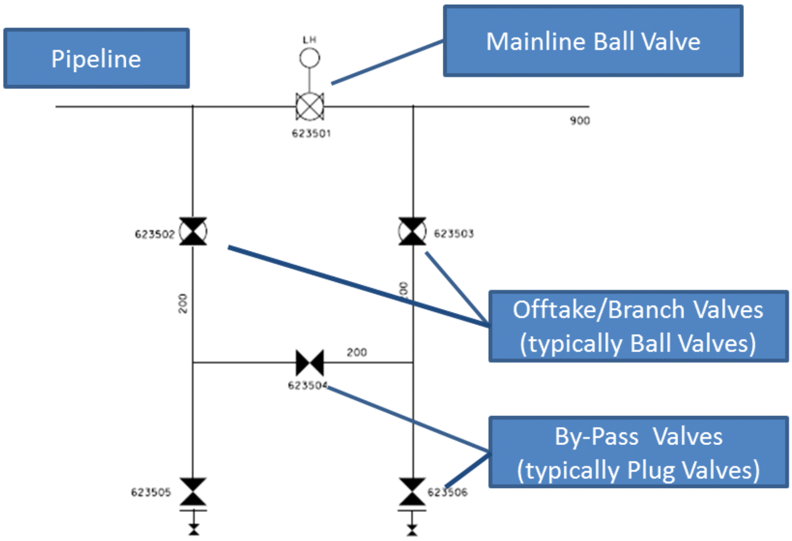


Noz-Check NRV

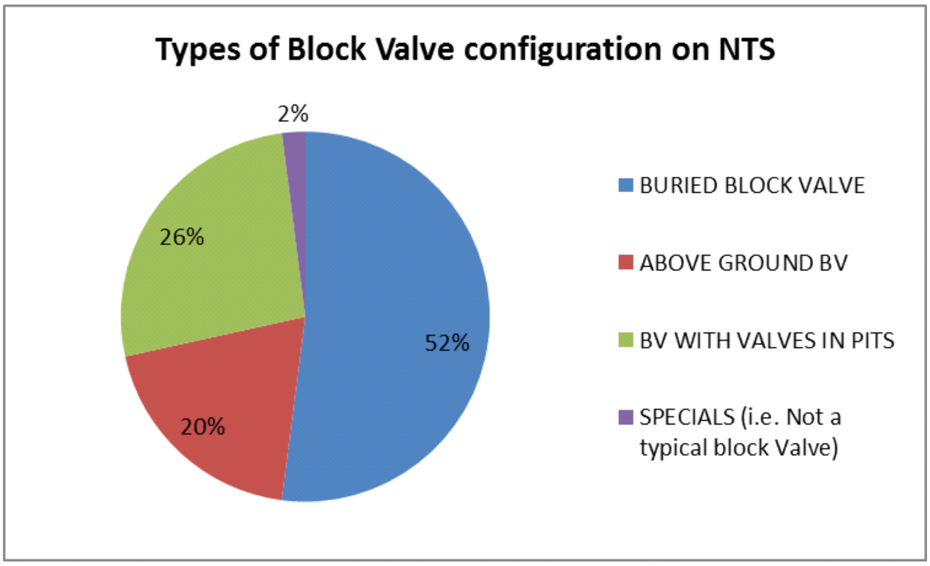
Appendix C – Block Valves

Block Valves are installed on cross country pipelines to limit inventory loss in an emergency, facilitate maintenance, flow direction, repair, modification, testing and commissioning on the Gas Transmission pipeline network.

A Block Valve also forms part of the Pipeline Primary Asset and is made up of typically 6 Locally Actuated Valves.



Block Valves are installed as one of four typical configurations:



Appendix D – Intervention Driver Categories

Intervention Driver Categories

	Name	Definition
A	Legislation & Industry Standards	Intervention required to ensure compliance with relevant safety legislation and/or adopted industry standards.
B	OEM Guidance	Intervention recommended by OEM to maintain intended asset performance and safe operation. Any deviation from this guidance shall be specifically risk-assessed to ensure compliance with relevant safety legislation.
C	Internal Policy	Internal policy defined intervention required to maintain asset performance, and to align with relevant safety legislative requirements