

UKOPA Recommendations for Pipeline Maintenance and Inspection

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INTRODUCTION

To ensure a high level of safety and reliability in operation, it is essential to have a system of maintenance and inspection for steel pipelines and pipeline systems, and their ancillary equipment operating above 7 barg.

The primary purpose of this strategy is to detect and prevent in-service damage, degradation, or defects which can lead to failures.

This paper provides the basis for a common strategy towards meeting the above objective, allowing efficient and cost effective maintenance and inspection whilst demonstrating compliance with appropriate legislation in the UK.

The maintenance strategies outlined in this document are considered best practice. Alternative strategies may be adopted if they can be demonstrated by the pipeline operator to result in equivalent levels of risk to those outlined in this document. In all cases, the maintenance strategies applied by the operator should be fully documented in terms of their scope, frequency and responsibility for their execution.

1. SCOPE

This paper covers the maintenance and inspection of buried steel pipelines operating at pressures greater than 7 barg. The requirements for maintenance on associated above ground installations are outside the scope of this document.

Maintenance intervals should be set in accordance with the recommendations given in PD 8010 2004 or IGE/TD/1 Edition 4. Alternatively, maintenance intervals can be set based on a risk based approach provided suitable reliability data is available to justify these risk based frequencies. Additionally, inspection regimes should be drawn up for items of equipment on above ground installations that are within the scope of the Pressure Systems Safety Regulations (PSSR), which require that the inspection requirements and frequencies for pressure vessels, pipework and protective devices are identified on the relevant Written Schemes of Examination (WSOE).

This document focuses on maintenance and inspection strategies for buried pipelines and is not intended to cover other safety management requirements, e.g. training and competency requirements, emergency planning, operating and maintenance plans, that will be a part of the pipeline operator's broader safety management strategy.

2. MAIN DRIVERS FOR MAINTENANCE AND INSPECTION

In general terms, the integrity of a pipeline is most secure whilst it remains buried. A strategy of maintenance requirements, in the form of route surveillance, condition monitoring and

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inspection, will help ensure that unnecessary intrusive maintenance is greatly reduced, if not avoided.

The following identifies the main issues that determine the need to carry out maintenance and inspection activities and suggests a strategy which must be developed to ensure a robust and economic means of undertaking these activities.

2.1 Legislative Compliance

Maintenance and inspection requirements must comply at all times with any statutory or legislative requirements. The main legislative driver in the UK is The Health and Safety at Work Act (1974) and the associated Regulations: The Pipelines Safety Regulations 1996 (PSR) and The Pressure Systems Safety Regulations (PSSR). A summary of legislative drivers is given in Table 1.

2.2 Operational Duty

The life cycle of a pipeline can be considered to follow the 'bath tub' failure probability curve with higher incidences of failure in early life followed by a fairly constant failure rate which gradually increases towards the end of the pipeline's life.

With pipelines, early life failures generally result from damage associated with construction and commissioning. A constant failure rate is then generally observed during the operating life, which is mainly due to random mechanical damage. A gradual increase in failure rate then may be caused by age and duty related damage mechanisms.

A maintenance and inspection strategy should be applied which can accommodate the early failures, minimise and respond to random failures, and anticipate and avoid predictable failures due to age and duty deterioration mechanisms.

2.3 Business and Economic Factors

The maintenance and inspection strategy should ensure transportation and delivery of the product to the satisfaction of the operator and/or the customers. It should be robustly planned to optimise performance by increasing the overall life and ensuring that the probability of failure remains at an acceptable level whilst minimising overall operating costs.

2.4 Safety and Environmental Issues

Effective maintenance and inspection is essential to minimise the risks to safety and the environment caused by pipeline failure. It is also essential to ensure maintenance and

inspection activities minimise impact on the safety of the public, staff and contractors or on the local environment.

2.5 Potential Damage Mechanisms

For pipelines operating in the UK, the main causes of failure are identified as impact damage due to 3rd party interference, ground movement, fatigue, corrosion and operator error. These causes of failure should be considered when determining maintenance and inspection activities. A robust emergency service should also be available to react to unforeseen situations.

2.6 Third Party Activities

It is essential that all reasonable precautions are taken to reduce the risk to pipelines being struck or damaged by third party activities. Monitoring of building developments should also be undertaken to control potential proximity and population density infringements along the pipeline route. Additional liaison with local authority planners will establish at an early stage any proposals for building work that may affect the integrity of the pipeline.

Information regarding the exact location of the pipeline should be available and detailed marking of the route should be carried out when planned works in the vicinity of the pipeline are notified to the operator. Consideration may be given to the use of one-call systems to access data on the location of other plant and pipelines prior to carrying out excavations.

3. LEGISLATIVE REQUIREMENTS

There are two main pieces of legislation, under the umbrella of The Health and Safety at Work Act 1974 which affect the operation of pipelines. They are the Pipelines Safety Regulations 1996 (PSR) and the Pressure Systems Safety Regulations (PSSR).

The PSR provide a goal setting, risk-based approach to operating and maintaining pipelines. The PSR cover:-

- the definition of a pipeline,
- the general duties for all pipelines, including design, safety systems, operation, maintenance etc.
- the need for co-operation among pipeline operators,
- arrangements to prevent damage to pipelines,

and additionally, for major accident hazard pipelines (MAHP), the Regulations cover:-

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- the description of a dangerous fluid,
- the notification structure,
- the major accident prevention document (MAPD),
- the arrangements for emergency plans and procedures.

The PSSR are aimed at preventing the risk of serious injury from stored energy as a result of the failure of a pressure system or part of it. The main aspects that apply to pipelines inspection and maintenance are:-

- Requirement for a design, construction, repair and modification procedure to be in place.
- Requirement for the user to establish the Safe Operating Limits (SOL) of that system.
- Requirement for the user to have in place, for each pressure system, a Written Scheme of Examination (WSOE), certified by a Competent Person, which identifies all protective devices; every pressure vessel and pipeline in which a defect may give rise to danger. The WSOE must specify the nature and frequency of examination.
- Requirement for the Examination of the pressure system in accordance with the WSOE to be arranged by the user.
- Requirement for the person undertaking the examination to act and report on instances of Imminent Danger.
- Requirement for the user to have in place adequate and suitable instructions for Operation of the pressure system.
- Requirement for the user to ensure the pressure system is properly maintained in good repair, so as to prevent danger.
- Requirement for the Keeping of Records by the user and identification the type of records to be kept.

4. DAMAGE MECHANISMS

The main pipeline damage mechanisms are:-

Impact Damage

In the majority of cases, impact damage such as gouges and dents is the result of third party interference with more than half the reported incidents being caused by mechanical excavating equipment. Pipeline surveillance activities will reduce the number of instances in which the operator is not aware of third party activities.

Ground Movement

Major ground movement can pose a threat to the integrity of pipelines. Careful pipeline routing, taking into account areas of known ground movement and subsidence, will significantly reduce the risk to the pipeline. Where pipelines do run through problem areas, in particular areas of mining subsidence, close liaison with the mine operators is essential in order to predict ground displacement. With this information the pipeline operator can determine stress levels on the pipeline and plan any necessary remedial actions.

Areas of susceptibility of the ground to natural land sliding along the pipeline route should be identified and monitored for any indications of movement.

Fatigue

Consideration must be given to the fatigue life of steel pipelines to ensure that minor defects which survive the hydrostatic test do not grow with time to a critical size under the influence of stress variations. Further consideration should be given to fatigue mechanisms resulting from changes in stress levels due to variations in the temperature of the fluid transported; however, the most significant stress changes will be in the hoop stress resulting from variations in pressure.

Corrosion

Steel pipelines are subject to corrosion in situations where interference with, faults on or damage to the pipeline coating and CP occur. The resulting corrosion may occur as localised pitting or generalised metal loss. In situations where specific combinations of environment and loading occur, a number of additional, less common corrosion mechanisms may affect a pipeline during its operating life and should be considered:

- Alternating current induced corrosion, which may be related to the specific coating properties and condition together with the proximity and orientation of the pipeline to high voltage overhead power cables.
- Stress corrosion cracking, which may be related to coating condition together with high pressure and temperature cycles and soil pH conditions.
- Microbial corrosion, which may be associated with coating condition and the presence of specific microbes in the soil or in the product.

Most pipelines are protected by both internal and external coatings. (Note: pipelines carrying white oil products may not be internally coated). The type of internal coating should relate to the corrosive nature of the product being transported. With the provision and use of an adequate cathodic protection system, corrosion can be reduced to a minimum if not eliminated. Both the coating and cathodic protection system are subject to deterioration through age, soil

contact and interference, and must be periodically checked. However, should corrosion take place, it has been found, in the UK, that failures will usually occur as leaks.

Operator Error

Operator error may occur in the control of pipeline pressure and /or where work is carried out on the pipeline during operation.

Procedures for the control of pipeline pressure in non-standard or non-routine situations should be applied. In particular, this applies to the control of any pressure restrictions or constraints applied as a result of damage to the pipeline, or when modifications and repairs are being carried out.

Damage can occur during operations being carried out on 'live' pipelines. It is important to employ a robust system for managing the safe control of operations, including the authorisation of the proposed works and competency of those involved.

5. CONSEQUENCES OF FAILURE

The dominant consequences of high pressure pipeline failures are thermal radiation from fire fuelled from escaping fluid, or toxic emissions, from the point of pipeline leak or rupture.

The consequences of failure of a high pressure liquid pipeline may also involve pollution of the ground, water table and water courses, both at the location of the failure and in the surrounding area where drain down can occur. In all cases involving hazardous fluids, pipeline failures may result in significant risk to the safety of the public, staff and contractors and to the environment. The impact of the time between failure resulting in product loss and identification of the leak and its location, the requirements for emergency response and its mobilisation should be considered and addressed in the operators documented operations and maintenance strategy.

6. MAINTENANCE AND INSPECTION ACTIVITIES

6.1 Safe Operating Limits and Maximum Operating Pressure

Prior to operating a pipeline, it is essential to establish appropriate safe operating limits based on the pipeline design, test pressure, and any operational constraints that may need to be applied. The SOL for pressure will be related to the declared maximum operating pressure (MOP). The operator must ensure that the pipeline is maintained within these limits.

These SOLs, along with the declared MOP should be periodically reviewed and redeclared in order to confirm continued fitness for purpose.

6.2 Provision of Information

The operator is required to provide those involved in operating, maintaining, inspecting, modifying and repairing a pipeline with sufficient written information as needed to perform their duties correctly and safely.

It is important that owners and occupiers of land through which a pipeline is routed, and third parties who may require to work in the vicinity, are reminded of, or made aware of, the pipeline's location.

Regular contact with owners and occupiers is essential (see 6.3 – Owner / Occupier Liaison).

In order to assist third parties, the operator should make available pipeline location plans of a scale suitable to identify the approximate location of the pipeline. Use of 'one-call' systems may be beneficial in this respect.

The pipeline route should be marked with location markers at all road, rail and river crossings. It is noted that PSR Regulation 16 requires that the operator should provide information on the location of the pipeline, the installations of markers along the route to identify the accurate location of the pipeline should be adequate for surveillance purposes and provision of general information to 3rd parties.

6.3 Route Surveillance

It is essential to take all reasonable precautions to reduce the risk of pipelines being struck or damaged by third party activities. The risk of damage to a pipeline or pipeline system needs to be assessed in order to determine appropriate surveillance methods and frequencies.

Route surveillance is employed to ensure that there are no unknown activities being carried out in the vicinity of pipelines that could cause damage to it. It should also be used to monitor building developments that may result in proximity or population density infringements. Where infringements do occur, they should be subjected to a risk assessment in order to determine if any additional protection or surveillance needs to be undertaken to reduce the risk posed by the pipeline to the surrounding population.

Where activities are being carried out by third parties in the vicinity of a pipeline, with the consent of the owner, it is necessary to monitor the activities and ensure agreed working methods and procedures are being adhered to.

The following are recommended methods of undertaking route surveillance:

Aerial Survey

Aerial surveillance (by helicopter or fixed wing aircraft) provides a fast and efficient means of surveying the route. Typical activities that the observer should be looking for are:

- construction of any building work which may infringe proximity or population density criteria,
- any previously unknown third-party activity on or adjacent to the pipeline,
- the condition of pipeline marker posts,
- fires of any description – including straw burning,
- tree felling and timber transportation,
- discolouration of vegetation or other evidence of leakage,
- blasting or mineral extraction,
- ground movement,
- erosion and changing water courses,
- soil removal,
- tipping,
- vegetation overgrowth on easement.

Vantage Point Survey

As an alternative to the aerial survey, and for sections of pipeline not flown because of location or due to the helicopter or aircraft being unable to fly (for example due to weather conditions), vantage point surveys should be undertaken. This survey should cover the complete pipeline route, equivalent to an aerial survey. The surveyor will be looking for activities identified in the section on aerial survey when undertaking vantage point surveys.

Line Walk

A further alternative to aerial and vantage point surveys would be a full line walk survey. The surveyor will be looking for activities identified in the section on aerial survey.

Owner / Occupier Liaison

Regular contact should be maintained with owners, tenants, occupiers and managers of land through which a pipeline runs. Contact with local authorities, statutory bodies, and selected contractors is also recommended. The purpose of this is as a reminder of the existence of the pipeline, to establish future intended work in the vicinity of the pipeline, and as an aid to updating records of those responsible for the land.

Water Crossing Survey

Water crossings, and their survey techniques, can be divided into three categories:

- Major:* Greater than 50 metres deep, tidal and navigable.
These should be surveyed by remote operated vehicles or hydrographic survey.
- Intermediate:* 10-50 metres deep and navigable.
These should be surveyed using remote operated vehicles or divers.
- Minor:* Up to 10 metres deep.
These require a river bed and bank profile to be taken from a small boat.

Survey frequencies must be based on consideration of crossing depth, water flow rates, likelihood of erosion, undercutting etc.

All water course crossings that are wadeable need only be visually inspected as part of other pipeline external condition monitoring surveys.

Exposed Crossings

Exposed crossings should be inspected for security, mechanical defects, condition of supports, paintwork and wrapping. The frequency of inspection should be determined by the location of the crossing and its vulnerability to external interference, including vandalism.

Nitrogen Filled Sleeve Monitoring

Nitrogen filled sleeves should maintain a positive nitrogen pressure. This pressure should be checked regularly. For sleeves not holding their charge, more frequent checks must be made in order to top up to ensure a positive pressure is maintained.

6.4 Condition Monitoring

The integrity of a pipeline is monitored periodically using on-line inspection techniques which can be either internal or external in nature, or alternatively by hydrostatic testing. Condition monitoring establishes a continued fitness for purpose assessment of pipelines.

Internal Inspection

Where practical, pipelines should be constructed to allow internal inspection utilising on-line inspection tools. A series of preparatory pigging runs, including cleaning, geometric and profile, are undertaken to ensure safe passage of the inspection pig. This inspection employs a magnetic flux leakage, or ultrasonic pig, to detect metal loss in pipe walls and will locate and size areas of corrosion and mechanical damage. The magnetic flux leakage pig can also detect circumferential cracks.

For pipelines which may be subject to stress corrosion cracking, consideration should be given to the use of an elastic wave or transverse flux leakage internal inspection tool.

External Inspection

Where the use of an internal on-line inspection tool is not practical, then an external above ground survey should be undertaken. This should involve a corrosion protection close interval potential survey (CIPS) and a coating defect survey (Pearson).

Close Interval Potential Survey (CIPS)

The CIPS survey determines the actual level of cathodic protection being experienced along the pipeline by measuring the pipe to soil potential and hence corrosion protection levels.

Coating Defect Survey (Pearson Survey)

This survey is carried out to determine the soundness of pipeline coating by looking for defects. It measures an impressed electrical signal along the pipe.

Hydrostatic Testing

For pipelines not suitable for internal or external on-line inspection, hydrostatic testing should be undertaken. With certain liquids, this test can be carried out by utilising that product.

A frequency strategy for undertaking appropriate condition monitoring techniques described above must be developed, taking into account legislative requirements,

operation duty, corrosion and other evidence of deterioration, and pipeline life requirements.

6.5 Cathodic Protection

All pipelines should be protected from corrosion by protective coatings and cathodic protection systems. The cathodic protection systems can be of sacrificial anode type or impressed current type. The selected system must be monitored to ensure continued correct operation. The system should also be applied to appropriate steel sleeves.

A sacrificial anode system, normally utilising magnesium anodes, should be monitored regularly at pipeline locations of known low protection followed by a routine full monitoring inspection.

An impressed current system should be monitored regularly at the point of application of the protective current (transformer/rectifier units) followed by a routine full monitoring inspection.

6.6 Pipeline Facilities, Equipment and Components

The condition of pipeline crossings, valves, protection devices, pig traps and sleeves should be inspected or examined as part of the maintenance and operation strategy.

Pipeline crossings should be checked for mechanical integrity and degradation of concrete or above ground supports and remedial action scheduled if required.

Pipeline valves should be examined and functional checks covering actuation and movement. Specific consideration should be given to remotely operable valves.

Protection devices, including actuators, associated instrumentation and control systems should be checked to ensure adequate condition, verification of installation, accuracy of setting, adequacy of activation and the occurrence of any leaks.

Pig traps should be examined and inspected and any telemetry and data acquisition systems required during use should be tested and calibrated before use. Any identified remedial action should be completed and checked before operation.

The condition of pipe sleeves or casings should be assessed to confirm condition, electrical isolation and the occurrence of any leaks into or from the sleeve or casing.

6.7 Reporting of Damage and Defects

All damage to pipelines should be recorded and reported to the pipeline operator. Any defect found, generally following a maintenance or inspection activity, should also be recorded and reported. Following the report, an assessment of the damage or defect should be carried out by a competent person. The results of the assessment and of any remedial actions should also be recorded.

It is recommended that the operator establish a database of all reported damage and defects, which can be used to assist in establishing continued fitness for purpose. In addition, it is recommended that the occurrence of faults or failures on the pipeline should be recorded in the UKOPA pipeline fault database, to ensure that comprehensive and current pipeline reliability data is available for use by all UK operators.

Following damage to a pipeline, it may be necessary to reduce the safe operating limits and maximum operating pressure until remedial actions have been carried out.

6.8 Emergency Maintenance and Repair

In order to respond to maintenance and repair requirements following pipeline damage, the operator should have immediate access to appropriate plant, materials and expertise as is needed to undertake remedial action (see 8 – Emergency and Repair).

6.9 Defect Assessment

The operator should have in place a process for assessing defects. This should include a competent person or persons with suitable qualifications and experience to be able to assess the affect the defect has on the integrity of the pipeline against appropriate defect acceptance criteria. If the defect is beyond the acceptance level, the competent person should recommend repair methods or other remedial actions to re-establish fitness for purpose (see 7 – Defect Assessment).

6.10 Modification and Repair

The operator should have in place a system for recording design details of all proposed modifications and repairs and having them appraised and approved prior to being carried out (see 10 – Modification and Repair Procedure).

6.11 Records

The operator should have in place a system for generating and maintaining sufficient records as to enable continued fitness for purpose to be demonstrated (see 9 – Keeping of Records).

6.12 Pipeline Integrity Management

The overall assessment and management of pipeline integrity requires that all condition and inspection data is related and compared on a section by section basis along the pipeline. Specifically, this should allow the identification of co-incident occurrences of for example:

- Coating damage
- CP under or overprotection levels
- Metal loss
- Material defects
- Pipe features (such as welds)
- Impact or interference damage

The relational assessment of such data allows the priority of any remedial actions to be prioritised and scheduled such that the overall integrity of the pipeline is maintained.

A matrix showing the main pipeline maintenance and inspection activities and the key functions is given in Table 2, and recommended frequencies for individual activities is given in Table 3.

7. DEFECT ASSESSMENT

Operator defect assessment procedures should address requirements for the inspection and measurement of damage on site by competent personnel as well as any requirements for the management of the pipeline while such work is being undertaken. In addition, the defect assessment procedure should identify the codes or company procedures to be used to assess the damage and its impact on the strength and fatigue life of the pipeline.

There are a number of generally accepted international codes for the assessment of specific types of damage and identification of when repair is needed. The ANSI/ASME B31.G Manual for Determining the Remaining Strength of Corroded Pipelines gives guidance on corrosion damage. The codes BS 7910 and API RP 579 provide guidance on the assessing the acceptability of flaws and the assessment of fatigue design and remaining life in welded structures generally and this has been successfully applied to pipelines. API RP 579 provides guidance on methods and procedures for the fitness for purpose assessment of pressurised equipment containing flaws or damage, including the assessment of remaining life, remediation and in-service monitoring of flaws, and again has been successfully applied to pipelines. Company and industry specific documents are also available which extend these principles.

Finally, the operator defect assessment procedures should specify the recommended repair methods to be used in specific situations.

8. EMERGENCY AND REPAIR

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Regardless of the robustness of the maintenance and inspection regime, unpredicted pipeline failures do occur. It is therefore essential to react and respond quickly for both safety and economic reasons.

Emergency procedures must be in place to react to pipeline 'hits', from assessing the damage, categorising damage then carrying out repairs as necessary, to isolating the affected section and then carrying out repairs.

The emergency response must also include the availability of plant and materials, equipment needed to make safe and work on pipelines under pressure, together with trained teams who can react quickly to make the situation safe and undertake permanent repairs. It is recommended that where feasible, pipeline operators share information on the availability of specific materials and equipment through the UKOPA register of emergency materials and equipment.

Damage and defects must be repaired to a standard that will maintain the overall fitness for purpose level of the pipeline.

9. KEEPING OF RECORDS

It is essential that a complete and accurate set of records are produced and retained which identify the pipeline's route, construction details, modifications, repairs, material certificates, test records etc., in order to confirm that the pipeline is suitable for operating within its declared safe operating limits and maximum operating pressure.

Typically pipeline records should:

- demonstrate that the pipeline system is operated and maintained in accordance with the operating and maintenance plans, through the results of the in-service inspections, surveillance, monitoring and assessment activities.
- provide the information necessary for reviewing the effectiveness of the operations and maintenance plans (i.e. details of accidental events, and damage to the pipeline system, repair and modifications).
- provide the information necessary for assessing the integrity of the pipeline system, including operational data affecting corrosion and other deterioration mechanisms (i.e. fluid composition, flow rate, pressure, temperature etc.).

10. MODIFICATION AND REPAIR PROCEDURE

All diversions, modifications, repairs etc should be subject to a procedure that checks, appraises and approves the design of the proposed work and has it authorised by the user. The system must incorporate the collation of records to ensure continued fitness for purpose.

11. REVIEW OF STRATEGY

A process to continually review all maintenance and inspection practices should be established. This should include recording and keeping data for analysis of existing maintenance and inspection activities and frequencies, damage, defects, repairs and modifications, which can be used to continually develop a safe, reliable and cost effective maintenance and inspection strategy.

It is recommended that the regular internal audits of the documented operations and maintenance strategy are carried out to ensure that procedures are in place, activities are being carried out in accordance with the specified schedules, data is recorded and records are up to date. Such audits should include an assessment of the adequacy of the performance of the strategy through comparison with of specific operational data with established performance standards and general industry trends.