IGEM/TD/1 Edition 6
Communication 1848

Steel pipelines for high pressure gas transmission

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Communication 1789 (2016) – 5th Edition with amendments July 2016.

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SECTION 1 : INTRODUCTION

1.1 Recommendations on the installation of steel pipelines for high pressure gas transmission were first published by the Institution of Gas Engineers in 1965.

Recommendations, superseding the 1965 edition, were published progressively between 1970 and 1977 and consolidated in IGE/TD/1 Edition 1.

Later in 1977, the then Section 5, Design, was further revised and issued as IGE/TD/1 Edition 2.

IGE/TD/1 Complete Edition 2 was published in 1984, extending the maximum permissible design pressure from 70 bar to 100 bar.

IGE/TD/1 Edition 3 was published in 1993, introducing guidance for risk analysis and providing more comprehensive guidance for testing, commissioning and condition monitoring.

Three Supplements to IGE/TD/1 Edition 3 were published in 1999 and 2000 on handling, transport and storage of steel pipe, bends and fittings (Supplement 1), 1219.2 mm (48 in) pipelines (Supplement 2) and uprating the design factor to 0.8 (Supplement 3).

IGE/TD/1 Edition 4 was published in 2001.

Supplements 2 and 3 to Edition 3 were included in IGE/TD/1 Edition 4 whereas Supplement 1 to Edition 3 became a supplement to Editions 4 and 5 and is now a Supplement 1 to IGEM/TD/1 Edition 6.

IGEM/TD/1 Edition 5 was published in 2008 and updated with amendments in 2016.

IGEM/TD/2 Edition 2 (with Amendments) Assessing the risks from high pressure Natural Gas pipelines, was published in 2015.

1.2 IGEM/TD/1 Edition 6 has been drafted by a Panel appointed by the Institution of Gas Engineers and Managers (IGEM's) Gas Transmission and Distribution Committee, subsequently approved by that Committee and published by the authority of the Council of IGEM.

1.3 This Standard applies to the design, construction, inspection, testing, operation and maintenance of pipelines, designed after the date of publication. Hence, this Edition applies to all new pipelines and diversions, as well as modifications of existing pipelines.

Existing pipelines that comply with IGE/TD/1 Editions 1, 2, 3 or 4 or IGEM/TD/1 Edition 5 may continue to be operated in accordance with the respective Edition, although surveillance, inspection and maintenance may be undertaken in accordance with Edition 6. Operating conditions are not allowed to pass outside the limits of Edition 1, 2, 3, 4 or 5 as appropriate, unless the new conditions are consistent with Edition 6.

Furthermore, existing associated installations that comply with IGE/TD/9 (obsolete) or IGEM/TD/1 Edition 5 may be surveyed, inspected and maintained in accordance with IGEM/TD/13 Edition 3, if appropriate.

IGEM/TD/1 Edition 6 compliments, as far as is practicable, the requirements of BS EN 1594, the equivalent European standards on which IGEM/TD/1 provides more specific requirements.

1.4 Significant amendments to IGEM/TD/1 have been made in this Edition. These include:

i) Scope applies to steel pipelines operating at pressures exceeding 7 bar.

ii) Associated installations are transferred to TD/13 Edition 3.

Note: It is the owner's and/or the designer's responsibility to select the standard and standard sections which most appropriately apply to the connection of an associated installation to a pipeline.

iii) Pressure terms and criteria to align with IGEM/TD/13 and BS EN 1594, including design pressure (DP), maximum operating pressure (MOP) and maximum incidental pressure (MIP) are included.

iv) Pipeline MOP shall not exceed any prescribed design pressure and it shall not exceed the maximum working pressure of any component.

Note: A class rating or PN rating can define a component's maximum working pressure or MOP at the pipeline maximum operating temperature.

v) New Type H area is defined as an S area subject to creeping developments resulting in a population density greater than 30 persons per hectare. Where a new development is planned or occurs in such an area, a safety evaluation as described in Sub-Sections 2.1 and 6.8 is required.

vi) High-density polyethylene (HDPE) slabs are allowed for protection against third party damage.

vii) Requirements for Affirmation of MOP are revised to:

a. confirm measures to detect and control external interference

b. clarify the procedure for raising the pressure to the MOP to be applied where the pipeline has operated at more than 7 bar below the declared MOP for a period exceeding 5 consecutive years.

1.5 Engineering requirements are set out for the safe design, construction, inspection, testing, operation and maintenance of pipelines in accordance with current knowledge.

This Standard is intended to protect from possible hazards members of the public and those who work with pipelines, as well as the environment, so far as is reasonably practicable. It is also intended to ensure that the security of gas supply is maintained.

1.6 This Standard is applicable to conditions normally encountered in the transmission of gas. Additional design considerations may be necessary where unusual conditions are encountered. These may include unstable ground (including the possibility of mining subsidence), mechanical or sonic vibrations, long self-supported spans, massive special attachments or thermal forces other than seasonal.

Note: Some guidance on dealing with subsidence is provided in Section 6.

1.7 This Standard makes use of the terms "must", "shall" and "should" when describing particular requirements. Notwithstanding Sub-Section 1.9:

- the term "must" identifies a requirement by law in Great Britain (GB) at the time of publication
- the term "shall" prescribes a requirement which, it is intended, will be complied with in full and without deviation
- the term "should" prescribes a requirement which, it is intended, will be complied with unless, after prior consideration, deviation is considered to be acceptable

Such terms may have different meanings when used in Legislation, or Health and Safety Executive (HSE) Approved Codes of Practice (ACoPs) or guidance, and reference needs to be made to such statutory Legislation, ACoPs or official guidance for information on legal obligations.

1.8 It is now widely accepted that the majority of accidents in industry generally are in some measure attributable to human as well as technical factors. People who initiated actions that caused or contributed to the accidents might have acted in a more appropriate manner to prevent them.

To assist in the control of risk and proper management of these human factors, due account is be taken of HSG48 and HSG65.

1.9 The primary responsibility for compliance with legal duties relating to health and safety at work rests with the employer. The fact that certain employees, for example "responsible engineers", are allowed to exercise their professional judgement does not allow employers to abrogate their primary responsibilities. Employers must:

- have done everything to ensure, so far as is reasonably practicable, that there are no better protective measures that can be taken other than relying on the exercise of professional judgement by "responsible engineers"
- have done everything to ensure, so far as is reasonably practicable, that "responsible engineers" have the skills, training, experience and personal qualities necessary for the proper exercise of professional judgement
- have systems and procedures in place to ensure that the exercise of professional judgement by "responsible engineers" is subject to appropriate monitoring and review
- not require "responsible engineers" to undertake tasks which would necessitate the exercise of professional judgement that is beyond their competence. There should be written procedures defining the extent to which "responsible engineers" can exercise their judgement. When "responsible engineers" are asked to undertake tasks that deviate from this, they should refer the matter for higher review.

Note: The responsible engineer is a suitably qualified, competent and experienced engineer appointed to be responsible for the execution and for approval of activities associated with the design, construction, operation and maintenance of pipelines.

1.10 Notwithstanding Sub-Section 1.7, this Standard does not attempt to make the use of any method or specification obligatory against the judgement of the responsible engineer. Where new and better techniques are developed and proved, they should be adopted without waiting for modification to this Standard. Amendments to this Standard will be issued when necessary and their publication will be announced in the Journal of IGEM and other publications as appropriate.

1.11 Requests for interpretation of this Standard in relation to matters within its scope, but not precisely covered by the current text, to be either:

- addressed to Technical Services, IGEM, IGEM House, 26 & 28 High Street, Kegworth, Derbyshire, DE74 2DA; or
- emailed to technical@igem.org.uk.

and will be submitted to the relevant Committee for consideration and advice, but in the context that the final responsibility is that of the engineer concerned. If any advice is given by, or on behalf of, IGEM, this does not relieve the responsible engineer of any of their obligations.

1.12 This Standard was published in October 2021.

SECTION 2 : SCOPE

2.1 This Standard covers the design, construction, inspection, testing, operation and maintenance of steel pipelines and certain associated installations (see Figure 1), for the transmission of dry Natural Gas (predominantly methane), with or without odorisation, at MOP exceeding 7 bar and not exceeding 100 bar. The scope may be extended beyond MOP of 100 bar but specific areas will require further justification and documentation which embraces a safety evaluation.

While the Standard may be appropriate for use with other gases, the characteristics of the gas and the consequential effect upon design, material, operations and maintenance of the pipeline have to be taken into account. In this context, other gases are those described by 1st family, other 2nd family and 3rd family gases as defined in BS EN 437.

Note 1: Requirements for steel pipelines of MOP not exceeding 7 bar are contained in IGEM/TD/3, and on steel services in IGE/TD/4.

Note 2: A safety evaluation involves a systematic study of the major hazard potential of a pipeline and its associated installations (see Sub-Section 6.8).

2.2 This Standard covers operating temperatures between – 25 ˚C and + 120 ˚C inclusive.

2.3 This Standard applies to pipelines laid between points on land, including water crossings. For pipelines of which any part is offshore, additional or alternative guidance may be required for the offshore section. However, many of these requirements will remain valid.

Note: Offshore pipelines are those that are on the seaward side of the low water mark or special boundaries drawn at bays and estuaries.

This Standard equally applies to pipework design for certain associated installations, including buried block valves and pig trap installations. IGEM/TD/13 applies to PRIs, manifolds, multi-junction stations, the main pipework at compressor stations, metering installations, connections and other off takes.

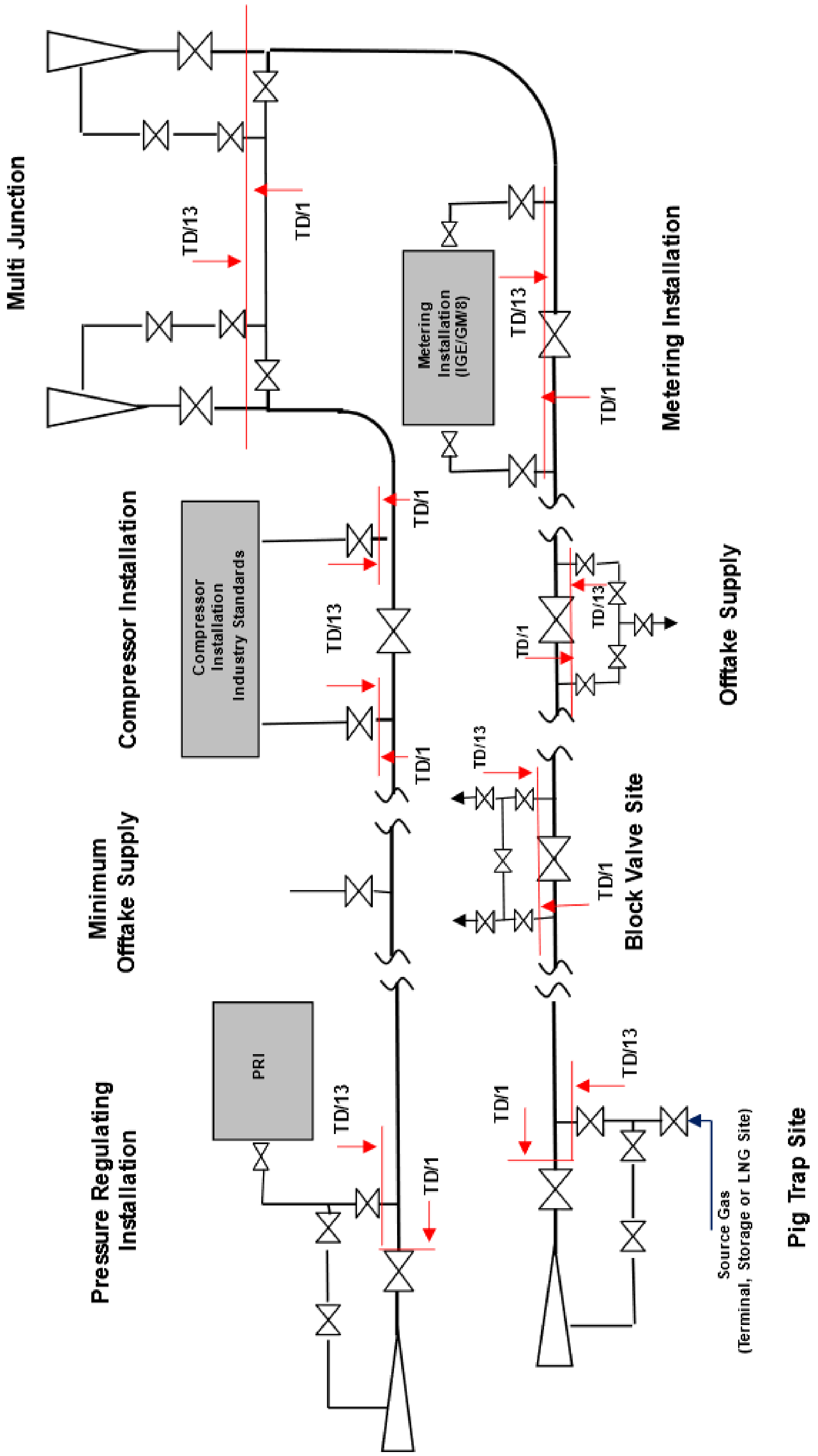
2.4 Pressures quoted are gauge pressure, unless otherwise stated.

2.5 Appendix 2 lists Legislation, Guidance Notes, Standards etc., which are identified within this Standard, as well as further items of Legislation that may be applicable.

Where Standards are quoted, equivalent national and international Standards, etc. equally may be appropriate. Unless otherwise stated the latest version of the referenced document is to be used.

2.6 Italicised text is informative and does not represent formal requirements.

2.7 Appendices are informative and do not represent formal requirements unless specifically referenced in the main sections via the prescriptive terms “must”, “shall” or “should”.



Note 1: *This diagram illustrates the interface between the design requirements of IGEM/TD/1 and IGEM/TD/13 – it does not demonstrate typical pipework arrangements.*

Note 2: *Additional design requirements for line valves, pig traps and overhead crossings are given in Section 6. These installations are to be tested, operated and maintained in accordance with IGEM/TD/1.*

FIGURE 1 - APPLICATION OF IGEM/TD/1 EDITION 6

SECTION 3 : MANAGEMENT SYSTEMS FOR PIPELINES

3.1 COMPETENCY

Any person engaged in the design, construction, commissioning, inspection, operation, maintenance or alteration of a pipeline shall be competent to carry out such work. This may be achieved by an appropriate combination of education, training, and practical experience.

3.2 QUALITY ASSURANCE AND QUALITY CONTROL

3.2.1 All materials and equipment shall be selected to ensure safety and suitability for the conditions of use, in accordance with relevant Legislation, standards, technical specifications and this Standard.

Note 1: All materials and components are to be obtained from suppliers operating a quality system in accordance with an appropriate standard such as BS EN ISO 9001 to ensure that products achieve consistently the required levels of quality.

Note 2: Material certification are to be critically reviewed to avoid procurement of counterfeit components. Guidance is provided in EEMUA Publication 224, A guide to risk-based procurement.

3.2.2 Effective arrangements shall be made to ensure that materials and workmanship are in accordance with the construction specification. All material certificates, test certificates, weld records and coat-and-wrap records shall be retained as part of the permanent construction record.

Particular emphasis should be placed on the inspection of materials, welding, pipe coatings, lowering-in, backfill, drainage, reinstatement, testing, and pigging operations. Any workmanship or materials not in accordance with this Standard or construction specifications should be rejected or an appropriate justification prepared.

3.2.3 The results of inspections shall be retained as an ongoing and permanent record of the pipeline.

3.2.4 A quality plan and associated work procedures shall be developed, to provide control and monitoring of all activities from design through to operation. A suitable audit plan should be formed to check adherence to procedures. A post construction site inspection audit can be used to establish that the as-built construction satisfies the design and construction requirements.

3.3 SAFETY MANAGEMENT (see Figure 2)

3.3.1 The initial integrity of any pipeline is established through proper design, material selection, sound construction practices and testing procedures. After commissioning and during operation, a programme of condition monitoring and maintenance shall be undertaken to ensure integrity is maintained (see clause 3.3.4).

3.3.2 In order to ensure that any installed pipeline operates at the levels of safety envisaged in Section 6, all of the requirements shall be considered and implemented as necessary. The criteria from any section of this Standard are not intended to be used in isolation. If changes are made to any criteria, the possible impact on other sections of the Standard should be considered.

Note 1: The integrity of a pipeline/pipeline system is dependent upon many inter-relating activities. Figure 3 shows the main links between the major activities. It does not attempt to show all the items necessary to ensure integrity, nor does it show the complex links within a major activity, but it does provide a flow chart/checklist to ensure that all aspects of integrity are being addressed.

Note 2: Increasingly, regulatory authorities require pipeline and installation operators to provide positive demonstration that integrity is properly established, monitored and maintained.

Note 3: Guidance on pipeline safety monitoring is given in UKOPA/GPG/003.

3.3.3 All workers involved in work on a pipeline or installations shall have the necessary qualifications, skills and experience for the work, and for the inspection and maintenance of the equipment they need to use.

All workers must be familiar with the workplace risks and the control measures in place.

Clear and effective communication shall be established and maintained with all parties throughout the planned operation. Consideration shall be given to language barriers where workers first languages are not the same. Hand signals can vary between countries so any non-verbal communication shall be well understood in advance of any operation.

3.3.4 After commissioning, continued integrity shall be ensured by implementing an appropriate safety management system (see also Sub-Section 3.4 and Figure 2).

Note: The safety management system would normally follow these principles in line with HSG65:

- *policy – the operator would have clearly defined policies which set out what is trying to be achieved in terms of safe management of the pipeline/installation*
- *organisation – there would be appropriate organisational structures in place to effectively deliver the policy requirements: These would include clearly defined roles and responsibilities within the organisational structure*
- *planning and implementation – there would be appropriate management controls in place to ensure that pipeline and/or installation operations are carried out safely and in line with the defined policies. These controls would include ensuring that individuals responsible for carrying out safety related activities have the appropriate training and competencies*
- *measure – the pipeline/installation performance would be measured against agreed standards to reveal when and where improvement is needed*
- *audit – there would be appropriate audit processes in place to ensure that policy requirements are being adequately delivered*
- *review – the overall management process would be under continuous review to ensure that it is delivering the required levels of performance. Normally, this would involve the monitoring of fault, accident and near miss data.*

The safety management system must be documented in the operator’s Major Accident Prevention Document (MAPD) and should be integrated within the operator’s Pipeline Integrity Management System (PIMS).

Note: Further guidance on safety management and PIMS (Pipeline Integrity Management System) is given in PD 8010 Pt.4, BS EN 16348:2013 and prEN 17649:2021.

3.4 ENVIRONMENTAL MANAGEMENT (see Figure 2)

Environmental management of any pipeline should be carried out in accordance with relevant statutory requirements and good engineering practice. Relevant statutory requirements include the environmental impact assessment (EIA), management of reinstatement materials, noise, management of radioactive materials and testing, disposal of waste (including water used for hydrostatic testing) and air emissions.

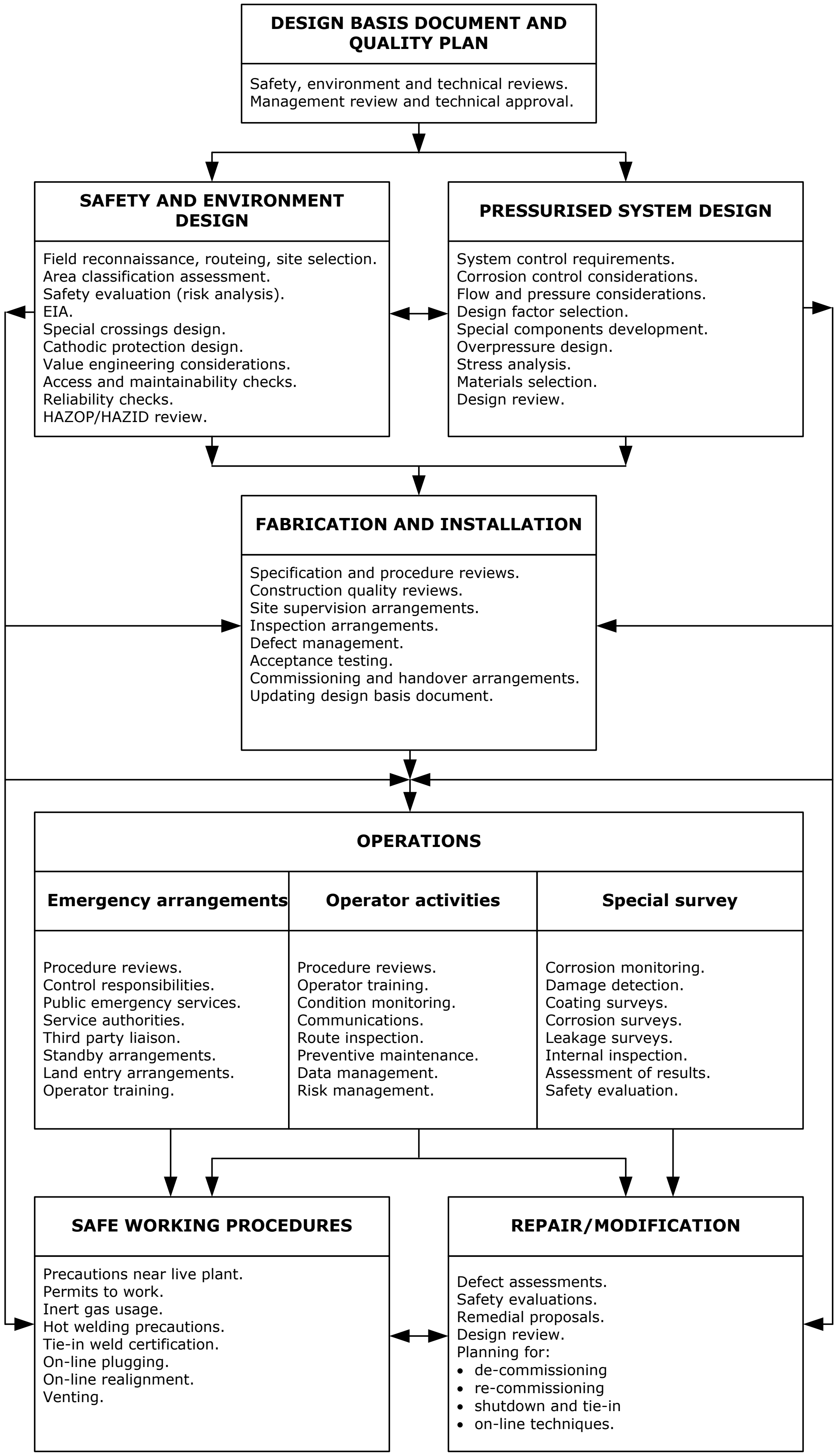


FIGURE 2 - SAFETY AND ENVIRONMENT MANAGEMENT SYSTEMS

3.5 INTEGRITY MANAGEMENT

Integrity is defined as the strength, quality and condition which provides resistance to applied loads and tolerance to damage such that the product is contained at an adequate level of safety. Comprehensive requirements for ensuring the integrity of a pipeline are given in Section 12. However, this Section concentrates on the integrity management of a buried pipeline, which in general is located on third party land and may be subject to activities of third parties, land use and environmental changes which are outside the control of the pipeline operator.

3.5.1 Integrity management process

3.5.1.1 Pipeline integrity shall be managed and controlled at all stages of the pipeline life cycle (see Figure 3). The primary requirement of the pipeline integrity management process is the identification of potential threats, evaluation of risks associated with each threat, and the implementation of specific risk control measures.

3.5.1.2 The threats to pipeline integrity include:

- material and construction defects
- ground movement
- external interference
- corrosion (external and internal corrosion, stress corrosion cracking (SCC), corrosion induced by AC/DC, etc.)
- fatigue
- overpressure.

These vary along the pipeline route, and this should be taken into account in the evaluation of risks and identification of risk control measures.

The requirements for pipeline integrity management at each stage of the pipeline life cycle required by this Standard are summarised in Table 1.

3.5.2 Integrity management system

3.5.2.1 A pipeline integrity management system, which facilitates the integration and relation of integrity data on a pipeline section-by-section basis, should be used to ensure that integrity data is accurately related to the condition of the pipeline protection, coating and pipe wall along the length of the pipeline.

3.5.2.2 The complexity of the system required should be determined by the operator taking into account the length, size and age of the pipeline, the operational arrangements and the competence and experience of personnel responsible for the management of pipeline integrity.

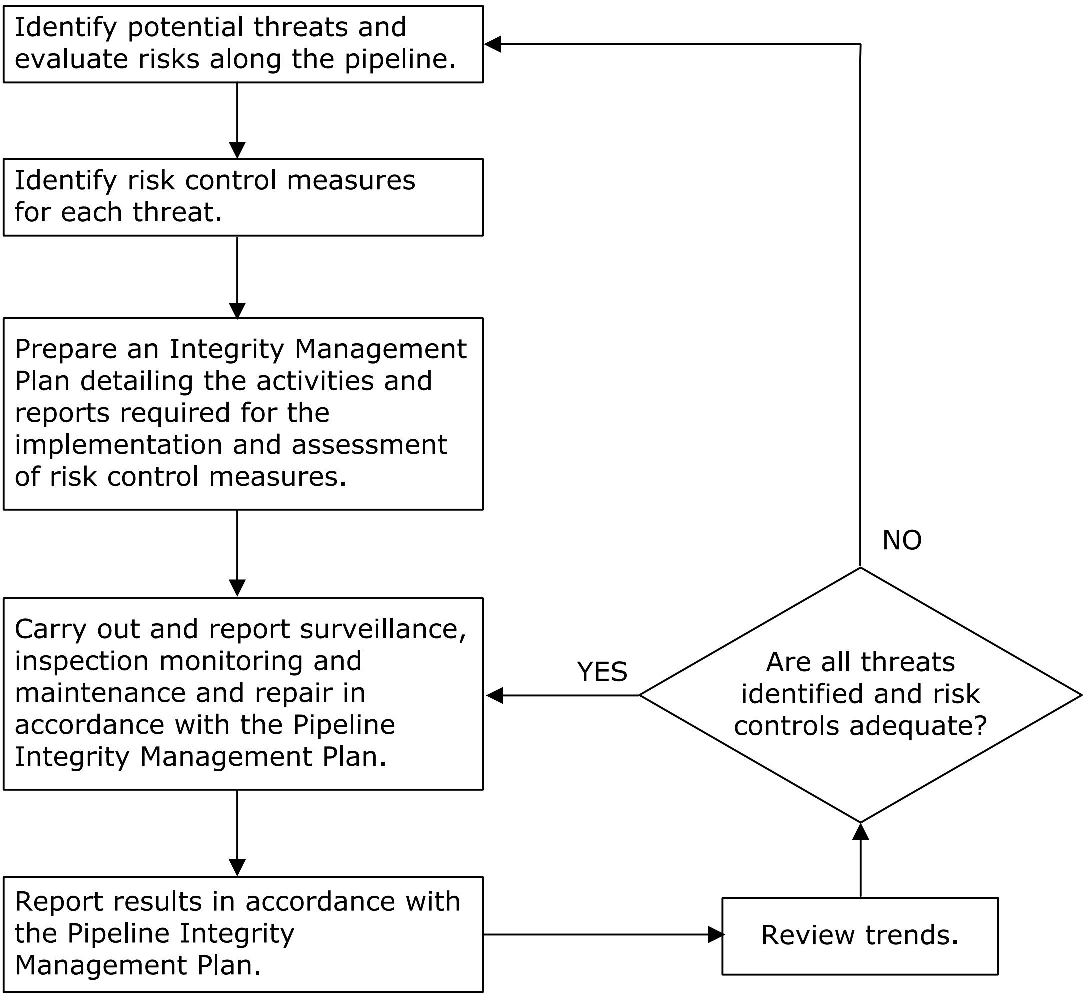


FIGURE 3 - PIPELINE INTEGRITY MANAGEMENT SYSTEM

STAGE OF PIPELINE LIFE CYCLE	INTEGRITY MANAGEMENT REQUIREMENT
Design	Identify route in accordance with Section 4. Select materials in accordance with Section 5. Design for area type, operational and additional loads and specific locations in accordance with Section 6. Apply corrosion protection in accordance with Section 10 to ensure an adequate level of design strength and resistance to loading and damage.
Construction and testing	Construct pipeline in accordance with Section 7. Test in accordance with Section 8 to ensure adequate quality.
Operation	Manage operational activities in accordance with safe operating procedures given in Sub-Section 12.2. Operate within the specified design limits in accordance with Sub-Section 12.4 to ensure an adequate safety margin is maintained.
Surveillance, monitoring, inspection, maintenance and repair	Survey in accordance with Sub-Section 12.7. Inspect in accordance with Sub-Section 12.8. Maintain in accordance with Sub-Section 12.9. Assess damage and repair in accordance with Sub-Section 12.9.

TABLE 1 - PIPELINE INTEGRITY MANAGEMENT REQUIREMENTS

SECTION 4 : PLANNING AND LEGAL CONSIDERATIONS FOR PIPELINES

The matters dealt with in this section refer to UK Legislation and their application to all aspects of the design, construction, commissioning, inspection, operation, maintenance, modification, decommissioning or disposal of a gas pipeline with an operating pressure exceeding 7 bar.

4.1 PLANNING

4.1.1 General

4.1.1.1 The effect a pipeline has on the environment depends largely on the route of the pipeline and shall be taken into account during design and construction.

4.1.1.2 The environmental impact of the route of a pipeline shall be assessed at an early stage. All areas requiring special consideration for environmental controls shall be identified and allowance made, thus minimising the possibility of changes in design or more expensive remedial measures on completion of the project.

Note: Consultation with outside organisations forms an important aspect of the route and the installation site selection process; not only to gather information on environmental issues but also to identify those issues perceived to be significant by third parties. These may require the use of "mitigation measures" such as special construction techniques, timing, etc. to achieve agreement on the acceptability of the project.

4.1.2 Route selection

This clause addresses pipeline routeing. Requirements for site selection for associated installations are given in IGEM/TD/13.

Route selection should be carried out in three levels of detail:

- Level 1: Route corridor selection
- Level 2: Preliminary route selection
- Level 3: Detail design.

4.1.2.1 *Level 1 – Route corridor selection*

The following applies for Level 1 route corridor selection. It identifies the preferred route by considering options from possible alternatives between the preferred start and end points within any area of interest.

Note 1: The evaluation of outline principles from desk study information allows informed decisions to be reached based on engineering and environmental constraints. Normally, this includes indicative costing and an outline programme indicating key dates and notification period to assist in the decision-making process.

Note 2: Preliminary consultation with planning authorities and consideration of local plans need to be included as part of the Level 1 work.

Note 3: Requirements for the environmental impact study need to be assessed during the Level 1 work programme and commenced, if required.

(a) The area of interest should be defined from the initial, intermediate and terminal points of the pipeline route, marked on suitably scaled maps, for example 1:50000, 1:25000, 1:10000.

Note: On longer pipelines, smaller mapping scales (1:250000) may be necessary for conceptual routeing.

Use of satellite imagery and/or aerial photography in the preliminary route selection should be considered.

(b) Route corridors should, as far as possible, avoid close proximity when parallel to high density traffic routes, railways, overhead electricity transmission lines, major pipelines or other buried plant.

(c) The length of the route should be kept to a reasonably practicable minimum.

(d) Possible route corridors should be identified using the following criteria:

- the pipeline start and finish points
- a safe route corridor that avoids populated areas where reasonably practicable and takes account of constructability
- any intermediate fixed points
- avoidance, as far as practicable, of any significant environmental, archaeological and future developments and of engineering constraints
- the shortest distance between the start and finish points, bearing in mind the above criteria and the implication for project costs
- the requirements in Section 6, including minimum proximity distances between the pipeline and normally-occupied dwellings.

(e) Records should be kept of factors influencing the final route, particularly those affecting construction, such as contours, crossfall, wet land, made-up ground, corrosion hazards (see Section 10), rock, landfill, areas of potential flooding and other special features.

(f) Note should be made of areas which call for early ground investigations, such as geomorphological or bore hole surveys, etc.

Consultation with geological and archaeological institutions should be carried out at this stage.

(g) The width of the route corridor depends on the complexity of the environment through which it passes but, in general, a width of 1 km should be used. The corridor width should also take into account any anticipated requirements for minor re-routes in congested areas.

Note: The corridor need not be of uniform width throughout its length and may alter in size due to constraints.

(h) Information required to select the route corridor should be sought from published sources, such as suitably scaled maps, geological surveys, etc. In addition, information on areas covered by major environmental designations should be obtained from published information or through the relevant planning authority(ies) and statutory environmental bodies.

(i) Sites for associated installations should be selected taking into account design criteria, access and environmental requirements (see IGEM/TD/13).

(j) The pipeline should be routed and designed in accordance with the requirements of Section 6.7 taking into account future development where this is identified or proposed.

(k) The selected route should be examined from vantage points such as public highways, high ground and other areas of unrestricted access.

Note: This may be supplemented by aerial photographic survey, visual survey by helicopter, satellite imagery or walking the route (subject to obtaining permission from the landowner).

4.1.2.2 *Level 2 – Preliminary route selection*

The Level 2 process should be used to identify and record more detailed information of environmental and other features, within the route corridor, that will be used to select a preliminary pipeline route. This may be used in negotiations with landowners/occupiers and as the basis for the next level of the process. Use of satellite imagery and/or aerial photography in Level 2 route selection work should be considered.

This phase of the planning process should be used to examine, develop and refine the proposed solutions/options to determine if they can meet realistically the specified project requirements. Ideas and working principles for the pipeline should be assessed in order to define the essential elements and options available, reducing them to just one for detail design (Level 3).

(a) Initially, the various constraints, and all potential planning problems likely to have an adverse effect on the pipeline route should be identified and recorded. Such constraints may be divided into, but are not limited to, the following categories:

- nature conservation
- ecology
- archaeology
- water resources
- land use
- landscape features
- planning policies
- agriculture
- socio-economic factors
- geology
- heritage features
- transport infrastructure.

Note: Some of these features may cover considerable areas requiring the boundary of the sites to be established.

(b) The scope of consultation should be expanded to include, but not be limited to:

- Landowners and relevant authorities
- conservation groups
- other utilities, etc.

(c) Negotiations for third party consents for special crossings should, normally, begin with the relevant authorities, for example railways, waterways, electricity infrastructure operators, telecoms, highways, etc.

(d) Any nature conservation site within the boundaries of the route corridor should be identified and recorded.

(e) Any statutorily-protected site or other known site of archaeological or heritage importance within, or in proximity to, the route corridor, should be identified and recorded.

(f) Any major water resource feature within the route corridor should be identified and recorded and information obtained on aquifer protection zones and major water abstraction sites.

(g) Any major geological feature should be recorded and its engineering implications considered.

(h) Any areas or type of existing land use that could affect the route and/or the design of the pipeline should be recorded.

(i) Any existing, planned or disused extraction zone should be identified and avoided where possible.

(j) Any area within the route corridor that is zoned for future development (domestic, industrial, commercial or mineral) or other developmental controls, should be identified and recorded. Discussions with relevant planning authorities, to establish recent changes in policies or departures from approved plans, should be considered.

(k) Any major landscape and topographical features within the route corridor should be identified and recorded, to avoid unnecessary difficulties or disturbance.

(l) Any areas of high-grade agricultural land within the route corridor should be identified and recorded.

(m) With all relevant information available, both from the above surveys and from the calculations carried out to comply with Section 6, a reference route should be selected and suitably scaled plans prepared (typically, 1:2500 or 1:10000).

Note: This requires a population density survey to be carried out in accordance with clause 6.7.2.

(n) At this stage, preliminary material requirements should be established in the form of a preliminary Material Take Off and the locations of the various grades and thicknesses of linepipe marked on the plans to comply with the marked area classification and route crossings etc., including the location and limits of heavy wall or proximity pipe.

4.1.2.3 *Level 3 – Detail design*

The Level 3 process should be used to identify and record information to refine the pipeline route.

(a) Permission should be sought from landowners to examine the route in detail, paying particular attention to those locations which impose engineering constraints on the proposed route, or of crossings where detailed surveys are required.

(b) Full consideration shall be given to designing for safety. This should include the use of specific construction techniques for pipeline details, and assessment of information regarding the physical nature of the land to assess whether this is likely to affect the safe constructability of the pipeline.

Note: Compliance with the Construction (Design and Management) Regulations (CDM) is required in the UK.

(c) Due regard should be paid to including suitably specified linepipe and protection at sites of future road/rail construction etc.

(d) Consideration shall be given to the completion of ecological and archaeological field surveys to define accurately the extent of a site or its environmental significance and to take any suitable mitigation measures. Ecological and archaeological surveys will form part of the EIA.

(e) Records should be kept of any special requirements necessary in respect of contagious/infectious animal and other diseases.

(f) The final examination of the route should identify whether any minor diversion is required to avoid short lengths of difficult terrain or to meet landowner/occupier objections or to facilitate trenchless construction/environmentally compatible construction techniques.

(g) Consideration shall be given to the negotiation of any use of access roads for construction or maintenance purposes and of the agreement of traffic management plans with local authorities (parking, access, egress, etc.).

Note: Planning approval may also be necessary for associated installations and cathodic protection (CP).

(h) Where necessary, planning permission should be obtained for temporary accommodation and material storage areas.

(i) Other "constraints" that occur along the route of the pipeline (noise, dust, availability of water and its means of disposal, etc.) should be identified.

Note: These are unlikely to affect the alignment of the pipeline but may have an effect on the design or management of construction.

(j) Fundamental environmental issues, to be addressed during construction, should be defined.

Note: These will contribute to an environmental management plan detailing requirements with regard to environmental matters and include appropriate emergency response procedures for environmental incidents such as spills, etc.

The plan should include details of actions to be taken once construction is completed, for example reinstatement of hedgerows, etc. Monitoring of the plan during construction and, possibly, operation, should be carried out to allow for any unforeseen impacts to be identified and controlled.

4.1.3 Land rights/easement details

4.1.3.1 Appropriate plans should be provided during negotiation of easements to enable establishment of the boundaries of each ownership and tenancy.

The information gained should be marked on suitable scale maps and each ownership given a separate reference number. The reference number should be used on all correspondence and the relevant easement file.

4.1.3.2 A "schedule of undertaking", setting out how to deal with the various aspects of the construction process, should be produced for issue to all landowners, occupiers, etc.

4.1.3.3 The working width should be specified.

4.1.3.4 The easement file should be readily accessible and contain the following information:

- easement reference number
- name and address of owner(s) and occupier(s) and their land agent(s) and legal adviser(s)
- name of the site where the easement is located
- field reference number or other means of identification
- map reference number and/or strip map number
- length of easement

- width of easement
- working width if different from the width of easement
- rate per unit length payable for easement
- total payment for easement
- date of deed of the easement and entry date
- special conditions applicable to any access routes and terms negotiated
- number of surface boxes or obstructions
- any special features, including marker posts.

4.1.3.5 When the consent of the owner(s) and occupier(s) has been obtained, the formal easement documentation should be prepared.

4.1.4 **Construction plans**

This sub-section addresses pipelines. Requirements for construction plans for associated installations are given in IGEM/TD/13.

4.1.4.1 Following the detailed examination/environmental assessment of the route, the construction maps (normally strip maps) and drawings should be prepared. Where critical clearances are required from existing features, these should be dimensioned on the strip maps as well as located by co-ordinates, to prevent small survey/co-ordinate inaccuracies resulting in unacceptable clearances.

The information on the strip map should include:

- the proposed position of the pipeline, showing any change of direction, wherever possible using a co-ordinated method based on a land survey
- the position of any associated installation, PRI, CP ground beds, AC mitigation schemes etc.
- pipe dump/accommodation access drawings
- easement details and special conditions
- details of additional and restricted working areas
- location of other services and apparatus
- cross reference to special crossings and other drawings
- local government and other relevant boundaries
- reference to any borehole or other geological information obtained
- any access routes negotiated
- changes in nominal wall thickness of the pipeline
- area classification details, i.e., R, S, H or T (see clause 6.7.1)
- road classification.

Note: Types of plans and drawings normally required, and their subsequent use, are shown in Table 2.

4.1.4.2 North points should be indicated on every drawing and strip map.

4.1.4.3 Strip maps should indicate the length and size of the pipeline. All field numbers, etc. should be shown.

4.1.4.4 Engineering line diagrams, indicating the extent of pressure regimes and the various control systems, should be prepared.

SCALE	USE BY PIPELINE PROMOTER	FOR ISSUE TO
1: 50000	Preliminary off-site survey.	Internal circulation.
1: 25000 or 1: 10000	Preliminary field survey. Contract documents. Land procurement.	Land agents.
1: 2500 or 1: 1250 in built up areas	Working drawings. Easement records. Permanent records. EIA.	Land agents. Contractors. Public bodies. Service industries where greater detail is required.
Larger scales	Construction details of special crossings, installations and other areas such as pipe dumps, access, and for record purposes.	Appropriate authorities and contractors.
Not to scale	Engineering line diagrams showing the extent of pressure regimes and control systems.	Internal circulation to appropriate bodies contractors.

Note: The suggested scales may be altered to suit local conditions.

TABLE 2 - TYPES OF PLAN USED IN PLANNING PIPELINES (TYPICAL EXAMPLE OF PLANS USED WITHIN THE UK)

4.2 LEGAL CONSIDERATIONS

The matters dealt with in clause 4.2.1 refer to general national and local legal requirements, particularly Legislation and its application to all aspects of design, planning, construction and operation.

The matters dealt with in clause 4.2.2 refer to specific UK Legislation in force at the time of publication.

4.2.1 General

4.2.1.1 *European Union (EU) Legislation*

In countries within the EU, it shall be ascertained, at the planning stage, whether a pipeline/associated installation is likely to be subject to EU Legislation.

4.2.1.2 *National and local Legislation*

Consideration must be given to relevant national and local Legislation which may control, regulate or protect, with respect to any pipeline:

- the route
- the specification
- the methods and procedures for construction
- the various authorisations, consents or permissions, whether from owners or occupiers of land through which a pipeline is laid or from private/public organisations having a function or interest in the construction
- the environmental impact.

4.2.1.3 *Land rights and easements*

It is advisable to obtain legal advice when proposing to develop land for any above-ground associated installation.

Holders of gas transporter licences have power under the Gas Act to obtain by negotiation the freehold or leasehold interest in land required for above-ground installations. Operators exempt from the need for a GT licence do not have such powers.

Whether a holder of a GT licence needs planning permission depends on the size of any structure which houses the above-ground installation and/or on where it is sited on land. The Town and Country Planning (General Permitted Development) Order provides the requirement (see clause 4.2.2.4). Any operator exempt from the need for a GT licence always needs planning permission.

Where an above-ground installation, including buildings housing a pipeline and/or associated apparatus, is to be constructed, planning permission must, generally, be sought.

The installing underground of an installation by a GT licence holder is permitted development under the Town and Country Planning (General Permitted Development) Order.

The rights necessary to lay, operate, inspect, maintain, repair and replace a pipeline and any ancillary equipment must be obtained from landowners and/or occupiers affected by the pipeline.

Note: Usually, this can be done by negotiation and agreement, but it may be appropriate to use compulsory powers of acquisition where appropriate Legislation is available for use.

The rights acquired should be such as to permit the satisfactory construction, use, maintenance and replacement of the pipeline and should last for at least the anticipated life of the pipeline/associated installation or the gas supply agreement.

Note: The precise nature of the rights acquired may vary according to the country of operation.

Excavated and other material should not be removed from the support strip without the landowner’s consent.

Care shall be taken to prevent dumping of material over the pipeline, to avoid excessive cover.

The rights shall anticipate the possibility of the whole or parts of the pipeline becoming redundant and/or being put to an alternative use.

Of special concern are the access rights of the pipeline easement, which should anticipate the needs of construction, remedial works to the land following construction and subsequent remedial works to, or replacement of, the pipeline, including consideration of storage and parking facilities on land contiguous to and neighbouring the pipeline.

Note 1: It is unlikely that access along the easement alone would be sufficient.

Note 2: Restrictions may apply to investigation works outside the perimeter of the landowner’s boundary, e.g., location of drilling equipment for borehole investigations.

Legal advice should be sought on the content of easement to be acquired and, in particular, on any problem likely to arise on the abandonment of the whole or parts of the pipeline.

The resultant form of agreement with the landowner/occupier should, typically, deal with:

- use of the pipeline
- access
- safe operation of the pipeline (including CP)
- restoration of drainage
- development of the land through which the pipeline runs or on which an associated installation is located.

4.2.1.4 *Building or engineering work*

Where necessary, permission must be sought for any building or engineering work, from public organisations charged with responsibilities for building and environmental control.

4.2.1.5 *Health and safety law*

Compliance must be achieved with any relevant health and safety law.

Note: This may affect to a considerable degree the route of a pipeline in terms of the acceptable proximity to significantly inhabited areas, the specification for the pipeline, the actual method of construction and the general working environment during construction and operation.

4.2.1.6 *Environmental protection*

The route of a proposed pipeline must take all relevant environmental considerations into account, including the special protection given by law to flora, fauna, the prevention of spreading invasive species and areas of special scientific, geological and historical interest, as well as the restrictions and prohibitions on building and engineering works which may arise. Consideration shall be given to the possible emissions of odour, dust, and noise.

4.2.1.7 *Transmittable diseases*

Consideration shall be given to the possibility of construction being affected by outbreaks of infectious/contagious animal and other diseases along, or in the vicinity of, the proposed route.

Advice should be taken to ensure that, where such outbreaks exist, appropriate procedures and practices are adopted so as to comply with both good farming and veterinary practice and relevant legal restrictions.

4.2.1.8 *Rivers, canals and foreshores*

Where crossings of rivers, canals or foreshores are contemplated, appropriate authorities or owners should be consulted. Information on tidal flows should be requested.

Note: Local Regulations may be in force which affect proposals to lay pipes over, under or adjacent to rivers, canals or foreshores.

4.2.1.9 *Railway land*

Consultation with railway undertakings should be carried out at an early stage where it is proposed to cross under or through the land of a railway undertaking.

4.2.1.10 *Deposits of waste*

The disposal of all wastes which are poisonous, noxious or polluting and likely, after disposal on land, to give rise to an environmental hazard, shall be given special attention.

Note 1: The activity may require authorisation or licensing from an appropriate authority.

Note 2: Disposals of non-toxic wastewater may be subject to licensing with special conditions and the advice of any relevant authority would need to be sought.

The dumping of waste at sea, whether in territorial waters, tidal waters, rivers or estuaries, may involve the obtaining of a licence, whether from government or a public authority, hence an approach should be made to the appropriate authority before such activities are undertaken.

4.2.1.11 *Control of noise*

Consideration must be given to the Legislation controlling the noise of construction works, and also should be given to the concept of being a good neighbour to those along a pipeline route.

4.2.2 **Legal considerations in the UK**

4.2.2.1 *Gas Act*

The construction of a high pressure gas pipeline is an activity which a holder of a GT licence is entitled to undertake under the Gas Act as amended.

In certain circumstances, holders of GT licences have powers to place structures and apparatus near houses, in streets.

4.2.2.2 *Pipelines Act as amended*

The Act regulates onshore pipelines in GB, except those of holders of GT licences, water companies, the government, and some other (minor) classes of pipeline. The Act creates two categories of pipeline:

- "Cross-country" pipelines (those exceeding 16.093 km long) require authorisation from the Secretary of State by means of a Pipeline Construction Authorisation (PCA) which carries deemed planning permission
- "Local" pipelines (those 16.093 km or less in length) including diversions and connections which do not require authorisation from the Secretary of State.

4.2.2.3 *New Roads and Street Works Act (NRSWA)*

In laying pipelines in streets, regard must be given to Part III (in Scotland, Part IV) of this Act. This requires street authorities to issue works licences and maintain a streetworks register, with the intention of co-ordinating works. Advance notice of certain works will be required, together with notices for starting dates of works.

4.2.2.4 *Town and Country Planning Act*

The laying underground of pipes or other apparatus by the holder of a GT licence is permitted development under the Town and Country Planning (General Permitted Development) Order. Parties operating under exemptions for the requirement for a GT licence require planning permission for their works.

4.2.2.5 *Health and Safety at Work etc. Act (HSWA)*

HSWA sets out general duties which employers have towards employees and members of the public, and employees have to themselves and to each other. It is also the "umbrella" under which safety Regulations are made, for example:

- Management of Health and Safety at Work Regulations (MHSWR)

  MHSWR apply to all work activities involving pipelines and require, among other things, that employers assess the risks to the health and safety of their employees and of persons not in their employment but who may be affected by their activities and then to make appropriate arrangements for preventative and protective safety measures.

- Pressure Systems Safety Regulations (PSSR)

  PSSR impose duties on designers, importers, suppliers, installers and users or owners to ensure that pressure systems do not give rise to danger due to the release of stored energy. This is done by the correct design, installation and maintenance, provision of information, operation within safe operating limits and, where applicable, examination in accordance with a written scheme of examination drawn up or approved by a competent person (as defined by PSSR).

  Relevant fluids for the purpose of this document would be Natural Gas at a pressure greater than 0.5 bar above atmospheric pressure. A pressure system would include bulk storage tanks, pressure vessels, pipelines and protective devices. Once the pressure in the pipework drops below 0.5 barg, and the user/owner can show clear evidence that the system does not contain, and is not liable to contain, a relevant fluid under foreseeable operating conditions, then that part of the system is no longer covered by PSSR. This is likely to be the case after the pressure relief valve associated with a pressure reducing valve which takes the pressure to below 0.5 barg, for example at the entry to a building.

  Note: The special requirements placed on protective devices in such systems (see para 110b of L122). PSSR also apply to pipelines and their protective devices in which the pressure exceeds 2 barg (see Sch 1 part 1 item 5 of L122). More information is available in L122 and some information is presented in the HSE free leaflets INDG 261 and INDG 178.

  Inspection is the process that ensures that the installation is suitable for further operation within the design or performance limits specified by the designer or competent person.

  It shall be determined whether an installation is within the scope of PSSR and, if so, safe operating limits shall be specified and written schemes of examinations must be available prior to commissioning.

- Pipelines Safety Regulations (PSR)

  PSR apply to pipelines constructed in Great Britain, both on and offshore, but exclude pipelines that are:
  - wholly within premises
  - contained wholly within caravan sites
  - used as part of a railway infrastructure
  - convey water.

  Above-ground installations are considered to be included in the definition of "pipeline" and are subject to PSR.

  Gas pipelines operating at a pressure of 7 bar or more are "Major Accident Hazard Pipelines" and are subject to additional duties, including notification to

HSE, the preparation of emergency plans and procedures, etc. PSR complement the Gas Safety (Management) Regulations (GS(M)R) and include:

- the definition of a pipeline
- the general duties for all pipelines
- the need for co-operation between pipeline operators
- arrangements to prevent damage to pipelines
- the description of a dangerous fluid
- notification requirements
- the major accident prevention document
- the arrangements for emergency plans and procedures.

- Gas Safety (Management) Regulations (GS(M)R)

  GS(M)R deal with the safe management of gas, whether a single system or a network of connected systems. It is unlawful for gas to be conveyed in a system or network without a safety case being prepared by the operator and accepted by HSE.

4.2.2.6 *Construction (Design and Management) Regulations (CDM)*

CDM place a duty on clients, designers and contractors to take health and safety matters into account and manage them effectively from the planning stage of a construction project through to commissioning and beyond.

4.2.2.7 *Provision and Use of Work Equipment Regulations (PUWER)*

PUWER place duties on employers in relation to selection, suitability, maintenance, inspection, installation, instruction and training, prevention of danger and control of equipment.

Note: More information on PUWER can be found in L22. Free leaflets include INDG 291 and INDG 229.

4.2.2.8 *Electricity at Work Regulations*

These Regulations apply to a wide range of electrical work, from overhead power lines to the use of office computers and batteries and include work on gas equipment using electrical energy.

They are concerned with the prevention of danger from electric shock, electric burn, electrical explosion or arcing, or from fire or explosion initiated by electrical energy.

They impose duties on every employer, employee and self-employed person and require that persons engaged in electrical work be competent or be supervised by competent persons.

Note: A "Memorandum of Guidance on the Electricity at Work Regulations, 1989" is available from HMSO and gives useful information on the Regulations. Further advice is contained in HS(R)25.

4.2.2.9 *Control of Substances Hazardous to Health Regulations (COSHH)*

COSHH, which reinforce existing statutory obligations under HSWA, impose a duty on employers to protect employees against risks to health, whether immediate or delayed, arising from exposure to substances hazardous to health, either used or encountered, as a result of a work activity. They also impose certain duties on employees.

Under COSHH, work must not be carried out which is liable to expose employees to hazardous substances unless the employer has made a suitable and sufficient assessment of the risk created by the work and the steps that need to be taken to comply with COSHH. After assessing the risk, it is necessary to inform employees of the risks and to carry out the appropriate training and instruction to ensure the risks are minimised. In certain cases, control measures such as ventilation or personal protective equipment may be necessary and, where provided, they must be used.

4.2.2.10 *Dangerous Substances and Explosive Atmospheres Regulations (DSEAR)*

These Regulations incorporate:

- ATEX Directive 94/9/EC (ATEX 95) – Safety of Apparatus
- ATEX Directive 99/92/EC (137A) – Safety of Installation
- Chemical Agents Directive (CAD) 98/24/EC.

DSEAR are concerned with protection against risks from fire, explosion and similar events arising from dangerous substances used or present in the workplace. DSEAR require that risks from dangerous substances are assessed, eliminated or reduced. They contain specific requirements to be applied where an explosive atmosphere may be present and require the provision of arrangements to deal with accidents, emergencies etc. and provision of information, training and use of dangerous substances. DSEAR also require the identification of pipelines and containers containing hazardous substances.

The following publications contain details of DSEAR and their application:

- L138
- INDG 370.

4.2.2.11 *Trees*

Under the Forestry Act, a licence from the forestry commissioners is not required for the felling of trees where the felling is immediately required for the purpose of carrying out permitted development but, where a tree preservation order under the Town and Country Planning Act is in force, the consent of the local authority must be obtained.

Under the Hedgerows Regulations, permission is required from the local planning authority for the removal of most countryside hedgerows.

4.2.2.12 *Transmittable diseases*

The Department of Environment, Food and Rural Affairs (DEFRA) advises that, at least one month before commencing work on agricultural land (or land previously used for agriculture), the DEFRA Divisional Officer and, in England and Wales, the Senior Plant Health and Seeds Inspector, or the Seeds Inspector, or in Scotland the Principal Agricultural Officer for the area concerned, should be contacted with respect to:

- any statutory restrictions which apply to the site or its immediate vicinity and any special precautions which may need to be taken, for example orders made under the Animal Health Act may regulate operations in infected areas
- the presence of any soil-borne diseases, for example rhizomania of beet, wart disease of potatoes etc.
- presence of carcass burial pits on the site or in its immediate vicinity.

Note: If the development involves removing trees, it is advised that the area Forestry Commission Plant Health Inspector be consulted for advice on how to avoid spreading tree diseases.

4.2.2.13 *Rivers, canals and foreshores*

Part 1 of the Environment Act established the Environment Agency (EA) and the Scottish Environment Protection Agency in Scotland (SEPA), and provided for the transfer of functions from the National Rivers Authority (NRA). The EA and SEPA determine and grant consents to discharge wastes into controlled waters and charge for such work – this includes the discharge of water which has been used for hydrostatic testing. In England and Wales, the EA also regulates the abstraction of water (which requires an abstraction licence).

The EA and SEPA also undertake pollution control and have the power to prosecute where "poisonous, noxious or polluting matter" is allowed to enter controlled waters. This includes the discharge of silty water from construction sites. Guidance on how to manage sites is obtainable from either agency in the form of Pollution Prevention Guidelines (PPGs), in particular PPG6 "Working at Construction and Demolition Sites".

The Canal & River Trust is a statutory body established by the Transport Act. It owns and manages approximately 2000 miles of canals and river navigations. The Canal & River Trust Code of Practice (COP) for works affecting the Canal & River Trust governs works that might affect its waterways and properties.

Consultation is required with relevant statutory water bodies including drainage boards where applicable.

Where works are to be constructed in, under or over the seashore below the high-water mark of ordinary spring tides, the consent of the Secretary of State is required under Section 34 of the Coastal Protection Act. Where the works are to cross the foreshore, an easement must be obtained from the owners, generally, the Crown Estate Commissioners.

4.2.2.14 *Railway land*

Where apparatus is to be laid through land owned or operated by railway infrastructure operators, the appropriate officers should be consulted at an early stage.

4.2.2.15 *Deposits of wastes*

Waste is defined in schedule 22 of the Environment Act as a substance or object which a holder discards or intends or is required to discard. This definition is based upon an EC (European Community) Directive 91/156 and is, therefore, known as "directive waste". "Controlled waste" is defined by the Environmental Protection Act (EPA) as "household, industrial and commercial waste". Controls under EPA, for example licensing requirements and the Duty of Care, apply only to controlled waste which is also "directive waste".

Section 34 of EPA introduced a duty of care for waste management. The duty of care applies to anyone who produces, imports, carries, keeps, treats, or disposes of controlled waste. There are a number of objectives, outlined below, which duty holders should achieve, as is reasonable in the circumstances.

Every person who is subject to the duty of care must ensure not only that they do not commit an offence but that any other person does not similarly commit an offence. In practice, this means that a waste holder is responsible for taking steps to prevent offences involving waste that they have controlled at some point. They must try to prevent other people from disposing of, treating or storing the waste:

- without a licence
- breaching the conditions of a licence
- in a manner likely to cause pollution or harm to health.

The producer or importer of waste must package it in such a way as to prevent escape of leakage while on site, in transit or in storage. The waste producer or holder must ensure that waste is only transferred to an authorised person. The categories of authorised persons are:

- a waste collection authority
- the holder of a waste management licence or someone who is exempt from holding a licence
- a registered carrier of controlled waste, or someone who is exempt from registration
- a waste disposal authority in Scotland.

In addition, an accurate, written description of the waste must be provided by the producer or importer of the waste and transferred alongside the waste at each stage.

4.2.2.16 *Control of noise*

Noise is a major issue both for designers who should endeavour to “design out” noisy processes wherever possible, and managers of construction/demolition sites where the potential of nuisance should be recognised at the earliest possible stage.

Part III of the Control of Pollution Act (COPA) relates to construction site noise, which is subject to noise abatement zones and licensing enforcement by the local authorities. Under Section 60 of the Act, local authorities have powers to control noise (and vibration) on or from building sites. This control is by the service of a notice placing obligations on the person responsible for the construction operations to observe specified controls to minimise noise. Such a notice can specify types of plant and machinery, permitted hours of operation, boundary noise levels, etc.

When drawing up such requirements, the local authority have regard to any code of practice approved or issued under COPA. They must also have regard to the concept of Best Practicable Means and any alternative plant or machinery which may be used.

BS 5228 has been adopted for this purpose (noise control on construction and open sites (in four parts)). Although these codes have been issued or adopted under COPA, they are not legally binding in themselves. However, the content of each should be taken to represent current good practice.

Noise abatement zones are established essentially for the purpose of rationalising competing sources of noise, particularly where industrial premises and domestic premises are in proximity. Local Authorities are required to keep registers of noise levels of specified premises within noise abatement zones.

Part II of EPA relates to statutory nuisances, which include noise nuisances. Statutory nuisances are defined as including circumstances in which noise is emitting from premises so as to be prejudicial to health or a nuisance. The local authority can serve an abatement notice and enforce criminal proceedings before a Magistrates Court in the event of non-compliance without reasonable excuse.

The Noise and Statutory Nuisance Act amends EPA to make noise from vehicles, machinery or equipment in the street a statutory nuisance. If the local authority is satisfied that noise from vehicles, machinery or equipment in the street is causing, or is likely to cause, a nuisance, it must serve an abatement notice on the person responsible.

4.2.2.17 *Pipe laying across country*

There are many bodies and authorities which have an interest in the operations of pipe laying across country. The following list, which is not exhaustive, identifies some of the key consultees:

- Planning officers of Country and District Councils, Local Unitary Authorities and, in Scotland, Regional Councils
- English Nature, Countryside Agency (England), and Countryside Council for Wales and Scottish Natural Heritage
- EA (England and Wales) and SEPA (Scotland)
- DEFRA
- Department for Transport, Local Government and the Regions (DTLR)
- Historic England and Historic Scotland
- Department for Business, Energy and Industrial Strategy (BEIS)
- HSE
- Country Landowners Association and the Scottish Landowners Federation
- National Farmers Union and the National Farmers Union of Scotland
- The Coal Authority
- Utilities – electricity, water, telecoms and gas companies etc.

4.2.2.18 *Environmental protection*

Consideration shall be given to the need for an environmental assessment under Regulations implementing EC Directive 97/11/EC.

For holders of GT licences, the relevant Legislation is the Public Gas Transporter Pipeline Works (Environmental Impact Assessment) Regulations. These make an Environmental Assessment mandatory for gas pipelines of more than 800 mm diameter and more than 40 km long.

In addition, schedule 3 of the Regulations describes pipeline works for which an environmental statement may be required and includes pipelines which pass through sensitive areas (as defined by the Regulations) or which operate at pressures greater than 7 bar. Such pipelines require an environmental determination by the Secretary of State at DEIS as to whether an EIA is required, unless a voluntary EIA is undertaken. Early recognition of the need for an EIA, or the need for an environmental determination, is essential if delay is to be avoided during later planning stages.

For parties exempt from the requirements to hold a GT licence, the relevant Regulations are the Pipeline Works (Environment Impact Assessment) Regulations and the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations.

For projects identified as requiring an environmental determination, it is recommended that as much information as possible is gathered at an early stage, so that the request for a determination can be accompanied by sufficient information to meet the requirements of schedule 3. A supporting statement should also accompany any request for a determination from the relevant planning authority expressing their opinion of the project.

An EIA requires consideration for the environment and public participation in the decision-making process of project development. An Environmental Statement (ES) is a review document prepared for assessment in the EIA process which should consider both the adverse and the beneficial effects of the project, their significance and the mitigation measures to be applied. Hence, for pipelines where EIA is required, this process will subsume the need for a Level 3 environmental study (see clause 4.1.2.3).

SECTION 5 : MATERIALS FOR PIPELINES

This section deals with materials for pipelines. Requirements for pipework on associated installations is given in IGEM/TD/13.

5.1 STANDARDS

Linepipe and fittings shall be selected from appropriate standards (suitable example references are provided below) in accordance with the specification required to meet the design requirements. The material specification should detail the specific testing and inspection requirements to be applied to all materials.

5.2 OPERATING AND DESIGN TEMPERATURES

5.2.1 For the majority of a buried transmission system, the normal operating temperature will vary according to the seasonal changes in the ground temperature, and the distance from compressor stations and PRIs. In GB, this will exceed 5 °C. The minimum design temperature should be 0 °C.

Note: In some areas and at some points in a system, the temperatures may be lower or higher than the nominal operating temperature due to local influences. In these circumstances, another design temperature may be appropriate.

The most common examples are:

- *at the exit from a PRI where pipe normally will be at a lower temperature for a considerable distance downstream*
- *at the exit from a compressor station where pipe normally will be at a higher temperature. However, consideration needs to be given to the conditions when the compressor is not working*
- *at an exposed overhead crossing or other above ground associated installation, including a PRI, where the pipe could be at a lower or higher temperature than normal due to ambient temperature or solar heating. Normally, raised temperatures due to these conditions do not influence the material properties of linepipe or fittings, but consideration has to be given to the influence of temperatures both above and below normal on the materials used for coating, lining and cladding.*

5.2.2 Materials should have adequate fracture toughness at or below the minimum design temperature.

Note: In GB, the minimum design temperature of above-ground pipework is usually taken as -20°C. However, materials that are impact-tested at 0°C and have a wall thickness of 15 mm or less may be used at a design temperature down to -20°C provided they satisfy all the impact testing requirements of Annex D of PD 5500.

5.2.3 The material properties of linepipe, fittings, coating and lining should be adequate for the conditions that arise both at the minimum and maximum design temperatures, including the effects of contraction and expansion due to climatic temperature variation, as well as the normal design condition.

5.3 LINEPIPE

5.3.1 Specification

The quality of linepipe should be verified with respect to strength and toughness, for example measured using the Charpy V Notch impact test and the Drop Weight Tear Test (DWTT), and if required, weldability, by testing in accordance with the appropriate linepipe specification.

Steel linepipe is available in a range of grades, defined by specified minimum yield strength (SMYS). The strength should be selected in conjunction with other design parameters to provide an optimum pipeline design.

Note 1: The material standards most commonly specified for linepipe worldwide are API 5L and BS EN ISO 3183. In Europe, increasing use is now being made of BS EN ISO 3183 Annex A *which applies to onshore gas transmission pipelines and is the linepipe standard referenced in BS EN 1594. ISO 3183 is referenced in ISO 13623 which has been adopted as BS EN 14161. Other industry specifications may be used to specify additional requirements, for example with respect to toughness, dimensions, fatigue etc. to the above national and international standards.*

Note 2: *Minimum toughness levels ensure that a pipeline has adequate resistance to fracture initiation and can be operated within its design limits without risk of propagating brittle or ductile fractures. For further guidance, see clause 5.3.4.*

Note 3: *Where necessary, requirements for steel weldability may be agreed to ensure the maximum opportunity for high quality construction under field welding conditions.*

5.3.2 Methods of pipe manufacture

The methods of manufacture of a pipe should be selected from Table 3.

METHOD OF MANUFACTURE[1]	**NORMALLY AVAILABLE SIZE**[2]
Seamless	610 mm diameter and below
High frequency welded[3] (HFW)	660 mm diameter and below
Straight seam SAW (SAWL)	406 mm diameter and greater
Helical SAW[3] (SAWH)	457 mm diameter and greater[4]

Note 1: *Other methods of manufacture may be considered.*

Note 2: *Some dimensions may be available only where orders are made directly with the manufacturer and will not be readily available from stock.*

Note 3: *Pipes containing strip end welds (where one coil of steel is welded onto the adjoining coil during the manufacturing process) are not to be used.*

Note 4: *Recommended wall thickness < 25.4 mm and recommended API 5L grade X65 and below (ISO 3183 grade L450 and below) (see Table 4).*

TABLE 3 - METHODS OF PIPE MANUFACTURE

5.3.3 Strength grades

SMYS and specified minimum tensile strength (SMTS) of commonly used grades of pipe to BS EN ISO 3183 and API 5L are given in Table 4 which should be referenced and used when selecting pipe.

API 5L			BS EN ISO 3183 Annex A		
Grade	**SMYS N mm^{-2}**	**SMTS N mm^{-2}**	Grade	SMYS N mm^{-2}	SMTS N mm^{-2}
L245[1] or B[1]	245	415	L245[3] E	245	415
L290[2] or X42[1]	290	415	L290[3] E	290	415
L320[2] or X46[2]	320	435			
L360[2] or X52[2]	360	460	L360[2] E	360	460
L390[2] or X56[2]	390	490			
L415[2] or X60[2]	415	520	L415[2] E	415	520
L450[4] or X65[4]	450	535	L450[4] E	450	535
L485[4] or X70[4]	485	570	L485[4] E	485	570
L555[4] or X80[4]	555	625	L555[4] E	555	625
L625[5] or X90[5]	625	695			
L690[5] or X100[5]	690	760			
1. Grade suffix : N, Q, M 2. Grade suffix : N, Q, M 3. Grade suffix : N, M 4. Grade suffix : Q, M 5. Grade suffix : M (see Note below)			Grade suffix: N = normalized or normalized rolled/formed Q = quenched and tempered M = thermomechanically-rolled		

Note: X90 and X100 grades may not fulfil IGEM/TD/1 requirements, so additional analysis will be needed before selecting these grades.

TABLE 4 - MATERIAL GRADES, SMYS AND SMTS

Note: Guidance on standard sizes of carbon steel and carbon manganese steel for operating pressures greater than 7 bar is given in GIS/DAT/6:2019

5.3.4 Testing

5.3.4.1 Testing shall be carried out in accordance with Annex A of BS EN ISO 3183.

5.3.4.2 Linepipe material shall meet the specified impact properties, established by suitable tests at an appropriate temperature (see Sub-Section 5.2).

5.3.4.3 For linepipe of diameter exceeding 323.9 mm, a full wall thickness DWTT shall be used to assess resistance to prevent propagating brittle fracture.

5.3.4.4 The full wall DWTT shall be carried out at a temperature of 0 °C.

5.3.4.5 For linepipe of diameter not exceeding 323.9 mm, extraction of a sample for DWTT is not possible and Charpy testing at an appropriate test temperature to guard against brittle fracture should be substituted.

5.3.4.6 The Charpy test pieces shall be prepared in accordance with BS EN ISO 148-1 (using a 2 mm radius striker) without flattening. The axis of the notch shall be perpendicular to the pipe surface.

Where pipe dimensions are such that transverse Charpy specimens of at least 10 mm x 5 mm cannot be obtained, see API 5L Table 22, longitudinal Charpy impact test pieces shall be used instead. Pipes of specified thickness less than 6.3mm need not be impact tested.

5.3.4.7 The Charpy impact test shall be carried out at the minimum design temperature (usually 0 °C) unless a lower test temperature is specified (reference Note to clause 5.2.2).

5.3.4.8 The Charpy impact test shall be carried out in accordance with BS EN ISO 148-1 using a 2 mm radius striker, and the DWTT in accordance with BS EN 10274 or API RP 5L3.

5.3.4.9 All pipe shall have sufficient energy absorption to ensure resistance to fracture initiation at the minimum design temperature.

Note: The energy absorption requirements of PSL2 of BE EN ISO 3183:2019 may be used for pipelines and the methods of Annex D of PD 5500 for installations.

5.3.4.10 When linepipe is intended to operate at a design factor exceeding 0.3, the possibility of propagating ductile fractures shall be minimised by ensuring that the material possesses an adequate ductile fracture energy absorption.

The specified energy absorption should be based on past experience and the service conditions. In some cases, pipeline specific analysis or experimental studies may be required. These cases include:

- where there is no existing full scale fracture propagation test data to confirm that crack arrest will occur
- where there has been a change in the pipeline parameters or in the fluid being transported which will result in an increased likelihood of fracture propagation.

If such studies show that the anticipated margins are small, validation by full scale crack arrest testing may be required.

Note 1: The energy absorption can be measured using the Charpy impact test. Acceptance levels can be determined from BS EN ISO 3183 Annex A or from published formulae for pipelines of strength grades up to and including L450 (X65). For higher grades, the guidance and published formulae may be unconservative and specialist advice is needed.

Note 2: For high strength steels it might be necessary to use integral or mechanical crack arrestors to ensure arrest of a running ductile fracture. An alternative to the use of crack arrestors would be to conduct a project-specific full-scale fracture propagation test to demonstrate that the proposed toughness requirements are sufficient to ensure crack arrest.

5.3.4.11 The specified frequency of testing shall be designed to ensure that the proportion of pipe reaching the required toughness level is sufficient to restrict the length of a fracture to acceptable levels.

Note: The practice in GB has been to achieve a minimum 95% probability of arrest in 5 pipe joints or fewer.

5.3.5 Weldability

The weldability of linepipe material should be demonstrated either by weldability testing or by providing weldability data previously obtained for the type of pipe concerned.

Note: The preferred approach is for the tests to be performed on full pipe lengths.

5.4 FATIGUE

Provided steels for linepipe are purchased in accordance with clause 5.3.1 and the design complies with Section 6, it is anticipated that all fatigue design requirements will be satisfied.

5.5 FITTINGS

5.5.1 General

5.5.1.1 Fittings shall be of the appropriate strength for the proposed design and test pressures. They shall be qualified with respect to strength, fracture toughness and weldability in a similar manner to pipe. Mechanical testing shall be carried out after hot forming and final heat treatment.

Where fittings of sufficient strength to match high strength pipe, such as L485 and L555, are not available, a lower strength fitting may be used with suitable thickness compensation. It is usual to limit the difference in strength (and hence the difference in thickness) between the fitting and linepipe to a factor of 1.5. Even when using fittings within this limit, care shall be taken to ensure that the design of transitions at weld ends is such that the required properties are maintained throughout the assembly.

Note: Further guidance on weld ends is given in GIS/P16:2020.

5.5.1.2 Tensile testing for forged components shall be carried out in accordance with a relevant standard, on specimens taken transverse to the direction of forging.

For fabricated components, specimens shall be taken transverse to the direction of rolling of the original plate.

5.5.1.3 Fittings shall be qualified with regard to fracture toughness by notch ductility testing, for example Charpy testing.

5.5.1.4 The weldability of fittings of a specific type and from a specified source of supply shall be assessed using a full-size production sample, and this should be a complete butt weld to a pipe pup of length at least equal to one nominal pipe diameter. Otherwise, weldability shall be demonstrated by providing weldability data previously obtained for the fitting being used.

Note: Where chemical composition changes that may affect the weldability of the supplied component are made, the weldability test is to be repeated.

Alternatively, small-scale weldability tests may be performed when the results can be correlated with field welding behaviour of full-size components.

Note: The field weldability of large diameter (e.g., >457 mm diameter), thick wall fittings can be improved by shop welding pup pieces of linepipe to each end, so that field joining involves only pipe to pipe joints. Where specified, these pup pieces are to be of length 250 mm or equal to the nominal pipe diameter where this is greater.

Unless otherwise specified, all non-destructive testing (NDT) of fittings shall be carried out after all processing, heat-treatment and final stress relief if applicable.

5.5.1.5 It should be confirmed that purchased fittings are in accordance with appropriate specifications.

5.5.2 Bends and tees

5.5.2.1 The following standards for wrought bends and tees shall be used, as appropriate:

- BS 1640-1,3
- ANSI/ASME B16.9
- ANSI/ASME B16.28
- ASTM A105
- ASTM A234
- ASTM A420

- ASTM A860
- MSS SP - 75
- ISO 3419
- ISO 15590-2.

Note 1: Bends made from pipe by the induction bending process are covered by ISO 15590-1 and API5LIB.

Note 2: Some material specifications do not contain sufficient requirements to fully qualify fittings in accordance with this section with respect, for example, toughness, dimensions, fatigue etc. In such cases, additional testing may be required.

5.5.2.2 Bends for inclusion within any pipeline shall be manufactured with a minimum radius of three times the nominal outside diameter of the pipe and should allow free passage of pigs (see Sub-Section 6.14).

5.5.2.3 Bends for inclusion in associated pipework not to be subject to pigging shall be to a minimum radius of one and a half times the nominal outside diameter of the pipe.

5.5.2.4 Bends shall be manufactured and tested in accordance with appropriate standards such as those listed in clause 5.5.2.1, supplemented by the requirements needed to qualify fittings in accordance with this Standard.

5.5.2.5 One-piece forged or extruded tees are preferred when available. These should be manufactured in accordance with appropriate standards such as those listed in clause 5.5.2.1, supplemented by the requirements needed to qualify fittings in accordance with this Standard.

5.5.2.6 Where it is not reasonably practicable to use a forged or extruded tee, the following types of fitting are acceptable but shall be subject to suitable qualification, including stress analysis where applicable:

- sweepolet or set in branch fitting
  This type of fitting is acceptable for all pressure ranges but shall only be used for d/D ratios of the fitting not exceeding 0.6.
- weldolet or set on branch fitting
  Although these fittings are, theoretically, acceptable for all pressures and fitting d/D ratios, particular precautions shall be applied for d/D greater than 0.3 when the proposed location in the linepipe shall be carefully examined for defects, including laminations
- full encirclement branch fitting
  This type of fitting is acceptable for all pressure ranges and for all ratios of d/D, provided the wrap-round plate completely encircles the main pipe. They shall be designed in accordance with standards such as ANSI/ASME B31.3.

Welding to the linepipe shall be carried out by a qualified welder to a qualified procedure.

5.5.2.7 Tee headers shall allow free passage of gauging pigs for which guide bars should be fitted if necessary.

Note: Typical design requirements are given in the standards listed in clause 5.5.2.1.

5.6 COMPONENT SELECTION

5.6.1 General

5.6.1.1 The maximum working pressure defined by the class rating or PN designation of a component shall be equal to or greater than the design pressure of the pipeline at the maximum design temperature.

Note 1: Component includes, but is not limited to:
- *flanges*
- *flanged and butt welding valves*
- *quick acting closures*
- *insulating joints.*

Note 2: The class rating or PN designation only defines the pressure strength of a component. The operational limits of some components such as valves may be set by other factors such as the performance of elastomers in seals and packings. These factors are to be considered in component selection.

5.6.1.2 A corrosion-resistant label should be securely fastened to each component, by the manufacturer, to indicate identification number, size, type, class rating and/or maximum working pressure and proof test pressure. The method of attachment of the label shall not adversely affect the strength of the component.

5.6.2 Insulating joints

5.6.2.1 Any insulating joint shall be designed in accordance with an appropriate pressure vessel standard and shall perform its function effectively under all combinations of pressure and externally-applied stresses, as specified to the manufacturer.

5.6.2.2 The properties of dielectric materials shall satisfy the insulation requirements specified. They shall also be resistant to methanol and any constituent of gas under normal or abnormal conditions.

5.6.2.3 Where insulating joints are to be welded into a pipeline, the design of the weld preparations shall meet the requirements of an appropriate standard. The fitting shall be designed so as to avoid overheating of the insulation material during site welding. The risk of differential movement shall be considered as part of the design.

5.6.2.4 All joints shall be hydrostatically and electrically tested and test certificates should be made available by the manufacturer. Conditions for hydrostatic testing should allow for free expansion of the joint. The duration of the hydrostatic test shall be in accordance with the requirements of Section 8. The hydrostatic test shall precede the electrical test.

5.6.3 Valves and actuators

5.6.3.1 Any valve body shall be of cast steel or of forged steel construction, have weld ends or flanges to BS EN 1759-1, ASME B16.5, ASME B16.47, MSS-SP-44 and ISO 15590-3, and shall be manufactured from fine-grained steel in accordance with BS EN 10028 and BS EN 10029.

Reference should be made to ISO 14313/BS EN 13942 and to an appropriate standard for detailed design recommendations for high-pressure valves.

Note: Further guidance on weld ends is given in GIS/V6:2019.

5.6.3.2 Performance testing of valves should be carried out in accordance with API 6D and ISO 14313/BS EN 13942.

5.6.3.3 All valves should be fitted with a device to indicate accurately the position of the plug, ball, gate or disc. Consideration shall be given to the need to vent/drain the body of the valve.

Where it is necessary to lubricate a valve for continued satisfactory operation, seals shall be provided to minimise the amount of excess lubricant passing into the gas stream.

Note 1: This is especially important if metering is directly associated with the installation.

Note 2: Particular attention is required in the selection of valves for sealant lines.

5.6.3.4 The dimensions of the flanged ends of any valve shall meet the requirements of appropriate standards such as BS 3293, BS EN 1759-1 or BS EN 1514**.** Requirements for preparation of the ends of valves to be welded in-line should be specified to the manufacturer.

5.6.3.5 All valve bodies shall be hydrostatically tested under the conditions stated in the standard relevant to the type and pressure rating selected, and test certificates provided by the manufacturer.

5.6.3.6 Hydrostatic and pneumatic seat leakage tests shall be applied to all valves under the conditions stated in relevant standards.

5.6.3.7 Care should be taken to ensure the correct matching of any actuator to a valve, both in terms of required torque and mechanical attachment. The conditions under which the valve is required to operate, including speed of action, should be specified to the manufacturer.

5.6.3.8 Where a valve is ordered with an actuator, a stem extension, or a gearbox etc., the valve manufacturer should be responsible for matching and fitting them and ensuring that each assembly functions correctly in the intended attitude(s). Removal of an actuator shall not affect the pressure-tightness of the valve.

5.6.3.9 Any actuator shall be fully weatherproof.

All electrical/instrumentation equipment shall be suitable for the hazardous area in which it is installed.

A mechanically independent hand-operated drive should be provided as part of any actuator, and it should be so designed that a maximum effort of 350 N would be sufficient to operate the valve. Interlocks shall be provided to prevent local or remote automatic operation while the hand-operated drive is engaged.

Note: Further guidance on actuators is given in GIS/VA1:2019 and GIS VA2.

5.7 FACTORY - APPLIED COATINGS

5.7.1 Reference should be made to the relevant parts of the appropriate standards, for example BS EN ISO 12944 for atmospherically exposed pipework and BS EN ISO 21809 for buried pipelines, for guidance on selection of materials and requirements for their application.

Note: High pH SCC may occur under disbonded or porous coatings at elevated temperatures (generally greater than 30 ˚C) where the applied CP creates an alkaline environment in the crevice beneath the coating.

5.7.2 Pipes and fittings should have the required internal and external protection applied at the manufacturer's works.

5.7.3 Materials that are factory-applied shall be compatible with those corrosion protection measures to be applied on site.

In selecting suitable materials, consideration shall be given to the operating regime and the eventual siting of the component, for example buried or above-ground, and the temperature range likely to be experienced.

Note: For example, some coating materials could be affected adversely by solar heating or exposure to ultraviolet radiation.

5.7.4 Coatings shall be tested according to the requirements of the relevant standard for physical durability and resistance to chemical attack.

Note 1: Detailed requirements for corrosion protection are provided in Section 10.

Note 2: Guidance on the specification for the external protection of steel line pipe and fittings using fusion bonded powder and other coating systems is given in GIS/CW6:2020.

SECTION 6 : DESIGN OF PIPELINES

This Section deals with the design of buried pipelines.

6.1 GAS PRESSURE AND QUALITY

6.1.1 Control of gas pressure

Pressure shall be controlled to ensure that it is within the appropriate specified design limits. IGEM/TD/13 should be consulted for design considerations for pressure reduction.

6.1.2 Pressure Terms and Criteria

IGEM/TD/1 references a number of pressure terms, which are defined below to align with IGEM/TD/13 and BS EN 1594:

- **DP (Design Pressure)**

  The pressure on which design calculations are based.

  DP is used to determine pipe wall thickness, component and equipment selection and the test pressure.

- **MOP (Maximum Operating Pressure)**

  The maximum pressure at which a pipeline system can be operated continuously under normal conditions. The MOP is normally equal to the design pressure, but can be lower.

  The MOP is set at the outlet of the upstream PRI.

- **MIP (Maximum Incidental Pressure)** ($\leq$1.1*MOP)

  The maximum pressure permitted by upstream Safety Devices.

  MIP is a temporary fault condition (see clause 12.5) permitted by the safety devices on the outlet of the upstream PRI, which must not be exceeded.

- **SOL (Safe Operating Limit)**

  SOL is the pressure above which the pipeline must not be operated and is a requirement of the Pipeline Safety Regulations (PSR) and Pressure Systems Safety Regulations (PSSR). The SOL is set at the outlet of the upstream PRI and must not be exceeded.

  PSR and PSSR require the establishment of Safe Operating Limits (SOLs). These may be specified in terms of maximum operating pressure and maximum and minimum operating temperature. In some cases, SOLs will also take into account such matters as fluid velocities and any limits set on the composition of the fluid.

Pressure shall be controlled to ensure that it is within the appropriate specified design limits. IGEM/TD/13 should be consulted for design considerations for pressure reduction.

6.1.3 Gas quality

Deposits in a pipeline should be avoided and internal corrosion should be minimised by:

- keeping the water dewpoint, at the operating pressure (OP), at all times below the temperature of the pipeline
- ensuring the hydrocarbon dewpoint, at OP (operating pressure), is at all times below the temperature of the pipeline

  Note: This will also ensure that the calorific value of the gas is not reduced by condensation of hydrocarbons.

- limiting dust in the pipeline.

Oil should be prevented from passing forward from compressors.

Note: In the UK, GS(M)R contain requirements for gas quality, including limits for sulphur content which minimises internal corrosion.

6.2 DESIGN VELOCITY

With gas of the quality prescribed in clause 6.1.3, there is no necessity to limit the design velocity in pipelines. Where the gas source causes dust particles which could cause abrasion, consideration shall be given to limiting the gas velocity in any section of the pipeline where changes of direction take place.

Note: Velocities up to 20 m s^{-1} are acceptable for unfiltered gas.

6.3 SIZING OF LINEPIPE

Initial sizing should be based on a simple steady-state concept.

Note: The method of determining the required size of pipe, for a given pipeline, will depend on a number of interacting technical and economic criteria.

A number of formulae have been developed for relating pressure drop to gas flow rate, for example Weymouth, Panhandle, Spitzgass, Oliphant and Unwin, which should be used for this purpose.

Note 1: Software and calculators based on these formulae are available, which give sufficiently accurate results for short pipelines. Pipelines over 50 km long require greater accuracy and the use of Panhandle "A", Panhandle "B" or AGA (American Gas Association) flow formulae is recommended. In particular, this is true where compression stations are required.

Note 2: It may be necessary to determine the influence of additional factors to cater for transient flow conditions, which may involve subjecting the system to analysis. By this means, the pipe dimensions necessary to cater for credible fault and planned abnormal operating conditions can be established. Other factors which may need to be considered include any intended use of a pipeline for line pack storage, the location of points of associated high volume storage along a pipeline and the manner of introduction and use of compression plant in a pipeline.

6.4 WALL-THICKNESS OF LINEPIPE

6.4.1 The minimum wall thickness of linepipe shall be considered to be the nominal wall thickness less the maximum manufacturing tolerance for under-thickness of the wall.

Note: These factors are given by the relevant linepipe specifications.

6.4.2 The minimum wall thickness of linepipe shall be equal to or greater than the design thickness as determined from:

$$t = PD(20fs)^{-1}$$

t = design thickness of pipe (mm) (nominal less under-tolerance)
P = design pressure at the relevant design temperature (bar)
D = outside diameter of the pipe (mm)
s = SMYS (N mm^{-2})
f = a factor not to exceed 0.8 but which may have to be reduced considerably by restrictions given below.

Note: For a pipeline operating in the range 0.72 < f ≤ 0.8, clause 6.7.4.3 applies.

In any event, to prevent problems during handling and trenching, the nominal thickness of linepipe shall not be less than indicated in Table 5.

OUTSIDE DIAMETER (mm)		**NOMINAL WALL THICKNESS (mm)**
Exceeding	Not exceeding	
	168.3	4.7
168.3	457	6.3
457	610	7.9
610	914	9.5
914	1067	11.9
1067	1219	12.5

TABLE 5 - NOMINAL WALL THICKNESS OF LINEPIPE FOR HANDLING PURPOSES

6.4.3 Nominal wall thickness values up to 0.05 mm below the calculated or stated value may be considered acceptable.

Note: In previous editions of IGEM/TD/1 some wall thickness values were derived using exact conversions to metric values of nominal values expressed in inches. In Edition 5 and later, values have been given using a precision appropriate to the manufacturing capability. This difference in practice may result in apparent discrepancies in requirements which are not significant.

6.5 ADDITIONAL LOADS

6.5.1 Classification of loads

Design and construction of pipelines to this Standard will, inevitably, eliminate many sources of additional loading through careful routing and standard depth of cover, trench preparation and backfilling, and accepted construction practices. Where standard construction practices cannot be accommodated and particular constraints apply and additional loading has to be accommodated, the design shall anticipate, and the pipeline shall be able to withstand, the following additional loads:

- operating loads, including;
  - thermal expansion and contraction loads. Provision shall be made for the effects of thermal expansion or contraction. Account should be taken of stresses induced as a result of restriction of free thermal movement owing to restraints, for example underground bends and underground swan necks
  - weight of the pipeline
  - the soil dead weight loading due to the depth of cover

- construction loads arising from;
  - impact protection slabs
  - pipe laying and alignment, for example tie-in connections
  - differential settlement due to variable support arising from trench bottom and bedding conditions
  - pressure testing
- environmental loads arising from:
  - subsidence or settlement due to mining and mineral extraction, de-watering, or the action of additional surface loads, typically embankments
  - subsidence due to the pipe being laid on top of disturbed or built-up land, taking into account the effects of differences in support between existing pipe and modified pipe at a tie in interface
  - slope instability
  - frost heave
  - buoyancy
  - live loading from vehicles
  - seismic activity.

Note: Environmental loading may change during the service life of a pipeline.

For in-service pipelines, the effects of any additional load shall be determined and assessed for acceptability.

Any uncertainty in loads and displacements, other than design or operational values, shall be taken into account in order to demonstrate that the resultant analysis is acceptable.

Assessment of additional loads at specific locations shall take into account the relevant pressure (including transient fault pressures if appropriate) and temperature.

6.5.2 Calculation of stresses

6.5.2.1 Circumferential (hoop and bending), longitudinal (axial and bending), shear and equivalent stresses should be taken into account to demonstrate that the resultant analysis is acceptable.

Note: For a pipeline affected by external loads, the worst case may occur in the depressurised condition, i.e., zero internal pressure.

6.5.2.2 Stress analysis shall include any restraints on the pipeline including anchors, supports, sleeves, tees, branch connections and the soil. The flexibility and stress concentration at bends, tees and other components shall be included in the analysis (see IGEM/TD/12).

6.5.2.3 Any uncertainty range shall be established for restraints and incorporated in the pipeline strength calculation.

6.5.2.4 Structural flexibility and stresses shall be based on nominal dimensions and modulus of elasticity at ambient temperature.

Equivalent stresses shall be calculated as follows:

$$\sigma_{eq} = \sqrt{\sigma_c^2 + \sigma_L^2 - \sigma_c.\sigma_L + 3\tau^2}$$

σ_{eq} = von Mises (equivalent) stress
σ_c = circumferential stress
σ_L = longitudinal stress
τ = shear stress in plane of pipe cross section.

Guidance on methods for stress analysis of buried pipelines in given in BS EN 1594, BS 9295 and BS EN 1295-1.

6.5.3 Acceptance criteria

Note: Alternative criteria to that given below, such as limit state design or allowable strain, may be used where it can be demonstrated that the criteria are relevant and applicable.

6.5.3.1 The maximum allowable through-wall circumferential (hoop) stress should meet the design factor set out in Sub-Section 6.7.

6.5.3.2 The maximum equivalent stress for uniform stress components should meet:

$s_{eq} \le 0.8$ SMYS where $\sigma_{eq} = \sqrt{\sigma_h^2 + \sigma_a^2 - \sigma_h.\sigma_a}$

σ_{eq} = equivalent stress
σ_h = hoop stress due to internal pressure
σ_a = axial stress due to axial forces in the pipeline.

Note: The objective of this condition is to ensure a factor of safety of 1.25 against gross section yield.

6.5.3.3 The maximum equivalent stress for total stresses (membrane and bending) should meet:

$\sigma_{eq} \le 0.9$ SMYS.

Note 1: See clause 6.5.2.4.

Note 2: For this condition, the longitudinal stress includes axial stress and nominal bending stress.

Note 3: The objective of this condition is to avoid yielding of the pipe wall whilst recognising the plastic reserve of the pipeline in bending.

6.5.3.4 For the assessment of ovalisation, the radial deflection shall not exceed 5% of the nominal pipe diameter.

6.5.3.5 For in-service pipelines that are subjected to significant overburden loads or significant compressive stresses, a check on buckling should be undertaken.

Note: Guidance for pipeline stress analysis is given in BS 9295 and API RP 1102, and for buckling assessments is provided in PD8010, ASME B31.8, DNVGL-ST-F101 and DNVGL-RP-F110.

6.6 FATIGUE

6.6.1 General

6.6.1.1 Consideration shall be given to the fatigue life of any pipeline, to ensure that any defect which survives the hydrostatic test, or which is not detected by subsequent internal inspection, does not grow to a critical size under the influence of pressure-cycling.

Special consideration shall be given to the adequacy of fittings.

Note: Generally, fittings are designed to a standard which will ensure that they experience lower stress ranges than linepipe when a pipeline is pressure-cycled. Where such circumstances prevail, fittings need not be subjected to a fatigue evaluation.

6.6.1.2 Consideration shall be given to other sources of cyclic stressing, for example thermal loading immediately downstream of a compressor station, which may affect the fatigue life of a pipeline. Specialist advice shall be obtained if these are likely to be significant, as the guidance in clause 6.6.2 is appropriate only for pressure-cycling.

6.6.2 Definition of fatigue life

6.6.2.1 *General*

Fatigue life may be defined by the simplified approach described in clause 6.6.2.2, provided the pipeline has been hydrostatically tested to the requirements of Table 11 and is constructed from linepipe purchased to clause 5.3.1. Alternatively, a detailed fracture mechanics calculation, as described in clause 6.6.2.3, should be used if:

- the pipeline has been hydrostatically tested to a level lower than specified in Table 11, or
- the pipeline will experience maximum stress ranges in excess of 165 N mm^{-2}.

The required fatigue life of the pipeline shall be defined in terms of allowable stress ranges and associated numbers of cycles. For the purposes of this Standard, a 40-year life has been assumed but other lives may be appropriate in which case they should be documented.

The nominal wall thickness should be used to calculate the cyclic stress range.

Note 1: Where the maximum daily hoop stress range is less than 35 N mm^{-2}, a fatigue assessment is not required.

Note 2: Where the sum of the cyclic pressure stress and the maximum hoop stress range from traffic loading is expected to be greater than 35 N mm^{-2}, these stress ranges are to be considered when undertaking the fatigue assessment.

6.6.2.2 *Simplified approach*

(a) Constant daily pressure-cycling

Where the magnitude of daily pressure-cycling is constant, the fatigue life should be determined from:

$S^3N = 2.93 \times 10^{10}$

S = constant amplitude stress range ($N\ mm^{-2}$)
N = number of cycles.

Note 1: For example, if a life of 15,000 stress cycles is required (equivalent to one cycle per day over 40 years), the equation limits the maximum daily variation in hoop stress to 125 $N\ mm^{-2}$.

Note 2: The relationship between stress range and the number of cycles is shown in Figure 4.

(b) Variable pressure-cycling

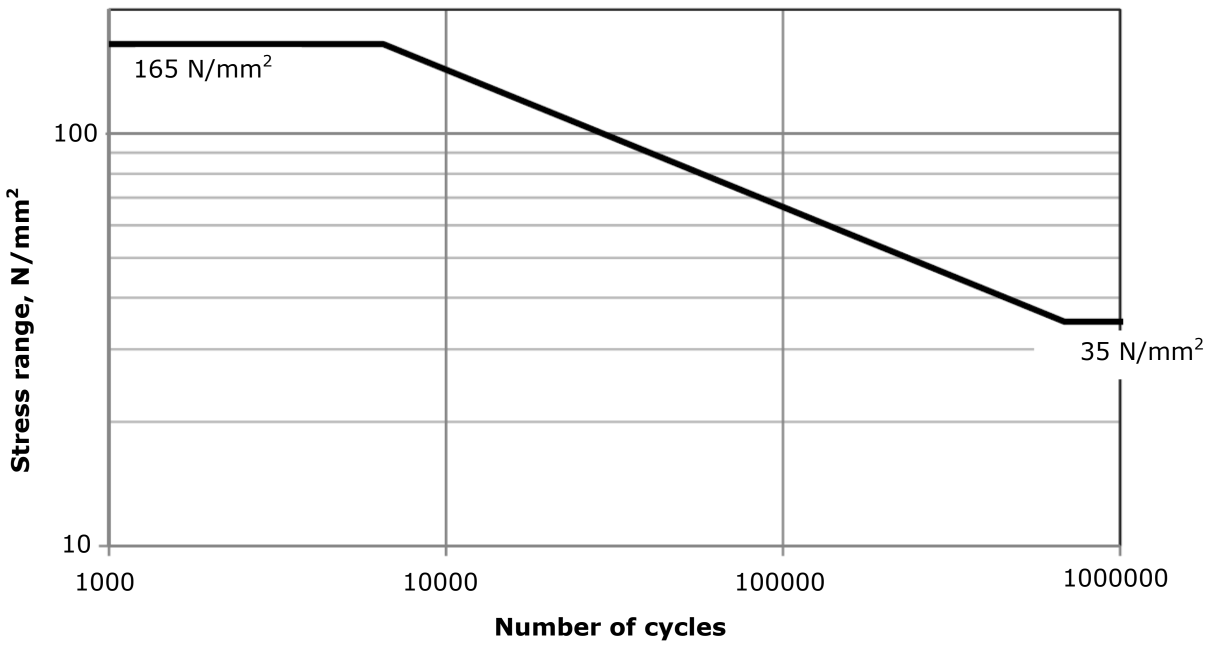
Where the magnitude of daily pressure cycling is not constant, the fatigue life should be evaluated on the basis of (a) above, by totalling the usage of fatigue life from each stress range.

The following condition for the damage fraction should be satisfied to obtain an acceptable fatigue life.

$$D_F = \Sigma \frac{n_i}{N_i} \leq 1.0$$

D_F = damage fraction
n_i = the actual number of cycles accumulated at stress range S_i
N_i = number of stress cycles allowed at stress range S_i (clause 6.6.2.2(a))
S_i = stress range (see N_i and n_i).

If the anticipated value of D_F exceeds 0.5, the actual cycles accumulated during operation should be determined in accordance with clause 6.6.3.



Note: This drawing is for illustrative purposes only and is not suitable to derive values.

FIGURE 4 - RELATIONSHIP BETWEEN STRESS RANGE AND NUMBER OF CYCLES

6.6.2.3 *Detailed fracture mechanics approach*

Where the maximum daily stress range exceeds 165 N mm^{-2}, and/or the simplified method in clause 6.6.2.2 is not appropriate or where it is required to assess the fatigue life of defects detected in service, a detailed fracture mechanics calculation should be used to determine the fatigue life.

Note: Recommended methods for such a calculation are given in BS 7910.

Account should be taken of the deleterious effect of pipe ovality and local shape deviations.

The analysis method, material properties and other input data used in the assessment should be documented and fully justified.

The actual cycles accumulated during operation should be determined in accordance with clause 6.6.3.

6.6.3 Definition of stress cycles

Any complex (variable amplitude) stress cycles should be recorded and then converted to an equivalent spectrum of constant amplitude stress cycles using a documented algorithm such as the Reservoir or Rainflow method. The appropriate method (see clause 6.6.2) should then be used to define the fatigue life.

Note: Further details of these algorithms are given in ASTM E1049.

6.6.4 Revalidation

When records or estimates show that the design fatigue life has been reached, the pipeline shall be revalidated by testing in accordance with Section 8, or by internal inspection using a tool capable of the detection of longitudinal crack-like defects, particularly in or near the seam weld. If inspection is used, the detection limits for crack-like defects shall be taken into account when establishing the future fatigue life of the revalidated pipeline (see also Section 12).

6.7 AREA TYPES AND DESIGN CRITERIA

6.7.1 Area types

6.7.1.1 The location adjacent to a pipeline should be categorized according to population density and/or the nature of the immediate surrounding area. The following designated areas should be used:

- Type R Rural areas with a population density not exceeding 2.5 persons per hectare
- Type S Areas which have been developed with residential properties, shops, schools, etc. where the population density is greater than 2.5 persons per hectare and less than 30 persons per hectare.
- Type H Areas where there is a high population density which is greater than 30 persons per hectare and is not a Type T Area. These areas are associated with creeping development near Type S Area locations for example where a shopping centre, or an entertainment centre, or a sporting stadium, or a hospital, or a multi-storey building has been constructed near a pipeline, or an industrial or commercial building has been repurposed for residential use.
- Type T Central areas of town or cities, with a high population density resulting from for example a combination of multi-storey buildings, hospitals, major transport hubs, public meeting places etc.

Note: The area types require different design criteria, with particular reference to operating stress level and proximity.

6.7.1.2 In some circumstances where there are clusters of dwellings, typically ribbon type developments, anomalies can occur as a result of a relatively high population density local to the development being averaged over a larger area which is more sparsely populated. This anomaly is more likely to occur when larger building proximity distances are being used in the method outlined in clause 6.7.2. When routing a new pipeline within four building proximity distances (BPD) of a development of this nature, consideration shall be given to designing the pipeline in line with the requirements of clause 6.7.5 if the development exhibits S area type characteristics as defined in clause 6.7.1.1.

Note: Additional guidance on population density assessment is given in Appendix 10.

6.7.1.3 The pipeline route shall avoid Type H Areas, which normally occur after a pipeline has been constructed where there has been further development of a Type S Area location.

For an existing pipeline, where a new development is planned and the population density increases such that the area would become a Type H area, then the location shall be subject to detailed assessment by means of a safety evaluation, as described in Sub-Sections 2.1 and 6.8.
This assessment shall consider all issues including failure credibility and the distribution of population densities along the pipeline route.

6.7.2 Estimation of population density

6.7.2.1 The population density, expressed as the number of persons per unit area, shall be the average within a 1.6 km strip centred on the pipeline of a width 8 times the minimum BPD for a Type R area pipeline as defined in Figure 5.

Note 1: For MOP exceeding 100 bar, Figure 5 may be extended by linear extrapolation using the correlations provided to define the width of the strip used in calculating population density.

Note 2: The strip width may be defined by the distance to a risk level of 0.3 chances per million (should) on the individual risk transect.

6.7.2.2 Measurement of population density shall be based on a survey, for example by aerial photography, of normally occupied buildings and premises where people congregate for significant periods of time, for example schools, public halls, etc.

6.7.2.3 The occupancy of houses should be determined from Census statistics, although the occupancy of typical houses may be assumed to be 3 persons per dwelling.

The occupancy of other buildings shall be assessed.

6.7.3 Boundaries

In order to determine the precise boundary between Type R and Type S areas, the population density shall be calculated within circles of diameter 8 times the minimum BPD determined from Figure 5, or the 0.3 cpm individual risk contour (see clause 6.7.2.1). By considering such circles in sequence outwards from the high-density area, the circle within which the population density first falls below 2.5 persons per hectare shall be determined. The centre of the circle shall be taken as the boundary of the Type S area. Clause 6.7.1.2 shall be considered when undertaking this assessment.

For further information, reference should be made to IGEM/TD/2.

6.7.4 Design of pipelines in Type R areas

6.7.4.1 *General*

Normally, pipelines should be designed to a maximum design factor of 0.72 (see clause 6.7.4.2).

Note: Under certain conditions and/or circumstances, consideration may be given to a maximum design factor of 0.8 (see clause 6.7.4.3).

6.7.4.2 *For a design factor not exceeding 0.72*

The minimum proximity of pipelines to normally-occupied buildings shall be related to MOP and be as defined in Figure 5, except that Figure 6 may be used if either:

- the pipeline has a design factor not exceeding 0.3, or
- the pipeline has a design factor not exceeding 0.5 (but exceeding 0.3) and a nominal wall thickness of not less than 19.1 mm.

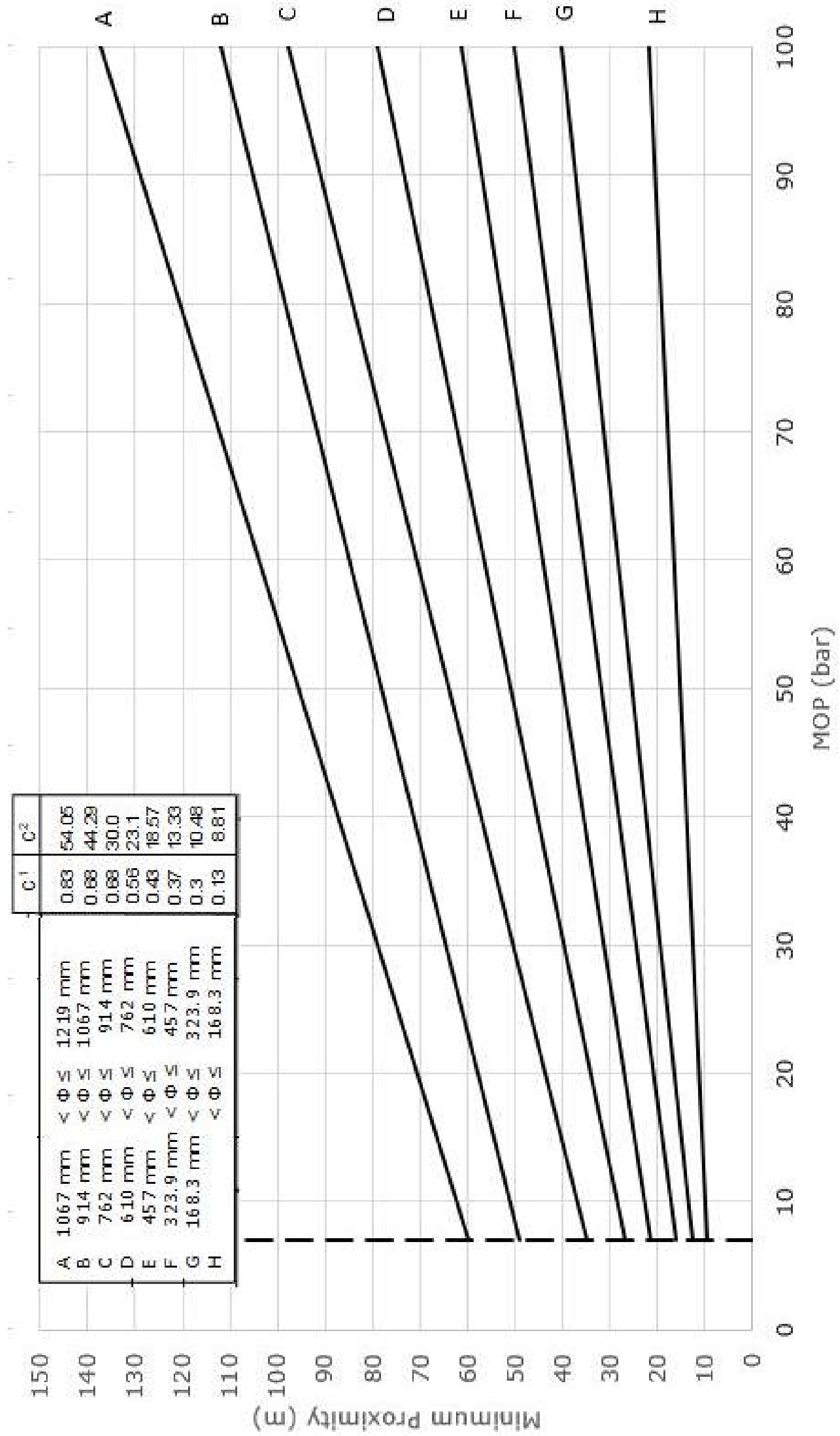
A safety evaluation of the whole pipeline should be carried out for design pressures greater than 100 bar (see Sub-Section 2.1, Sub-Section 6.8 and Appendix 3).

In any event, the proximity distance shall not be less than 3 m.

6.7.4.3 *For a design factor exceeding 0.72, but not exceeding 0.8*

In addition to the requirements of clause 6.7.4.2, structural reliability analysis (SRA) should be undertaken, in accordance with Appendix 4.

Note: The SRA may be subject to regulatory review.



MINIMUM BPD = (C1 x MOP) + C2 and is calculated from the centre line of the pipe, rounded to the nearest metre.

FIGURE 5 - MINIMUM PROXIMITY DISTANCE TO NORMALLY-OCCUPIED BUILDINGS OF PIPELINES DESIGNED TO OPERATE IN TYPE R AREAS

6.7.5 Design of pipelines in Type S areas

6.7.5.1 The population density of a Type S Area shall be calculated for the pipeline BPD corridor as per 6.7.2.1 between the maximum Type R area BPD as per Figure 5 and the minimum BPD for a Type S pipe as per Figure 6. The maximum allowable population for a new pipeline is 30 persons per hectare.

6.7.5.2 Normally, pipelines should be designed to a maximum design factor of:

- 0.3 or
- 0.5 for pipelines having a nominal wall thickness of not less than 19.1 mm.

Note 1: A higher design factor (but not exceeding 0.72) may be justified by a risk analysis as part of a safety evaluation (see Sub-Section 6.8 and Appendix 3).

Note 2: Safety evaluation in this context is defined as a full risk assessment of the section of pipeline being considered, taking account of all factors affecting safety. Normally, it is not intended to mean a safety evaluation of the whole pipeline.

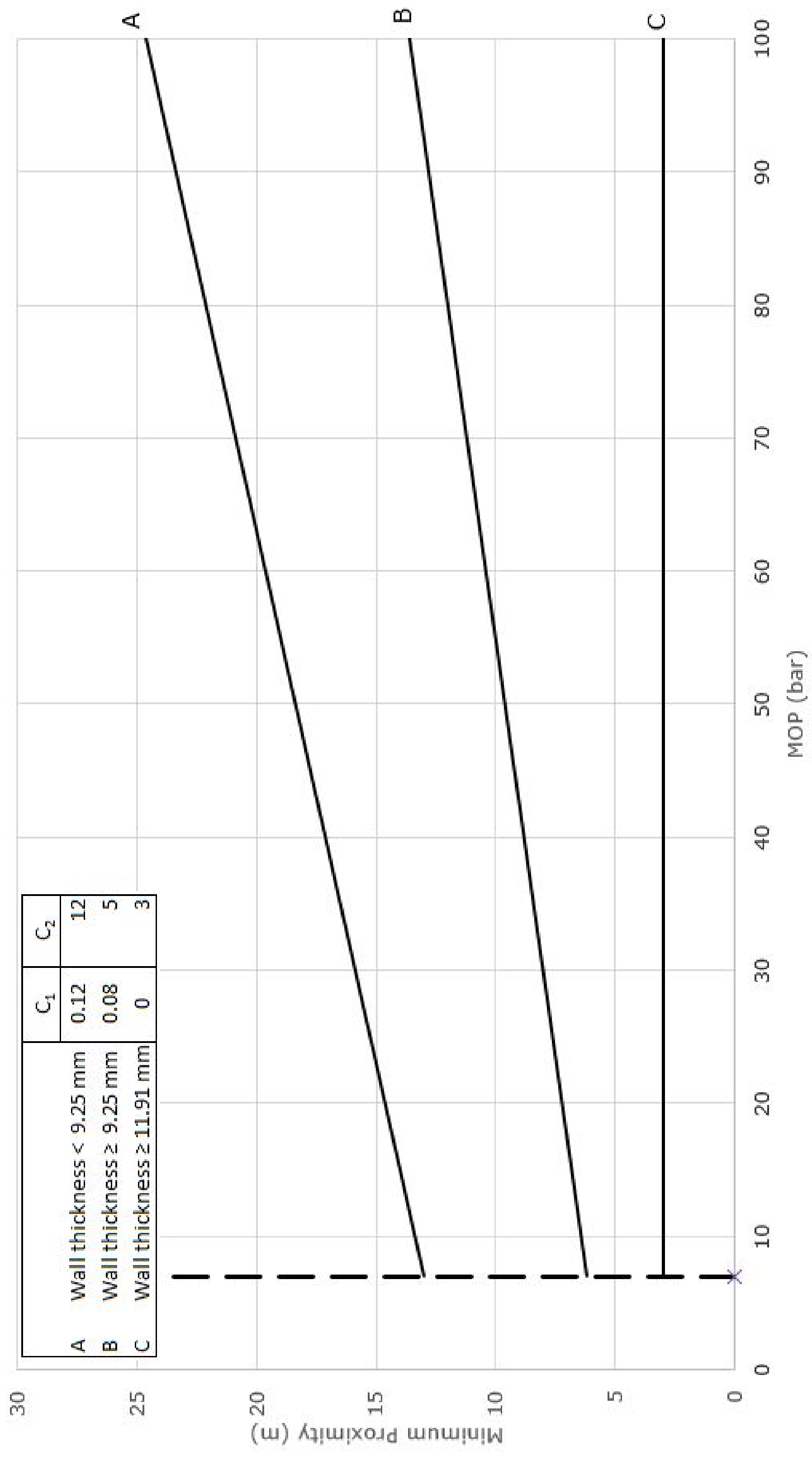
6.7.5.3 When uprating a pipeline, design factors exceeding 0.72 but not exceeding 0.8 may be used if justified by a structural reliability analysis and risk analysis (see Appendices 3 and 4). However, design factors in this range should not be used unless the pipeline is located predominantly within Type R areas with only minor excursions in Type S areas.

Note: "Minor excursions" in Type S areas are where a pipeline route is considered, in general, to conform to a Type R area classification but displays Type S characteristics. Examples of features associated with such minor excursions are:

- *a short length of affected pipeline*
- *affected length of pipeline in predominantly agricultural land*
- *low population density, albeit in excess of 2.5 persons per hectare*
- *population concentration beyond the Type R proximity distance defined in Figure 5 (see also clause 6.7.1).*

6.7.5.4 The minimum proximity of pipelines to normally-occupied buildings shall be related to MOP and be as defined in Figure 6.

In any event, the proximity distance shall not be less than 3 m.



Note 1: For design factor not exceeding 0.3 and nominal wall thickness < 9.52 mm, a pipeline can be operated with proximities derived from curve B

Note 2: A pipeline with a wall thickness <11.91 mm may be operated with proximities less than those derived from Curves A or B (but not less than curve C) if this can be justified by a risk analysis carried out as part of a safety evaluation (see Clause 6.8)

MINIMUM BPD = (C1 x MOP) + C2 and is calculated from the centre line of the pipe, rounded to the nearest metre.

FIGURE 6 - MINIMUM PROXIMITY DISTANCE TO NORMALLY-OCCUPIED BUILDINGS OF PIPELINES DESIGNED TO OPERATE IN TYPE S AREAS

6.7.6 **Design of pipelines in Type T areas**

A pipeline in a Type T area shall be designed, constructed, operated and maintained in accordance with IGEM/TD/3.

6.7.7 **Deviation from prescribed proximity criteria**

When new development occurs in the vicinity of a pipeline that results in non-compliance with the criterion in clauses 6.7.4 and 6.7.5, consideration shall be given to a safety evaluation to assess the risk and determine whether any remedial measures need to be taken. Further guidance is given in Appendix 10.

Note: Safety evaluation in this context is defined as a design review, full risk assessment and consideration of maintenance and risk control methods for the section of pipeline being considered, taking account of all factors affecting safety. Normally, it is not intended to mean a safety evaluation of the whole pipeline.

6.7.8 **Proximity from wind turbines**

The minimum proximity distance between any pipeline and any industrial/commercial sized wind turbine should be 1.5 times the fixed mast height excluding turbine of the wind turbine.

Note: Guidance on the siting of wind turbines is given in UKOPA/GPG/013

6.7.9 **Sensitive locations**

Careful consideration shall be given to pipelines in the vicinity of sensitive locations which may result in a change of pipeline design; e.g., location, wall thickness, proximity, protection, etc.

Note: Development of such locations during service could have a serious impact on pipeline operation. Additional guidance is provided in Appendix 10.

6.7.10 **Seismic activity**

6.7.10.1 Consideration shall be given to the effects of seismic loading on pipelines and installations in accordance with BS EN 1998-4 and the relevant National annexes. Seismic loading can result from ground shaking during the earthquake event, followed by permanent ground movements resulting from the earthquake, which may include displacement of geological faults, soil liquefaction and landsliding associated with soil and slope instability.

Note: BS EN 1998 states that there are, generally, no requirements in the UK to consider seismic loading, and the whole of the UK may be considered an area of very low seismicity in which the provisions of BS EN 1998 need not be applied. However, the UK National Annex to BS EN 1998, PD 6698, states that certain types of structure, including large diameter high pressure gas pipelines and the associated installations, by reason of their function, location or form, may warrant an explicit consideration of seismic actions.

6.7.10.2 In areas where seismic loading on large diameter pipelines and associated installations is identified for consideration, full geological and seismological investigations should be carried out to identify pre-existing faults and their potential for movement, soil type and strata and the existence of any areas susceptible to landsliding in the vicinity of the fault. Analysis of historical seismic data should be carried out to assess the earthquake return period and associated magnitude to be considered.

6.7.10.3 Where the likelihood of a damaging earthquake is considered significant, the static and dynamic effects of ground shaking should be considered on above ground pipework and plant, and the static effects of potential permanent ground movement should be considered on the above ground and buried pipeline sections which may be affected. The analysis of buried pipeline sections should include pipe-soil interaction effects. The analysis should assess whether the pipeline section has sufficient flexibility to accommodate design case displacements, and whether the magnitudes of stresses and strains which may be induced are acceptable.

Note: Guidance on seismic screening is given in UKOPA/GPG/019.

6.8 SAFETY EVALUATION AND RISK ANALYSIS

6.8.1 The design rules and criteria presented in this Standard shall be applied and adhered to in all cases, unless this is not reasonable or practicable. In such cases, the Standard allows a documented safety evaluation to be carried out, including a quantified risk analysis.

6.8.2 A safety evaluation shall include a systematic study of the major hazard potential of a pipeline. The study shall cover design, construction and operation. The purpose is to demonstrate that all necessary measures to prevent a major accident, and limit its consequences, have been taken. The evaluation shall include a full, quantified risk assessment and specific consideration of material requirements, pressure boundaries and the control regime, additional maintenance and risk management requirements. All methods, data and assumptions shall be recorded in the documented safety evaluation.

6.8.3 Any risk analysis performed as part of a safety evaluation shall take into account the likelihood of damage and the frequency and consequences of all significant pipeline failure modes. Care shall be taken to ensure that the methodology adopted is consistent with the criteria used to assess the results.

6.8.4 It is not intended that risk analysis is used to justify deviations from the design criteria included in this Standard. Where the construction of new infrastructure, or upgrades to existing infrastructure, such as roads and railways, impacts on the pipeline design, the pipeline shall be modified to meet the requirements of this Standard.

However, risk analysis is a valuable decision aid, and may be applied to investigate and justify alternatives as part of the design process for new pipelines or modification to an existing pipeline where the design requirements cannot be achieved. In such cases, the justification for any deviation from the design requirements shall be fully documented as part of a safety evaluation and shall include an “as low as reasonably practicable” (ALARP) assessment.

6.8.5 The safety evaluation and risk analysis must be specified and accepted by the duty holder responsible for managing risks posed by the pipeline.

Note 1: Guidance on risk assessment techniques and criteria is given in Appendix 3 together with examples. Further information can be found in IGEM/G/7.

Note 2: The documented safety evaluation, including the results of such a risk analysis may need to be considered by the relevant statutory body.

6.9 IMPACT PROTECTION AGAINST THIRD PARTY INTERFERENCE

6.9.1 Protection against third party interference can be an effective means of reducing the likelihood of third party damage at, for example, road crossings, sensitive locations, etc.

6.9.2 For new build pipelines, preference should be given to using pipe of increased wall thickness. When protection is to be provided to an existing pipeline, commonly used methods are:

- protection slabs including concrete or high-density polyethylene (HDPE) slabs and slabs without side supports
- increased cover
- concrete surround.

Note 1: The implications for maintenance requirements of impact protection measures have to be considered. Additional protection can affect the efficiency of above-ground surveys, such as Pearson Surveys and close interval potential surveys (CIPS).

Note 2: Heavy duty marker tape may be used to supplement protection measures such as concrete or HDPE slabs and concrete surround.

The form of protection shall be selected by the designer or operator to suit the circumstances and the reasons for the selection shall be justified and documented.

6.9.3 For minor crossings and ditches, where increased future use and maintenance operations are likely, and where the pipeline is installed by open cut methods, thick wall pipe i.e., design factor ≤ 0.3, shall be installed.

Note: Where the pipeline nominal wall thickness is 19.1 mm or greater, the design factor may be increased to 0.5.

For drainage ditches on existing crossings, protection slab of adequate strength and dimensions shall be placed between the pipe and the cleaned bottom of the ditch to prevent impact damage. The top of the slab shall be not less than 300 mm below the true clean bed of the crossing/ditch.

6.9.4 In Figure 7, which shows typical protection slab design, the dimension "h" should be not less than 500 mm which is considered to be the length of the drill bit of a hand-held pneumatic jackhammer. "h" should be taken from the highest layer of reinforcement within the slab to the pipe.

6.9.5 The overall width of the protection should be adequate to guard against lateral encroachment from excavating machinery.

6.9.6 The reinforcing shown in Figure 7 is indicative only and should be designed for each situation. If pre-cast concrete slabs are used, consideration shall be given to stresses due to handling and any additional reinforcement should be provided as required. If HDPE slabs are used, the design shall ensure that the slab is sufficiently stiff and has adequate impact resistance. HDPE material shall be Ultra high weight Polyethylene (UHMWPE) with elongation at break point of 300 %, modulus of elasticity 800 MPa tested in accordance with BS EN ISO 527 and impact resistance Kcv = 2 J/cm^2 tested in accordance with BS EN ISO 179.

6.9.7 When using the "slab with side supports" protection (Figure 7), the reinforcement should be designed and positioned to suit the method of construction.

6.9.8 The use of any protection measures may alter the distribution and intensity of external loads around the pipe. The design should consider such effects and demonstrate that they do not result in unacceptable stresses within the pipe.

Note: In particular, this is important where construction or other traffic loading may arise.

6.9.9 Care shall be taken during design and installation to ensure that the satisfactory operation of the pipeline CP system will not be affected by the construction of impact protection.

Note: On extended contiguous sections of impact protection, consideration is to be given to installing representative CP coupons beneath the protection slab, including AC coupons.

6.9.10 When designing impact protection for installation on existing pipelines to provide risk reduction, the UKOPA/GPG/006 'Impact Protection Slabs' shall be applied for the risk reductions factors given in IGEM/TD/2 to be achieved. Alternative specifications may be used where appropriate risk reduction factors are justified.

6.9.11 A coating survey (DCVG) shall be carried out prior to the installation of slabbing, and the results of previous in-line inspections shall be reviewed to determine whether there are any indications of corrosion in the length of pipeline to be slabbed which may need assessment and/or repair prior to slabbing, and the functionality and integrity of the CP system shall be confirmed before and after installation of the slabbing.

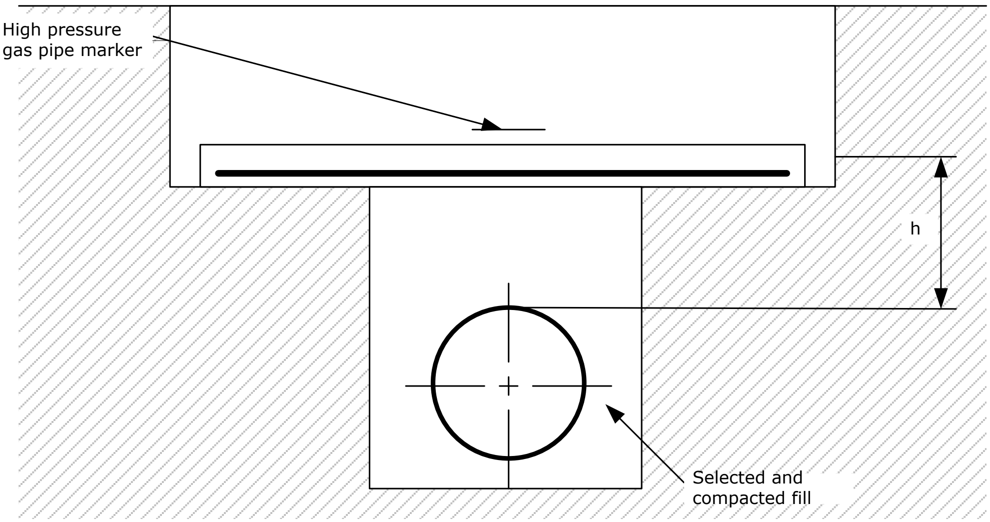


FIGURE 7(a) - Slab

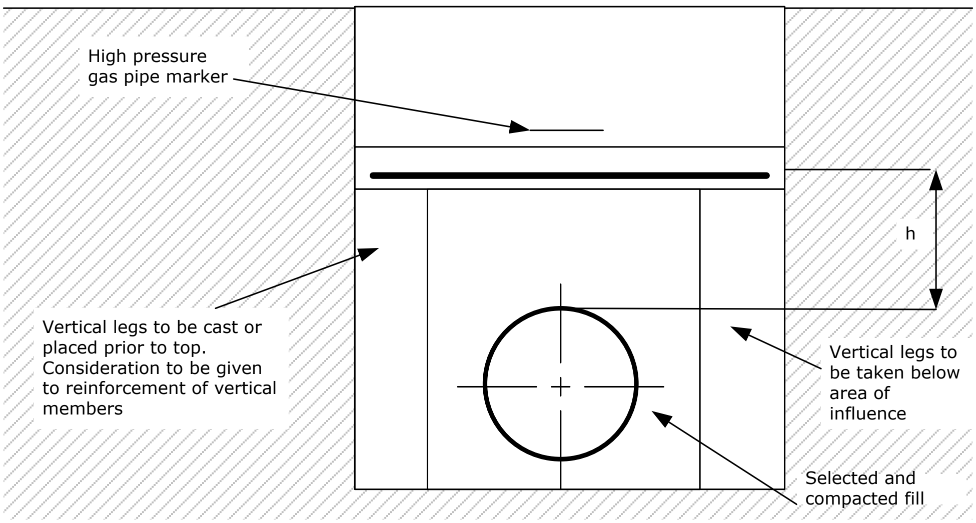


FIGURE 7(b) - Slab with support

FIGURE 7 - COMMONLY USED FORMS OF IMPACT PROTECTION

6.10 TRAFFIC ROUTES (including roads, railways and water courses)

6.10.1 General

Requirements for a pipeline crossing, running along or running under traffic routes (which include roads, railways and water courses) are given in clauses 6.10.2 to 6.10.6. Two categories of road and rail traffic route have been designated according to the traffic density (high density traffic routes and other traffic routes). The decision as to which category a particular route belongs should be made taking account of the risk of interference and diurnal or seasonal variations in traffic density.

Note: Where geotechnical structures (i.e., tunnels, embankments and cuttings) or similar structures are being constructed to accommodate traffic routes, subsequent stress changes to existing pipelines due to ground movement and soil overburden are to be assessed in accordance with clause 6.5.2 (calculation of stresses).

6.10.2 High density traffic routes (roads and railways)

Note: High density traffic routes are defined in Appendix 1.

6.10.2.1 A pipeline which either crosses, or encroaches within, the appropriate minimum proximity distance of a high density traffic route, shall:

- have a nominal wall thickness of not less than 11.9 mm
- have a design factor not exceeding 0.3, or 0.5 for pipelines of nominal wall thickness not less than 19.1 mm.

6.10.2.2 Any additional wall thickness shall be extended beyond the edge of the carriageway including the entry or exit slip road, or hard shoulder if present, or railway track. This extension shall ensure that no part of the unmodified pipeline is closer than the minimum proximity distance derived from Figures 5 or 6, as appropriate to the design conditions of the unmodified pipeline. The distance shall be measured at 90º from the edge of the carriageway, entry or exit slip road or the outer edge of the hard shoulder, or the outer rail of railway track.

6.10.3 Other traffic routes (i.e., not high density traffic routes) (roads and railways)

6.10.3.1 A pipeline which either crosses or runs within the boundary of traffic routes that are not high density traffic routes (see clause 6.10.2) shall either have a nominal wall thickness of not less than 9.5 mm or shall be provided with impact protection in accordance with Sub-Section 6.9.

6.10.3.2 The design factor shall not exceed 0.3, or 0.5 for pipelines of nominal wall thickness not less than 19.1 mm.

6.10.4 Changes to traffic routes (roads and railways)

Additional traffic routes or modifications to existing routes on a pipeline represent a significant increased risk of third party damage throughout the construction and over the remaining life of the pipeline. The additional traffic also increases the population exposure to risk from the pipeline. The pipeline design and integrity shall be reviewed in order to manage the additional risks over the life of the pipeline.

Where the addition of a new traffic route or construction work to upgrade an existing traffic route impacts upon the design of a pipeline, the developments should include provisions to modify the existing pipeline. The pipeline shall be modified to meet the requirements of clauses 6.10.2 to 6.10.3.

If it is not reasonable or practicable to modify the pipeline to meet the requirements of clauses 6.10.2 to 6.10.3, appropriately designed and specified protection agreed by the pipeline operator may be installed.

Note: Appropriate protection includes the use of specially designed epoxy sleeves.

If it is not reasonable or practicable to carry out the required modifications to the pipeline or the installation of appropriately designed and specified protection, a documented safety evaluation, including a quantified risk analysis, may be carried out in accordance with Section 6.8.

6.10.5 **Traffic routes (water courses)**

6.10.5.1 Pipeline crossings of rivers and canals that convey waterborne commercial or recreational traffic shall be classified and treated as if an "other traffic route" (see clause 6.10.3).

6.10.5.2 The design of water course crossings shall identify all foreseeable events, the likelihood and consequence of such events taking place and mitigation of identified risks.

6.10.5.3 The design of water course crossings shall not be less onerous than that required for the land pipeline and should take into account the following additional features within the selected pipeline crossing route corridor:

- type and intensity of shipping, fishing and other commercial or recreational activities
- geology, environmental, currents, stability and erosion of banks and beds
- ship anchoring, dredging and dumping
- presence of other services
- installation methods, loads and stresses, buoyancy effects, stability analysis
- coating, corrosion protection requirements
- operational requirements, including consideration of isolating line valves at each side of a crossing.

6.10.6 **Pipelines running parallel to other traffic routes**

Normally, special precautions are not required for a pipeline running parallel to another traffic route, but consideration shall be given to such precautions if the pipeline route is at any point inside the boundary of the traffic route.

6.11 **PIPELINES RUNNING PARALLEL TO OR CROSSING OTHER MAJOR PIPELINES**

6.11.1 **Pipelines running parallel to other major pipelines**

Where practical, new pipelines should be routed to avoid close proximity when running parallel with existing major accident hazard pipelines (see clause 4.1.2). Where this is impractical, construction of a new pipeline in parallel with an existing one is acceptable where a sufficient separation distance between the two pipelines can be maintained to limit the possibility of interaction and escalation in the event of a failure.

Note 1: The easement arrangements for the existing pipeline need to be taken into account when constructing a second pipeline.

Note 2: Where gas pipelines are routed in pipeline corridors or in close proximity to other product pipelines, relevant marking of the gas pipelines (e.g., PE Slabs marked GAS) are to be installed.

The minimum separation distance required to prevent escalation is a complex function of the pipeline parameters and ground conditions. Reference to Table 6 should be made for guidance on the minimum separation distance expected for a range of pipeline diameters and ground conditions for two parallel buried Natural Gas pipelines of MOP $\leq$ 80 bar.

Provided that the separation distance between the centreline of the larger diameter pipeline and the nearest point on the circumference of the other pipeline is greater than the minimum separation distance estimated for the larger diameter pipeline, escalation as a result of a failure on one pipeline interacting with the other can be considered extremely unlikely. Where these minimum distances cannot be achieved due to practical constraints, specialist advice should be sought.

NOMINAL PIPELINE DIAMETER (mm)	**MINIMUM SEPARATION DISTANCE (m)**		
	SOIL TYPE		
	Sandy	**Mixed**	**Clay**
≤323.9	7	5	3
>323.9 ≤457	8	5	3
>457 ≤610	8	5	4
>610 ≤762	9	6	5
>762 ≤914	10	6	6
>914 ≤1067	11	7	7
>1067 ≤1219	12	8	8

Note 1: The table is applicable to parallel NG pipelines only. Situations where a NG pipeline is parallel to a pipeline transporting another gas or liquid (or where MOP for a NG pipeline exceeds 80 bar) are outside the scope of this simple guidance and have to be assessed on a case-by-case basis.

Note 2: The calculated separation distances assume that both pipelines are at the same depth and that this depth is approximately as given in Sub-Section 7.16.

Note 3: This table is applicable to new or diverted pipelines. Where existing pipelines are not in compliance with this table, and where a connection is to be made into one of the pipelines, then this needs to be assessed on a case by case basis.

TABLE 6 - MINIMUM SEPARATION DISTANCE (m) FOR PARALLEL NATURAL GAS PIPELINES. MOP ≤ 80 bar

6.11.2 Pipelines crossing other major pipelines

Where the route of a new pipeline crosses an existing major accident hazard pipeline, a minimum vertical separation distance of 600mm between the pipelines shall be required to:

(a) ensure electrical interference is minimised

(b) mitigate the potential for damage to the existing pipeline during construction of the new pipeline

(c) mitigate any transfer of loading between the two pipelines.

Where this cannot be achieved, the separation distance and any additional mitigation measures shall be agreed between both parties.

The design shall incorporate a crossing using thick wall pipe i.e., design factor ≤ 0.3.

Note: Where the pipeline nominal wall thickness is 19.1mm or greater, the design factor may be increased to 0.5

The potential for escalation as a result of leakage should be assessed and limited by appropriate design, taking into account both vertical separation and angle of crossing. Where practicable and to reduce the level of risk, the design should accommodate a crossing perpendicular to the existing pipeline.

The need for a physical barrier or marker tape above the pipe at the crossing point shall be considered.

6.11.3 Pipelines running parallel to or crossing other major pipelines

For pipelines running parallel to, or crossing other major accident hazard pipelines, due consideration shall be given to the possibility of DC stray interaction and the location of transformer rectifier and ground-bed locations. Where possible a new pipeline should not be routed such that it is between an existing pipeline and its groundbed(s).

Note: The typical distance of influence from a groundbed on a third-party pipeline is between 150-200 m but where groundbeds are operating at high current output i.e., typically above 10 A the minimum separation distance between a third party pipeline and groundbed can approach 400 m. The separation distance can vary significantly and is dependent on soil resistivity and other geological conditions e.g., coal seams etc. Expert advice is to be sought in such circumstances.

6.12 SLEEVING

6.12.1 General

6.12.1.1 Only construction sleeves should be used on a pipeline designed in accordance with this Standard, i.e., when required to facilitate construction of a carrier pipe. Where a pipeline is to cross a major obstacle such as a road, railway, river, etc., pipe of increased wall thickness shall be used in preference to sleeving.

Note: Existing sleeves which meet the Class 1 or Class 2 design requirements of IGE/TD/1 Edition 2 may continue to be used to allow the pipeline to operate up to its original design factor.

6.12.1.2 Where uprating of a pipeline above the original design factor would cause an existing sleeve to exceed its design limit, risk assessment shall be used to determine acceptability at the increased design factor.

6.12.1.3 If a sleeve is to exceed 150 m in length or the incorporation of a bend is required, specialist advice should be sought.

6.12.1.4 The sleeving of valves, tees and isolating joints is not considered practicable and such items should not be included in construction sleeves.

6.12.2 Selection of a sleeving system

6.12.2.1 Where it is considered necessary to install a sleeve to facilitate construction, preference should be given to the use of grouted concrete pipe to reduce the CP problems inherent with steel sleeving.

6.12.2.2 Where a concrete sleeve cannot be used, a steel sleeve may be used. The steel sleeve and carrier pipes shall be designed and constructed to maintain electrical isolation between them.

The carrier pipe should be coated using approved materials and procedures, installed so as to avoid damage to the coating, and the annulus fully grouted with a suitable pumpable cementitious material.

Test cable attachments should be made to the sleeve and carrier pipes to enable suitable monitoring to be carried out.

6.12.3 **Materials and standards**

6.12.3.1 Plastic pipes shall not be used for sleeving as this will prevent CP of the carrier pipe within.

6.12.3.2 Concrete sleeve sections should be made to BS 5911 and be designed for the fill and surcharge loads and for the type of bedding.

Note: Guidance is given in BS EN 1295-1

6.12.4 **Sleeve diameter**

The internal diameter of a sleeve shall exceed that of the external diameter of the carrier pipe by at least 150 mm. Consideration shall be given to a diametral difference of 300 mm where constructional difficulties may arise, for example in a long sleeve.

6.12.5 **Sleeve length**

6.12.5.1 The length of a construction type sleeve shall be the minimum necessary for construction of the carrier pipe.

6.12.5.2 The nominal wall thickness of a steel sleeve shall not be less than that indicated in Table 7, to protect against damage by mechanical plant and/or provide adequate strength for handling.

NOMINAL OUTSIDE DIAMETER OF SLEEVE (mm)		LEAST NOMINAL WALL THICKNESS (mm)
	≤457	6.4
>457	≤610	7.9
>610	≤914	9.5
>914	≤1067	11.9
>1067	≤1219	12.7
>1219	≤1422	15.8

TABLE 7 - LEAST NOMINAL WALL THICKNESS OF STEEL SLEEVES

6.12.6 **Carrier pipe support**

6.12.6.1 A suitable support system shall be designed to enable the carrier pipe to be installed, and to remain supported adequately and positioned within the sleeve.

6.12.6.2 Support shall be capable of withstanding the mechanical loads that arise due to the weight of the carrier pipe when filled with water (for hydrostatic testing) and the forces caused by the relative movement of the carrier pipe normal to, or along, the pipe axis during construction, without causing damage to the protective coating of the carrier pipe.

6.12.6.3 The support system shall be designed such that the carrier pipe is supported adequately around the circumference, is positioned concentrically within the sleeve, and the flow of grout through the annulus during grouting is unimpeded as far as practicable.

6.12.6.4 Where a steel sleeve is used, the spacer support system shall provide and maintain electrical isolation between the sleeve and carrier pipes.

6.12.7 End-seals

6.12.7.1 Any end-seal shall be designed to contain twice the maximum pressure exerted by the fill in the annulus between the carrier pipe and the sleeve, during installation and in service.

Note: Cementitious or proprietary end-seals may be used for concrete sleeves, dependent upon the requirements to install fill and drain pipes through the seals.

6.12.7.2 Proprietary rubber seals or other options that provide electrical insulation shall be used for grouted steel sleeves.

6.12.8 Attachments

Any attachment such as vent and fill pipes and cable connections should be designed to standards appropriate to their intended use.

6.12.9 Drain points

6.12.9.1 Whilst any sleeve should be designed to prevent the ingress of water, drain-points should be fitted to remove water following construction.

Note: These may be of a temporary nature and may be removed following commissioning.

6.12.9.2 Any sleeve should be laid to a fall with the drain point(s) at the lowest point(s) of the sleeve.

6.12.10 Annular filling

6.12.10.1 In selecting fill material, consideration shall be given to the requirements of any relevant authority and of maintenance requirements.

6.12.10.2 The annulus shall be filled completely.

Note: Cementitious grout is recommended for filling the annulus between sleeve and carrier pipe. Alternative fill materials may be used provided they either inhibit corrosion (e.g., non-corrosive visco-elastic compounds, inhibited wax) or allow cathodic protection current to reach the carrier pipe (e.g., concrete, alkaline grout).

Where the sleeve is water filled (fresh or sea water) CP must be maintained on the carrier pipe.

6.12.10.3 The differential of the annular pressure over the internal pressure in the carrier pipe should not exceed the values given in Table 8 at any time during the annular filling. This is to avoid the possibility of collapsing the carrier pipe during annular filling

D/t_{min}	**MAXIMUM EXCESS OF ANNULUS PRESSURE OVER INTERNAL PRESSURE OF CARRIER PIPE (bar)**
50	9.7
60	5.2
70	3.4
80	2.2
90	1.6
100	1.2
t_{min} minimum wall thickness of the carrier pipe (mm) as defined in Sub-Section 6.4 and D is the outside diameter of the carrier pipe.	

TABLE 8 - LIMITING PRESSURE DIFFERENTIALS FOR CARRIER PIPE

6.12.10.4 Material for filling the annulus shall either inhibit corrosion (e.g., non-corrosive visco-elastic compounds, inhibited wax) or allow cathodic protection current to reach the carrier pipe (e.g., concrete, alkaline grout).

Note 1: Normally, control of corrosion will be achieved by a combination of pipe coating, annular fill and CP.

Note 2: The intent of cementitious fill is to provide a non-corrosive environment, to allow CP current to flow to the carrier pipe, to withstand external loads imposed on the sleeve and carrier pipe and to resist the ingress of free water.

6.12.10.5 Cementitious fill should be demonstrated not to cause deterioration of the sleeve or carrier pipe. Excessive quantities of chlorides, nitrates and sulphates have potential to cause deterioration of steel.

Note: It is recommended that proprietary grout that shows no significant change in volume when placed and ensures the corrosion rate for steel is low be used.

6.13 VALVES

6.13.1 In a cross-country pipeline, valves shall be provided to limit inventory loss and facilitate maintenance, repair, modification, testing and commissioning. Installation of remotely operable valves shall consider the cyber risk posed.

Note: These may be hand-operated, automatic or remotely controlled valves.

6.13.2 Section isolation valves (also referred to as "block valves") shall be installed at a maximum spacing of 16 km unless a wider spacing is justified through assessment which should be based upon safety, environmental and commercial considerations. The assessment should take account of:

- MOP of the pipeline
- diameter of the pipeline
- time taken to arrive at the valve site
- probability of leakage
- areas of high population density, such as residential, industrial and commercial areas
- the inventory of gas that will be released prior to being able to achieve isolation in the event of pipeline failure
- the inventory of gas that will be released to the environment in the event of temporary or permanent decommissioning of the pipeline
- need for valves for operational purposes
- position of the nearest offtakes and other existing valves
- topography and terrain covered by the pipeline
- ease of continuous access for operation and maintenance
- protection from vandalism
- continuity of service/supply
- expected development along or adjacent to the pipeline section between valves
- significant natural conditions that may affect the operation and security of the pipeline, for example ground movement, etc.
- time to blow down/vent the isolated section of pipeline in case of emergency or maintenance

- sections required for hydrostatic pressure testing of the pipeline

Note 1: Valves may reduce the total duration of a release. In terms of risk reduction, it would be necessary to install valves, with a rapid response to any failure, at short intervals along the pipeline to significantly reduce the risk level.

Note 2: In industrial and commercial areas, and residential areas of high population density, an assessment based on the above factors may identify that it is appropriate to reduce the 16 km maximum spacing.

Any main isolation valve shall be of the full-bore ball type.

6.13.3 Section isolation valves should be installed at either side of any major river or estuary crossing where the pipeline could be damaged by a ship's anchor or scouring of the riverbed.

6.13.4 Any block valve should be installed below ground with the valve-operating device readily accessible from above ground.

Note: Stem extensions can be used to elevate the valve operator above ground.

Consideration shall be given to extending the sealant/lubrication and valve vent pipework for ease of access.

Any valve shall be supported to prevent settlement which may affect the integrity of the pipeline system.

6.13.5 Where necessary, suitable pressurising bridle/bypass and vent connections should be provided either side of any main line isolation valve in the pipeline.

Note: This is to facilitate valve operation while minimising the risk of seat damage and to allow any section of pipeline to be vented within a reasonable time.

Any vent connection provided shall be located so as to allow venting operations without causing undue hazard.

Where vents and/or bypasses are required, their sizing shall be such as to allow a section of pipeline to be depressurised as rapidly as practicable during an emergency situation. They should be designed in accordance with IGEM/TD/13.

6.14 PIGGING

6.14.1 Pipelines shall be designed to allow initial and periodic internal inspection using pigs. Consideration shall be given to equipment and sufficient space for loading and unloading pigs and to the selection of bends, valves, tees and other components, so as to permit effective and safe pigging. In cases where pigging is not feasible or practical at the design and construction stage, the design shall enable internal inspection in future operation without the need for modification of the pipeline.

6.14.2 Pigging stations shall be provided at intervals as required for the techniques being used for internal inspection.

Consideration shall be given to whether a permanent or portable facility is required, and what type of pig trap configuration is needed, i.e., launch, receive or universal (which has launch and receive capability) in conjunction with the relevant user/operator function.

6.14.3 The design, construction and testing of pig traps shall meet an acceptable pressure vessel standard, such as PD 5500, appropriate to the MOP of the pipeline, with dimensions to accommodate the pigs to be used.

6.14.4 When designing a pig trap for a pipeline, the following should be incorporated:

- an oversize diameter of at least 100 mm greater than the nominal diameter of the pipeline.

  Note: Typically, an eccentric reducer is incorporated in the pig trap so that when the pig enters the receive facility, the "cups" which ensure there is a gas-tight seal between the pig and the inside of the pipeline to allow the vehicle to be propelled along it, are disengaged and allow gas to flow around the pig, which helps to stop the pig.

- pipework design and selection of bends, valves, tees and other components shall be in accordance with IGEM/TD/13.
- suitable tappings of at least 25 mm nominal size, so that the trap may be purged in front of, and behind, the pig, with interconnecting pipework to enable the pressure to be equalised across the pig during pressurisation and depressurisation.

  Note: An equalising bridle arrangement is required to balance the gas pressure around the pig trap to prevent sudden and uncontrolled pig movement. The bridle arrangement also enables parts of the facility to be vented and purged.

- adequate access to, and working space in front of, the trap for the delivery of pigs/inspection vehicles, craneage etc. Consideration shall be given to equipment access and clearances for loading and unloading all types of "pigs" and internal inspection equipment, i.e., pig trap height-above-ground level and, where possible, a standing area to allow for the cleaning of the on-line inspection vehicle.
- bonding of the pig trap and closure to earth.

6.14.5 Consideration shall be given to the selection of bends, valves, tees and other components, to ensure effective and safe pigging of any pipeline. In particular:

- where a branch connection diameter exceeds 25% of the pipeline diameter, guide bars should be incorporated in the branch connection.

  The design of guide bars should be to a suitable standard.
- care shall be taken to ensure thermowells or other insertion devices are not installed on the pipeline that is to be pigged
- the number of bends on the final approach to, or initial despatch from, a pig trap should be kept to a minimum
- bends for inclusion in the pipeline should have minimum bend radius of 3 times the pipe outside diameter
- pipework configurations with multiple branch connections, such as tees and sweepolets, in close proximity, should be avoided to ensure that the pig will not come to rest with one "cup" being bypassed in one connection and the second "cup" in the second connection.

6.14.6 On pig launch facilities, the length of the pig trap between the closure and the small end of the reducer should be sufficient to accommodate the longest pig to be used. The length of pipework between the pig trap reducer and the isolation valve should take account of the designs of pigs to be used and should allow for satisfactory engagement of pig cups.

6.14.7 On pig receive facilities, the length of pipework between the isolation valve and the small end of the pig trap reducer should exceed the longest length of pig to be used.

6.14.8 A safety latch should be fitted on any pig trap door, the design of which should include the provision of suitable devices:

- to securely fasten the door while it is subject to internal pressure and
- to prevent the door being blown open violently by any residual pressure in the vessel.

The door shall be pressure interlocked, i.e., it cannot be opened under pressure. Interlocking can utilise suitable devices incorporated into the door design that prevents it from being opened under pressure, or by the use of a suitable interlocked vent.

Consideration shall be given to interlocking the door to pig trap isolation valving to prevent the vessel from being pressurised without the door being securely fastened. As a minimum, there shall be clear indication that the door is in the closed position and all holding elements are in the correct position before the vessel is pressurised.

The door design shall ensure that in the event of holding elements being released under residual pressure, the door is restrained from fully opening and is in such a position that the door seal ceases to function allowing the contents to be released in a safe manner. Alternative designs may be acceptable to the Network Operator, e.g., the door is required to be moved against the residual pressure force prior to release proving that there is negligible residual pressure prior to release.

6.14.9 Sufficient pressure monitoring points should be included to allow temporary pig tracking equipment to be installed for pigging operations.

6.14.10 Indication devices, for example "pig alerts" should be positioned strategically on the pigging facility to give warning of despatch or receipt of pigs.

The pig alerts incorporated on the pipeline should be provided with a suitable valve arrangement to facilitate removal in the event of damage.

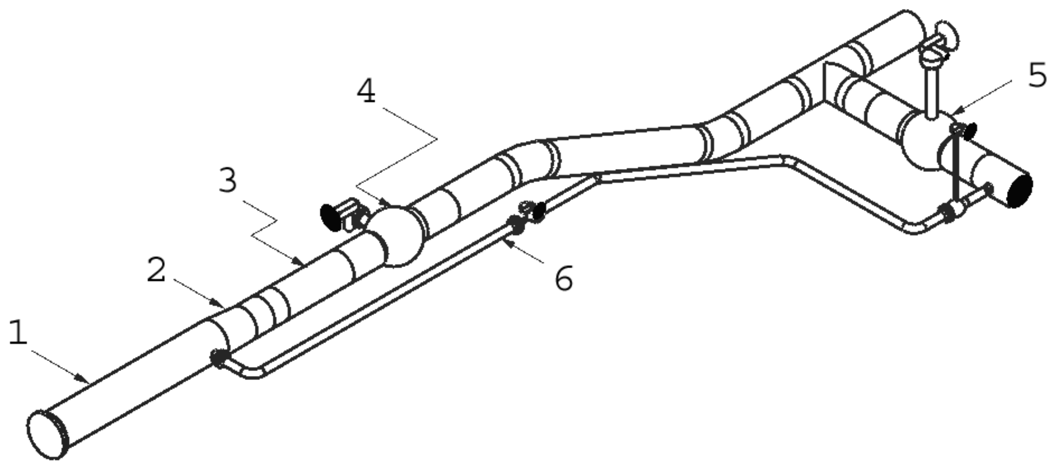
6.14.11 If the pigging facilities are to be used for internal inspection, additional provisions and clearances should be provided, if required (see clause 12.10.3).

Note: An example of a typical layout for pig traps for use with internal inspection equipment is shown in Figure 8.

6.14.12 A pig trap installation should provide, as a minimum, the following:

- insulation joints for CP purposes
- drains, vents, pressure points and control connections (see Figure 8)
- a facility for removing or replacing the trap, where it is not part of the permanent installation.

6.14.13 Consideration shall be given to the design, location and operation of any liquid collection or despatch system, to ensure the safety of operators and to prevent spillage.



Key
1 Pig trap barrel
2 Eccentric reducer
3 Pig trap throat
4 Pig trap isolation valve
5 Branch/offtake valve
6 Forcing/receive gas line

FIGURE 8 - TYPICAL PIG TRAP INSTALLATION

6.15 OVERHEAD PIPE CROSSINGS

6.15.1 Overhead pipe crossings, for example of rivers, canals, railways and roads, should be avoided, wherever possible.

6.15.2 Where an overhead crossing is unavoidable, it shall be designed, located and maintained to:

- accept the stresses imposed on the pipe, carrier system and foundations and supports, within acceptable limits. Reference should be made to IGEM/TD/12
- be acceptable in environmental aspects
- have sufficient headroom to ensure the piping system is secure from possible damage due to the movement of vehicles, railstock or shipping beneath them
- have suitable barriers to restrict access, except to those concerned with maintenance
- avoid touch potential, step potentials, and AC interference risks shall be considered near electrified railway lines. Insulation joints may be necessary either side of the above ground crossing to manage this
- maintain security and discourage vandalism
- have suitable accessibility to all components for the purpose of painting and lubrication
- avoid interference, including touch potentials, between the CP system for the pipeline and any supporting structure, including temporary CP systems
- have suitable barriers or protection to prevent damage to the carrier pipe by vehicles, or for watercourse crossings, vessels
- have supports whose bases are on firm ground and incapable of being weakened by scouring
- Suitable signage and contact details to warn and inform trespassers

Note: A risk-based approach may be suitable to assess the above ground pipe crossing access risks.

6.16 OTHER DESIGN ISSUES

In certain circumstances, specification of linepipe wall thickness, use of specific components or requirements for specific design details, may result in local wall thickness requirements greater than 30 mm. In such cases, heat treatment of site fabrications may be necessary. The designer shall give consideration to the selection of materials to which post weld heat treatment (PWHT) may be applied and the specific requirements for stress relief using post-weld heat treatment on thick sections. Alternatively, an engineering critical assessment (ECA) may be used to demonstrate that PWHT is not required. The ECA should confirm (or specify) the material toughness requirements, determine the critical crack sizes and define relevant inspection requirements.

The effect of PWHT on material properties should be taken into account in the design process.

Note: Methods for ECA are given in BS 7910.

6.17 DESIGN RECORDS

Comprehensive records shall be compiled during the design phase and, upon completion, should form part of the package of "as-built" documentation that is handed over to the operator.

Such records should include maps showing, where appropriate, where thick wall pipe was required, together with the reasoning, any calculations, drawings of any installations, materials and coating properties.

SECTION 7 : CONSTRUCTION OF PIPELINES

This Section deals with the construction of buried pipelines. Construction requirements for associated installations are covered in IGEM/TD/13.

7.1 GENERAL

The following requirements should not be considered as exhaustive and are intended to cover only points of particular significance.

7.2 ADMINISTRATION

7.2.1 Communications

Good communication between construction centres and field crews, at all levels, should be maintained. Maximum use should be made of modern communication techniques in the control of all activities on pipeline systems. Operatives should be trained in the effective and disciplined use of such equipment.

7.2.2 Supervision

7.2.2.1 In selecting the level of supervision required, consideration shall be given to:

- the nature and complexity of operations being undertaken
- the potential risks that operations impose.

7.2.2.2 Supervisory activities shall only be undertaken by people who are competent and have the appropriate level of authority.

7.2.2.3 Every endeavour should be made to plan the operations so that the period of occupation of land is kept to a minimum.

Note: Depending on the size of the project, it may be necessary to divide it into sections (either by location or by activity or by a combination of both) each supervised by personnel experienced in the activities taking place in the section.

7.2.3 Construction records

Comprehensive “as laid” records of the pipeline shall be prepared during the construction period. These should include details such as:

- grade and wall thickness of linepipe used for the carrier pipe
- information on, and the location of, butt welds
- protective materials used
- precise pipeline route and depth at frequent intervals
- details of land ownership
- land drain reinstatement
- particulars of the CP system (including any temporary CP schemes), sleeves (including materials and components), bends, valves, tees, etc.
- test records
- location of tie-in welds between test sections
- differences between “design” and “as laid” information, with reasons
- presence of other nearby below-ground plant and connections to other pipelines
- any other relevant information that is not readily obtainable by surface inspection, including archaeological details
- modification to the original design.

Where explosives have been used, the relevant sections should be indicated on the "as laid" records.

Following completion of construction work, the construction records should be deposited with the pipeline owner/operator under a formal handover system.

7.3 SAFETY

7.3.1 General

7.3.1.1 A high standard of safety shall be maintained at all times.

7.3.1.2 A safety management plan shall be prepared, which clearly defines:

- how health and safety law is to be managed
- the safety procedures, codes of practice and standards to be implemented
- the roles and responsibilities of individuals on the pipeline project.

7.3.1.3 Where a pipeline forms part of a larger installation, the health and safety plans shall encompass the interfaces of the different elements of the project.

7.3.1.4 Adequate supervision shall be provided to protect employees, the public, property and plant.

7.3.1.5 Work supervisors shall be capable of ensuring that all necessary safety precautions are taken for the protection of personnel, members of the public and property that might be affected by the works.

7.3.2 Safety training

Employers must provide such instruction, training and equipment as is necessary to ensure, as far as is reasonably practicable, the health and safety of all personnel.

7.4 ENVIRONMENT

7.4.1 General

7.4.1.1 Work shall be conducted within the framework of the project environmental management plan, adopting the same principles as for the safety management plan which should identify existing Legislation, and shall be in accordance with appropriate guidance and codes of practice.

7.4.1.2 Consideration shall be given to the identification and minimisation of emissions to air, surface and ground water courses and also the disturbance of all land involved in the works.

7.4.1.3 Efforts shall be made to minimise disturbance to natural resources, ecologically sensitive habitats and archaeological sites.

7.4.2 Noise abatement

7.4.2.1 A certain amount of noise is inherent in all construction operations. The best practicable methods shall be employed to minimise noise emissions to levels acceptable to site personnel and third parties and must be employed sufficiently so as to comply with Regulations.

7.4.2.2 Special consideration shall be given to:

- designing out noise-generating operations before construction starts
- siting and possible screening of plant and equipment

- use of acoustically attenuated powered tools, compressors and generators
- avoiding operations outside normal working hours
- controlling noise related to venting operations associated with pigging and/or following testing.

7.4.3 **Contamination of water courses**

Any fuel, lubricant, chemical or other liquid contaminant shall be stored, used and disposed of in such a way as to minimise the possibility of adverse environmental impact.

7.4.4 **Traffic**

Consideration shall be given to implementation of a Traffic Management Plan, agreed with the appropriate statutory authority, in order to minimise the nuisance and damage caused to public roads and footpaths.

7.5 **RECEIVING MATERIALS**

7.5.1 A formal control system shall be adopted for the recording of materials throughout receipt, storage, transport and issue.

7.5.2 All materials shall be inspected upon receipt on site. Any damaged materials shall be rejected or, in cases of minor damage, conditionally accepted. The storage and handling of pipes shall be such as to prevent damage to the pipe (see IGEM/TD/1 Supplement 1). Certain types of surface damage to the pipe may be repaired by an approved method. Otherwise, the section of pipe containing the damaged section shall be cut out.

7.5.3 Great care shall be taken to prevent damage to, or disbondment of, any protective coating. Slings or other equipment used for handling pipes shall be designed so as to avoid damage to the pipes or coating. If the coating is disturbed or damaged, the portion affected shall be repaired by an approved method. Where the damage is extensive, the affected area shall be recoated completely.

7.5.4 Pipework materials shall be handled, transported and stored in accordance with IGEM/TD/1 Supplement 1.

7.5.5 Materials shall not be stored below overhead power lines.

7.6 **ENTRY ONTO LAND AND SETTING OUT**

7.6.1 A pre-entry survey of the route should be carried out to establish and record initial conditions of the site and to agree with the landowners and occupiers the requirements for such as route fencing, points of access, location of temporary water troughs, temporary crossings of the working width, etc.

7.6.2 The setting out of the route of the pipeline in accordance with maps and drawings should be checked and agreed before construction begins. Such setting out should include locating and marking existing services.

7.7 **WORKING WIDTH AND FENCING**

7.7.1 In all circumstances, the limits of the working width shall be marked clearly. Temporary fencing should be provided throughout the period of construction, along each side of the working width, to protect trees with preservation orders and also to close off the working width at all points of access from public roads. This should be stock-proof where stock is kept on adjoining land.

7.7.2 Where appropriate, consideration shall be given to the installation of cut-off or header drains along and outside the working width.

Note: *This can assist in maintaining a dry working width during construction and prevent silting or blockage of any existing drainage system.*

7.7.3 Before pipes are strung, the working width should be cleared of all standing crops, scrub, hedges and similar obstruction, stripped of topsoil and graded where necessary. This work should be planned to cause the least possible disturbance to the owners and occupiers.

7.7.4 Trees and hedgerows shall not be removed without the prior consent of the landowner (see also clause 4.2.2.11 regarding legal issues).

7.7.5 Any topsoil and surface material stripped shall be kept separate from the subsoil, preferably on the opposite side of the working width.

Note: *The width and depth of topsoil to be stripped will vary according to local circumstances.*

Where a pipeline already exists, either parallel or adjacent to the working width, due consideration shall be given to the risks associated with material overburden and the movement of excavating machinery in their vicinity.

7.7.6 Consideration shall be given to the protection of the environment and ecology, including measures required when crossing areas of moorland where topsoil stripping may need to be limited to the width of the trench and special protection provided to heathers and grasses. Consideration shall be given to protected wildlife species.

7.8 SURVEYING FOR BENDS

A survey should be made to schedule bend requirements, taking into account changes in direction in both the horizontal and vertical planes and making allowance for any grading which will be carried out.

Note: *It is advisable to indicate the position of bends and the deflection required, by suitable means, at the side of the working width.*

7.9 PIPE STRINGING

7.9.1 Linepipe shall be strung in such a manner that the least interference is caused with the land crossed. Gaps shall be left at intervals as agreed with the occupier of the land to permit the passage of farm stock and equipment across the working width.

7.9.2 Care shall be taken to avoid damage to pipe and fittings during stringing by handling in accordance with IGEM/TD/1 Supplement 1.

7.9.3 If pipes are strung out on ground of a nature that could cause damage to the coating, they should be laid on padded timber bearers of appropriate size, with two timbers per pipe. Wooden wedges should be used to hold the pipes in position.

7.9.4 When using cranes on pipe spreads, a survey of overhead power supply lines shall be made and suitable safeguards introduced to protect personnel and plant. Reference should be made to HSE Guidance Note GS6. Ideally, the risk from this hazard should be eliminated or reduced at the design stage by either adjusting the pipeline route or diverting overhead power supply lines.

When it is necessary to work in the vicinity of overhead electric cables, reference shall be made to the electricity supply authority before site work commences. Its advice should be sought, for example on possible temporary isolation; minimum clearances; alternative access points; barriers and goal posts.

The same methodology as for overhead power supply lines shall be applied when working in the vicinity of buried services (see HSG47 and IGEM/SR/18). Where stringing is taking place parallelisms may be unavoidable, in such instances it may be necessary to manage the earthing of individual strings or pipelines prior to and during welding activities.

7.10 FIELD BENDING

7.10.1 Pipes may be bent cold in the field. Bending shall be performed, without wrinkling, on a suitable machine.

An internal mandrel should be used, particularly for larger diameters.

7.10.2 In the finished bend, the angular deflection measured along any axial length equal to the diameter of the pipe shall not exceed 1.5 °.

Note: This corresponds to the minimum ratio of radius (measured from the inside of the bend) to diameter of the pipe being in the order of 40 to 1.

7.10.3 Each pipe that is bent shall incorporate a minimum length of 1.25 m of straight pipe before and after the bent portion.

7.10.4 A bend shall not be made within two pipe diameters of a girth weld which has already been made.

7.10.5 When longitudinally welded pipes are used, the weld shall be at about 45 ° to the plane of the bend and longitudinal welds of consecutive cold bends shall not coincide.

7.10.6 Before any bend is incorporated in the pipeline, it shall be tested for ovality with a gauging plate of diameter not less than 95 % of the nominal bore, subject to a minimum clearance of 25 mm. Coating and wrapping applied before bending shall be examined and any damage made good.

7.11 LINING-UP FOR WELDING

Pipes shall be supported adequately to avoid damage to coatings and to enable both safe access and sufficient clearance for the welding and subsequent weld inspection and coating activities.

7.12 WELDING

7.12.1 General

Prior to any welding operation on a pipeline, welding processes and systems shall be assessed and approved. This should include the testing, qualification, approval of welding procedures and welders as well as arrangements for inspection, acceptance criteria and rectification of welds.

Pipe and fittings shall be prepared, welded and inspected in accordance with BS 4515-1. Cut pipes should have details of pipe reference numbers transferred to the inside of the pipe on each cut end.

Where pipe is welded above ground prior to lowering into the trench, the pipe shall be supported on suitably placed padded timbers. The support should be designed so as to prevent movement of sections of pipe. Where tie-ins are being undertaken, for example at special crossing locations, particular care shall be taken to ensure that the support is designed to suit the specific requirements at the location. Support shall remain in place until all welding operations have been completed.

Note: The risks of DC stray current interference from the welding construction process will need to be assessed (see guidance given in UKOPA/GPG/031 'DC Interference'). The DC -ve connection where specified in the weld procedure specification is to be connected to the component to be welded, otherwise current flow from the pipeline under certain circumstances may result in significant metal loss.

7.12.2 Non-destructive testing (NDT)

7.12.2.1 All welded joints shall be inspected using NDT procedures in accordance with a suitable specification.

Where radiographic inspection is required, it should be planned in relation to other work to ensure safety and avoid delay. Fabrications should be planned to enable portable spools and pipework to be transported to a purpose designed and built radiographic enclosure in line with the ionising radiation Regulations.

7.12.2.2 Phased array ultrasonic inspection in accordance with BS EN ISO 13588 or BS EN ISO 20601 may be used in place of radiography. The acceptance specification should take account of the additional information on imperfection sizes that is provided by the phased array ultrasonic method.

Note: Tier 2 of the European Pipeline Research Group Guidelines on the Assessment of Defects in Transmission Pipeline Girth Welds (2014 revision) is a suitable basis for such a specification.

7.12.2.3 Final NDT shall be performed after any repair welding and/or stress relief treatment, if required, has been performed.

7.12.3 Stress relief

In certain circumstances, for example where the pipe wall thickness is greater than 30 mm, heat treatment of site fabrications may be necessary. Consideration shall be given to the need for stress relief using post-weld heat treatment on thick sections, or alternatively the need to carry out an Engineering Critical Assessment to confirm (specify) the toughness requirements, determine the critical crack size and define relevant inspection requirements. Reference should be made to such as PD 5500, BS 7910 and BS 2633.

7.13 NIGHT CAPS

The open ends of welded sections of pipeline shall be closed by the use of suitable nightcaps, to prevent the ingress of foreign bodies and water.

7.14 JOINT COATING

The uncoated external portion of pipeline joints shall be protected to a standard at least equivalent to, and compatible with, the linepipe coating.

Note: Further guidance on cold applied wrapping tapes and tapes is given in GIS/CW2:2020, and the specification for field applied external coatings for buried pipework and systems is given in GIS/CW5:2020.

7.15 TRENCH EXCAVATION

7.15.1 The trench width shall exceed the pipe diameter by a margin which will permit proper back filling and compaction. Consideration shall be given to increasing this margin for larger diameter pipes.

7.15.2 The bottom of the trench shall be prepared to permit even bedding of the pipeline and shall be free from all objects or material that might cause damage to, or deterioration of, the pipe and pipe coating.

7.15.3 Care shall be taken during excavation by the adoption of appropriate safe excavation techniques, to ensure the stability of excavations, that other buried plant is not damaged and that the minimum amount of damage or disturbance is caused to land drains.

The position of all services and land drains affected by pipeline construction, shall be marked carefully at the edges of the working width.

7.15.4 Where any part of a pipeline is laid on top of disturbed or made-up ground, for example embankments, the ground shall first be consolidated as far as possible. Any likely further compaction or settlement shall be treated as an additional environmental load.

7.15.5 Where it is necessary to use explosives, statutory Regulations regarding their storage must be strictly observed. Agreement shall be obtained from landowners and authorities affected concerning the use of explosives and the timing of blasting operations.

The presence of adjoining underground structures or services and their proximity to the line of the trench shall be considered when deciding on the size of the explosive charge to be used. The same considerations shall be applied where the line of the trench is near to buildings which may be affected by blasting.

A condition survey shall be undertaken in advance of blasting, for any structures that might be affected. Blasting shall not be undertaken beneath overhead power lines that are in service.

7.15.6 Whenever trenchless methods are used, such as horizontal directional drilling (HDD) or pipejacking, the pipe coating shall be inspected prior to installation and any defects repaired. Immediately after installation, a current drain test shall be undertaken, and an assessment made to ensure that any coating damage that may have occurred during installation will not affect the capacity of the CP system to provide protection for the lifetime of the pipeline.

Note: Guidance on trenchless crossing methods is given in IGEM/SR/28.

7.16 DEPTH OF COVER

The minimum depth of cover over a pipeline shall be in accordance with Table 9. The depth of cover shall be measured from the lowest ground surface level to the top of the pipe, including coatings and attachments.

LOCATION	MINIMUM DEPTH OF COVER (m)
Rural	1.1
Suburban	1.1
Roads[1]	1.2
Watercourses, canals, rivers[2]	1.2
Railways	1.4[3]

Note 1: Measured from the true clean bottom of adjacent drainage ditches.

Note 2: Measured from the lowest anticipated true clean bed level.

Note 3: Refer to the appropriate authorities.

TABLE 9 - MINIMUM DEPTH OF COVER

7.17 INSPECTION OF COATING

7.17.1 Immediately before pipe is lowered, the whole of the pipe coating shall be examined carefully by means of a suitable holiday detector set at an appropriate voltage to provide a sufficient arc length for the thickness and nature of the coating material. All flaws indicated by the holiday detector shall be marked and repaired before the pipe is lowered. A record should be kept of such damage and should be included in construction records.

7.17.2 If disbondment of the coating is suspected at any point, the coating shall be removed, replaced and retested.

7.17.3 In addition to the holiday detection of the coating, pipe shall be inspected for damage such as dents, gouges, grooves, notches, arc burns, etc. Such damage shall be rectified by grinding or by cutting out the section of pipe containing the damage.

7.18 LOWERING PIPE INTO A TRENCH

7.18.1 All equipment in contact with the pipe coating when pipe is lowered into a trench shall be appropriate to prevent damage to the coating.

7.18.2 Care shall be taken to ensure that over-stressing of the pipeline does not occur during the lifting and lowering operation and that, after lowering, the pipe is not over-stressed or damaged.

7.19 BEDDING AND COVERING PIPE

7.19.1 Pipe shall be evenly bedded on the bottom of the trench throughout its length. All material used for bedding and surrounding the pipe shall be suitable for the purpose and free from sharp-edged stones.

7.19.2 Special measures shall be considered at branch connections to avoid undue stresses occurring.

Note: Uneven vertical movements or settlements can be reduced or avoided by using more substantial foundations or bedding techniques to support the branch connection and main pipeline in the area of the connection.

For larger diameter pipes, consideration shall be given to bedding and haunching the pipe to provide support to the underside of the pipe to prevent pipe ovality resulting from the surcharging of backfill material over the pipe (see Sub-Section 7.20).

7.19.3 Where conditions are such that flotation may occur after backfilling, consideration shall be given to the installation of depth markers to indicate the position of the pipe relative to the land surface.

7.19.4 Where weighted pipe is installed through peat bog, marshland, etc., consideration shall be given to the installation of depth markers to indicate the position of the pipe relative to the land surface.

Note: Guidance on the specification for External concrete coatings is given in GIS/CW9:2020

7.19.5 Where the excavation is in rock or sharp-edged stone, there shall be a bed of earth, sand or other suitable material to a minimum depth of 150 mm beneath the pipe.

7.20 BACKFILLING

7.20.1 Backfilling should follow soon after the lowering-in of the pipe.

Fine-grade material free from sharp-edged stones shall be filled and compacted carefully round the side of the pipe and to a minimum consolidated height of 150 mm above the pipe and supervised during execution.

Note: Fine grade material is defined as sand aggregate passing a 5 mm test sieve.

The materials and methods used for backfilling around a pipeline should be detailed and types of material, number of layers and compaction effort should be specified.

7.20.2 The trench should be backfilled in layers, each layer being compacted adequately. A method or performance-based approach should be developed to ensure a 90% compaction density is achieved.

Note 1: Further Guidance can be found in BS 9295:2020 'Guide to the structural design of buried pipes' and Department of Transport (2006); Practical Guide to Street Works; Highways Authorities & Utilities Committee (HAUC).

Note 2: When modifications at or in close proximity to an existing pipeline are undertaken, the pipeline compaction will require reviewing to ensure additional settlement that may increase the stress in the pipeline does not occur.

7.20.3 Care shall be taken to prevent any solid or liquid material that could be injurious to the coating of the pipe from coming into contact with the pipeline.

7.20.4 Wherever reasonably practicable, excavated materials shall be replaced such that the original soil sequence is preserved.

7.20.5 Where, on sloping ground, pipe bedding and surround material has been installed, care shall be taken to prevent loss due to slippage or washout.

Note: This could, in extreme cases such as in rocky ground, lead to physical damage to the pipeline if preventative measures are not put in place. There are a number of additional precautions that may be taken to deal with this problem, which include physical barriers and specialist fill materials. The pipeline is particularly vulnerable to this form of damage during hydrostatic testing due to its increased weight.

7.20.6 Backfilling, drainage and replacement of the topsoil should be completed prior to hydrostatic testing. If, under exceptional circumstances, it is necessary to undertake the topsoiling or further work within the working width after hydrostatic testing, the position of the pipeline shall be marked clearly and precautions taken to ensure that heavy plant and vehicles do not pass over it except at properly constructed and clearly defined crossing points.

7.20.7 Close supervision shall be given for all work over the pipeline and work activities shall be carried out and managed under a formalised written procedure such as a permit to work system.

7.21 CROSSINGS

7.21.1 General

Crossings shall be constructed by a procedure acceptable to, and approved by, the appropriate statutory authority.

Note: These may include open cut, boring, directional drilling or tunnelling methods.

7.21.2 Road and rail crossings

Crossings shall be carried out in a manner that minimises the disruption to normal traffic flow. Particular attention must be given to the statutory requirements for warning signs and lights during the construction of road crossings.

7.21.3 Water crossings, including drainage ditches

7.21.3.1 At water crossings, the pipeline shall be laid at a cover allowing for future bed movement, invert lowering, dredging operations, etc. Where water crossings are installed by the open cut method, temporary flume pipes or other methods should be considered to ensure that there is no disruption to water flow during construction. Consideration shall be given to the application of a weight coating to maintain negative buoyancy of the pipe during construction and in service. Attention should be given to maintaining the integrity of flood or tidal barriers during construction. Care shall be taken to prevent pollution of watercourses by oil, silt, etc.

7.21.3.2 Consideration shall be given to the possibility of future cleaning and deepening operations on drainage ditches. Where such operations are likely, and where the pipeline is installed by open cut methods, heavy wall pipe i.e., design factor ≤ 0.3 should be installed. Where such activities are considered for drainage ditches on existing crossings, the installation of a concrete protection slab of adequate strength and dimensions should be placed between the pipe and the cleaned bottom of the ditch to prevent impact damage. The top of the slab should be not less than 300 mm below the true cleaned bed of the crossing/ditch.

Note: The impact of a protection slab on future requirements for CIP and DCVG surveys will need to be considered.

7.22 SLEEVED AND TUNNEL CROSSINGS

7.22.1 General

7.22.1.1 A sleeve is a close-fitting casing through which a carrier pipe is inserted. Normally, the carrier pipe is concentrically located and the annular space between the pipe and sleeve is relatively small; typically, the internal sleeve diameter will be 150 mm to 300 mm greater than the external diameter of the carrier pipe. Usually, the ends of the sleeve are sealed, and the annulus filled with either grout or nitrogen.

Note: Accepted construction techniques include micro-tunnelling and pipe jacking.

7.22.1.2 A tunnel is an underground or underwater passage, the dimensions of which are significantly greater than the pipeline diameter. The minimum diameter of a tunnel is often determined by the access requirements of the miners and the specialist equipment used for construction. In such cases, the design and construction shall be in accordance with relevant codes.

Consideration shall be given to the requirements of pipeline installation, pipeline support, restraint of pipeline movement, venting of enclosed spaces, access for maintenance, corrosion protection, testing and validation, de-commissioning and dismantling at the end of the asset life.

7.22.1.3 Where, due to ground conditions, it is considered necessary to install a construction sleeve for bored crossings, special consideration shall be given to cathodic protection during the design stage. Preference should be given to the use of concrete pipe sleeves to reduce CP problems inherent with steel sleeving. Appropriate standards should be selected for each material.

Note: The choice of other materials will depend on their ability to meet the relevant design requirements of Sub-Section 6.12.

7.22.2 **Concrete and alternative materials for sleeves**

Concrete pipes used for sleeves shall comply with an appropriate standard and be installed, one length at a time, to a true line with suitable gradient. The jointing requirements specified by the manufacturer shall be followed.

Provision for the annular fill which, normally, will be cementitious, should be made by fixing risers of 50 mm diameter at each end. For longer lengths of continuous sleeving, the maximum annular space should be provided and consideration given to using intermediate filling points.

7.22.3 **Steel sleeves**

7.22.3.1 Checks shall be carried out before and after carrier pipe tie-in operations to ensure that there is no electrical contact between the carrier pipe and the sleeve.

Note: Such a contact would make it impossible to cathodically protect the carrier pipe within the sleeve.

Such checks shall be carried out and any electrical short circuit remedied before the annulus is grouted. A further check shall be carried out after grouting operations to ensure that electrical isolation is maintained.

Welding and inspection procedures shall be in accordance with the appropriate standards.

7.22.3.2 Whenever welding is carried out on a sleeve in position, precautions should be taken to prevent damage to the spacers or the external coating of the carrier pipe. Any protective material used for this purpose should either be fixed securely or be removed after construction.

7.22.4 **Pipe spacers for sleeves**

7.22.4.1 The carrier pipe support system shall be designed so as to avoid any damage to the carrier pipe coating during installation. Care shall be taken to avoid:

- blocking drain points or annular fill inlets
- displacement of the carrier pipe.

The carrier pipe should be adequately supported at the sleeve ends.

7.22.4.2 Particular attention shall be given to the consolidation of the backfill under the sleeve ends and the adjacent carrier pipe.

7.22.5 **Annular filling of sleeves**

7.22.5.1 *General*

Filling of the sleeve annulus should be carried out after hydrostatic testing of the pipeline.

7.22.5.2 *Grout filled sleeves*

Checks shall be carried out immediately before and after grouting, to confirm continuing electrical isolation between the sleeve and carrier pipe.

The annular fill shall be tested to ensure compliance with the specification. Water for mixing should be clean.

The total volume should be calculated prior to the start of filling and a check made to ensure that the actual volume placed correlates closely with that calculated.

The annulus between the carrier pipe and the sleeve should be clean and drained of water before any filling operations commence. Care should be taken to ensure the recommended water/solids ratio is not exceeded and that grouting pressures do not exceed specified levels.

Suitable means of sealing should be used to prevent undue loss of material from sleeve ends. Due consideration shall be given to avoiding spillages that could cause environmental damage.

7.23 FOUNDATIONS

Foundations shall be constructed to accommodate the nature of the grounds and the requirements of the structure to be supported. Such equipment includes valves, pig traps, filters, pipe supports etc. Construction shall conform to BS EN 19928110-1 and/or BS 8004, as appropriate.

Note: HSE Research Report 319 "Safer foundations by design" provides guidance on the management of risks arising from various ground engineering processes.

7.24 REINSTATEMENT

7.24.1 In order to protect the pipeline from construction damage, every effort shall be made to complete all reinstatement activities prior to hydrostatic testing.

7.24.2 Any operation that cannot be completed prior to the hydrostatic test shall be carried out under a formalised written procedure such as a permit to work system.

7.24.3 Work shall not be undertaken while the hydrostatic test is in progress.

7.24.4 As soon as practical after backfilling, and prior to topsoiling, the work width should be cleared of all construction debris and any surplus materials. The ground profile should be reinstated so that the pipeline working width matches as closely as reasonably practical its original contour.

7.24.5 Consideration shall be given to the "ripping" of subsoil to break up the compaction that will have occurred with the passage of heavy construction plant.

Note: This activity can help prevent future drainage problems due to an effect known as "panning".

7.24.6 Consideration shall be given to either reinstating existing land drainage or installing new header drains.

Note 1: Any new header drains may be additional to any cut off drains that were installed prior to the commencement of pipeline construction.

Note 2: The previously excavated trench line could suffer from settlement that could lead to future drainage problems if special measures are not undertaken.

Note 3: Drainage issues can result in high operating costs during the life of the pipeline if not undertaken to an appropriate design and to a high standard of workmanship.

Note 4: Areas subject to erosion, such as the banks of watercourses, may require specialist reinstatement techniques. In some cases, these will be under the control of an Authority and any technique will have to be agreed with it in advance. Similarly, public roads and accesses will require prior agreement with the relevant authority for any reinstatement technique that is used.

7.24.7 Once the topsoil has been replaced and fences reinstated, a joint inspection should be undertaken with the landowner or occupier prior to formally returning the land back to their use.

7.25 PIGGING

7.25.1 Steps shall be taken to ensure that the pipeline is free from internal obstruction following construction operations.

Note: It is recommended that a cleaning/swabbing procedure be carried out prior to gauging.

7.25.2 Pigging shall also be carried out if associated pig traps and test ends are designed specifically for the purpose.

7.25.3 At the stage before testing and again at the stage before commissioning, a suitable gauge plate or geometric pig shall be passed through the pipeline to prove the bore to the specified acceptance procedure.
If a geometric pig is used, all local reductions in diameter equal or greater than 2.5% diameter should be investigated, assessed and, where necessary, remedial action should be taken.

Note 1: For large diameter high strength pipelines, the use of a geometric pig run prior to commissioning may identify any dents caused as a result of construction activity.

Note 2: Geometric pigs are to have lineal measurement capability.

Note 3: Guidance on managing pipeline dents is given in UKOPA/GPG/004.

If a gauge plate is used, its diameter shall be 95% of the minimum bore of the pipeline/fittings, subject to a minimum clearance of 25 mm on diameter.

Note: The recommended acceptance level of 5% for diameter reduction is specified to identify ovality or out-of-roundness of the pipe as a result of construction activities.

7.26 MARKER POSTS

7.26.1 The position of the pipeline shall be indicated at suitable intervals by means of marker posts (MP) and/or aerial marker posts (AMP). These should be at all field boundaries so as to be seen in the line of sight, at all crossings and, where practicable, at changes in direction. They shall indicate the location of the pipeline after reinstatement of the ground.

At locations where the pipeline crosses a public highway, AMP or MP markers shall be installed on both sides of the road where it is reasonably practicable.

Note 1: AMP and MP posts are to be positioned such that a post can be seen in the line of sight at any point along the pipeline.

Note 2: 1 metre of permanent clearance is required, where practical, around marker and CP posts to ensure that they do not become obscured between inspections.

7.26.2 Consideration shall be given to the provision of suitably located markers specially designed for observation from the air.

7.27 TESTING

Testing should be undertaken in accordance with Section 8.

7.28 TIE-INS AFTER TESTING

7.28.1 Consecutive sections of pipework should be made so as to overlap such that the tie-ins can be made with a single weld. Where the tie-in is required between two previously tested sections, and cannot be achieved in a single weld, it shall be made using pipe previously hydrostatically tested to a pressure not less than the test pressure of the adjacent sections.

7.28.2 Tie-ins shall be aligned properly without the use of jacks to prevent joints being left under stress. Changes to ambient temperatures should be given due consideration when tie-ins involve long lengths of exposed pipe. They should not be made when the temperature is above 30 °C or below 5 °C.

7.28.3 All tie-in welds shall be subjected to full NDT to a specification giving an equivalent level of integrity to that of the rest of the pipeline. This should include:

- Visual and dye penetrant (DP) or magnetic particle inspection (MPI) of the weld end preparation
- 100% radiography and 100% ultrasonic testing (UT, manual or phased array)
- DP or MPI of the completed weld.

7.29 POST-CONSTRUCTION COATING and CLOSE INTERVAL POTENTIAL SURVEY

On completion of pipeline installation and where possible before any slab protection is installed, a close interval potential (CIPS) and coating defect survey shall be carried out using an appropriate technique to locate any areas of coating damage on the buried pipeline. Any damage found shall be investigated, assessed and, where appropriate, repaired. A CIP survey shall be carried out following commissioning of the CP system.

7.30 CATHODIC PROTECTION (CP)

CP should be installed in accordance with Sub-Section 10.4.

7.31 COMMISSIONING

Commissioning should be undertaken in accordance with Section 9.

SECTION 8 : TESTING OF PIPELINES

This Section covers testing of pipelines. Testing, filling and emptying procedures shall be in accordance with Appendices 5 and 6.

Prior to the use of any high pressure pipeline, a hydrostatic strength test shall be carried out.

Note: For pipework, this is achieved by pressurising the pipework to a level above MOP.

With the current standards of construction, supervision and inspection, it is no longer considered appropriate to carry out pneumatic leak testing of pipelines either prior to, or after, the hydrostatic strength test.

Note 1: Pneumatic testing may be employed as a leak test where items are omitted from the hydrostatic test.

Note 2: Pneumatic strength testing is appropriate only in instances where the removal of test water is extremely difficult, such as with pipework of diameter not exceeding 40 mm.

8.1 PLANNING/PRELIMINARY PREQUIREMENTS

8.1.1 The following shall be specified in a method statement:

- the required maximum test pressure and the test duration
- acceptance criteria
- the testing specification to be followed
- whether a pressure/volume plot is required
- any items to be excluded from the test
- additional client requirements to be added
- drawings detailing the site specific safety distances required during testing.

8.1.2 Responsibilities shall be defined clearly and should include, but may not be limited to:

- the management of the test
- obtaining appropriate approval for the test procedure
- ensuring that adequate safety precautions are implemented and followed
- ensuring that the test procedure is followed correctly
- compilation of the final test record.

8.1.3 At least two people, with experience in pressure testing, shall be present during testing.

8.1.4 A schedule shall be prepared for all operations for the test, stating clearly responsibilities during all phases of the work. The schedule should include:

- safety precautions
- details of the design and supply of any test fittings
- proposed location of the test cabin, pumps and other test equipment
- means of filling and pressurising, including water sources, test connections and vent points
- a test procedure, including details of the test sections
- means of de-pressurising and emptying, including details of drainage connections and method of disposal of water
- a detailed test program, giving proposed dates
- an emergency procedure to be carried out in the event of a test failure through rupture
- requirements for permits and notifications to regulatory bodies.

8.2 HYDROSTATIC STRENGTH TESTING

8.2.1 Preparation for testing

Prior to the commencement of testing, a method statement shall be prepared, detailing the following:

- an accurate description of the pipework to be tested and the limits of the test section
- where necessary, the test limits specified by weld, pipework section and local or national co-ordinates
- for complex pipework configurations or installations, an engineering drawing. Such drawings should, ultimately, form part of the final test documentation
- the maximum specified test pressure required in the test section (see clause 8.2.2)
- the differences in elevation between the lowest and highest points in the test section and the test pressure control point
- the maximum test pressure to be reached at the test pressure control point, considering the effects of the hydraulic head due to differences in elevation
- the total volume of the test section, expressed in litres of water
- the maximum permitted air content of the test section, expressed as a percentage of its total volume
- the required rate of pressure rise in the test section and, where applicable, the calibration of the pressurising pump, expressed in litres per stroke of the pump
- the specification, its current edition and section to which the test procedure is to comply.

8.2.2 Testing of pipelines

8.2.2.1 Except as permitted by Note 2 below, a pipeline designed for operation at a design factor exceeding 0.3 shall be tested to the requirements of Table 11, thus ensuring freedom from defects which might reach a critical size in service.

Note 1: Upper limits are set according to the manufacturing process and the pipe coating.

Note 2: This test requirement may be relaxed to a pressure of 1.5 x MOP if either:

- *the pipeline is not significantly line packed i.e., the daily variation in hoop stress does not exceed 35 N mm^{-2} or*
- *a detailed fatigue assessment (see clause 6.6.2.3) of the expected pressure cycling shows that the required design life is achieved.*

Note 3: The fatigue life data, provided in Sub-Section 6.6, are based on the benefits of high-level testing in limiting the size of defects entering service, as well as the introduction of beneficial residual compressive stresses on the remaining defects.

When considering a diversion which has a design factor not exceeding 0.3 (typically for impact protection or proximity infringement measures) which will form part of an existing pipeline designed to operate at a design factor above 0.3, then the test pressure of the diversion shall be set at the test pressure of the existing pipeline. Where due to lack of records, this is not known, the test pressure shall be calculated using the measured wall thickness, SMYS of the pipeline material and outside diameter of the existing pipeline. Where the existing pipeline has a design factor not exceeding 0.3, refer to clause 8.2.2.2.

8.2.2.2 Except as permitted by the Note below, a pipeline designed for operation at a design factor not exceeding 0.3 shall be tested to a pressure of at least 1.5 x MOP (see Table 10), except when subject to daily stress cycles exceeding 35 N mm^{-2}, the pipeline shall be tested to a test level determined by a fatigue assessment.

Note: This requirement may be relaxed to Table 10 conditions if a fatigue assessment shows that the required design life due to pressure-cycling is achieved with a lower test level.

Reduction of the test pressure to 1.5 x MOP may restrict the possibilities regarding future uprating or re-declaration of the pipeline MOP. The test pressure should be evaluated relative to the original design pressure as opposed to the current operating pressure.

Tests to Table 11 shall be measured at the lowest point of the test section whereas tests to Table 10 shall be measured at the highest point of the test section.

MINIMUM TEST PRESSURE FOR SEAM WELDED AND SEAMLESS PIPE	
Pre-installation test	**Main test**
1.5 MOP + 10%	1.5 MOP

Note: Higher values may be applied at the discretion of the responsible engineer. The upper limit would be that indicated in Table 11.

TABLE 10 - HYDROSTATIC TEST CONDITIONS FOR PIPELINES DESIGNED TO OPERATE AT A DESIGN FACTOR NOT EXCEEDING 0.3

SEAM WELDED PIPE (SAW)		**SEAMLESS PIPE**		**SEAM WELDED PIPE (ERW/HFW)**	
Pre-installation test	**Main test**	**Pre-installation test**	**Main test**	**Pre-installation test**	**Main test**
FIRST occurring of: (a) f = 1.1 (b) Half-slope P/V Plot	FIRST occurring of: (a) f = 1.05 (b) Half-slope P/V Plot (c) Max pressure in pre-installation test	FIRST occurring of: (a) f = 1.0* (b) Half-slope P/V Plot	FIRST occurring of: (a) f = 0.9** (b) Half-slope P/V Plot (c) Max pressure in pre-installation test	FIRST occurring of: (a) f = 1.05 (b) Half-slope P/V Plot	FIRST occurring of: (a) f = 1.0 (b) Half-slope P/V Plot (c) Max pressure in pre-installation test.
Note 1 & 7	Note 2 & 7	Note 3 & 7	Note 4 & 7	Note 5 & 7	Note 6 & 7

Notes
1. Attempts should be made to ensure test reaches not less than f = 1.05. See clause 8.9.2.
2. Special investigations are required if test does not reach f = 1.0. See A5.2.10.
3. Attempts should be made to ensure test reaches not less than f = 0.95. See clause 8.9.2.
4. Special investigations are required if test does not reach f = 0.85. See A5.2.10.
5. Attempts should be made to ensure test reaches not less than f = 1.0. See clause 8.9.2.
6. Special investigations are required if test does not reach f = 0.95. See A5.2.10.
7. See A5.2.9 for definition of half slope.

* For seamless pipe with coal tar coating, the test pressure should be limited to that equivalent to a design factor of 0.9 and the test followed by an inspection for coating damage.

** For seamless pipe with coal tar coating, the test pressure should be limited to that equivalent to a design factor of 0.85.

TABLE 11 - HYDROSTATIC TEST CONDITIONS FOR PIPELINES DESIGNED TO OPERATE AT A DESIGN FACTOR EXCEEDING 0.3

8.2.3 Test limits

Where reference is made to a test limit being a fraction of the design factor, the required test pressure shall be calculated:

$$P_t = 20t_n fsD^{-1}$$

P_t = test pressure (bar)
t_n = nominal wall thickness (mm)
s = specified minimum yield strength (N mm^{-2})
f = design factor (as defined in Table 11 or clause 8.2.2)
D = outside diameter of the pipe (mm).

8.3 PRE-TESTING

Pipe and fittings shall be pre-tested if any of the following circumstances apply:

- the pipe or fittings cannot be hydrostatically tested after installation, for example for tie-in sections/pups or sub-assemblies which are to be incorporated into an existing operational installation
- the pipe or fittings are to be installed in close proximity to operating plant and where it is not possible to protect the plant against a hydrostatic test failure or where the use of a sub-assembly as above is impractical
- it is considered that the consequences of a post-construction test failure are such as to justify pre-testing.

Note: Otherwise, pre-testing is not necessary.

8.4 TEST EQUIPMENT

8.4.1 Instrumentation

Pressure gauges, dead weight testers, pressure recorders and test equipment for the measurement of volume, pressure and temperature, shall have current test certificates as verification that they are in accordance with the accuracy and sensitivity requirements of this section.

8.4.2 Measurement of pressure

8.4.2.1 For hydrostatic testing of small fabrications and pneumatic testing of small bore pipework (see Appendix 5), a certified Standard Test Gauge to BS EN 837-2 or a digital gauge to ASME B40.100, having an accuracy of + 0.25% may be used.

8.4.2.2 The gauge selected should have a full-scale deflection such that the test pressure falls between 60% and 90% of that full-scale deflection.

8.4.2.3 In all other cases, the hydrostatic test pressure should be measured by a dead weight gauge having resolution of 0.02 bar between 30 and 600 bar and an accuracy of 0.03% ± 0.05 bar at the pressure being read.

8.4.3 Measurement of volume

8.4.3.1 The accuracy of the equipment used to measure the water which is added or removed during the test is of paramount importance, as this equipment will be the basis of the accuracy of the air content plot.

8.4.3.2 The equipment used for adding or subtracting water shall have a resolution of at least 0.0002% of the fill volume for a pipeline which is subject to a yield test, and a resolution of at least 0.0005% of the fill volume for a non-yield test pipeline and smaller installations.

8.4.4 Measurement of temperature

8.4.4.1 The water temperature within the test section shall be monitored, either by direct measurement or by measuring the pipe wall temperature. The ground temperature adjacent to buried pipework shall be monitored and compared with the water temperature readings. Consideration shall be given to the effects of exposed pipework relative to buried pipework in any particular test section.

8.4.4.2 Measurement of temperature shall be made using thermocouples to BS 1041-4 Type K or equivalent.

Note: These will enable remote readings to be taken from a safe distance (at least 100 m).

8.4.4.3 Any digital meter or glass thermometer should have a resolution of 0.1°C.

Note: Although the repeatability of digital equipment is very good, the accuracy between zero and 400°C can be ± 3°C, so it is recommended that, before use, meters or recorders, extension leads and thermocouples are checked by a liquid in glass, Laboratory Series 'A' thermometer, to BS 593, having an accuracy of + 0.02°C between –20°C and +100°C.

8.4.5 Test ends

8.4.5.1 Test ends shall be suitable for a design pressure of not less than the expected maximum test pressure.

8.4.5.2 Any test end shall be subject to a strength test at not less than 1.25 times the expected maximum test pressure.

8.4.5.3 The design of a test end shall state the maximum number of operating cycles prior to revalidation or disposal.

8.4.5.4 Test ends shall be given a unique identifier which is clearly displayed on each test end body or frame as appropriate.

8.4.5.5 A system shall be established to record the usage of each individual test end.

8.5 ACCEPTANCE CRITERIA

8.5.1 Air content (see Figure 9)

The air content shall not exceed 0.2 % of the fill volume of a pipeline under test or 0.5 % of the volume of a short length pipeline diversion (typically up to 1 km).

Note: It is essential that all air is dissolved in solution to obtain a true hydrostatic test to which hydraulic parameters and criteria will apply.

Reference should be made to the relevant part of Appendix 5 for the procedure to calculate air content.

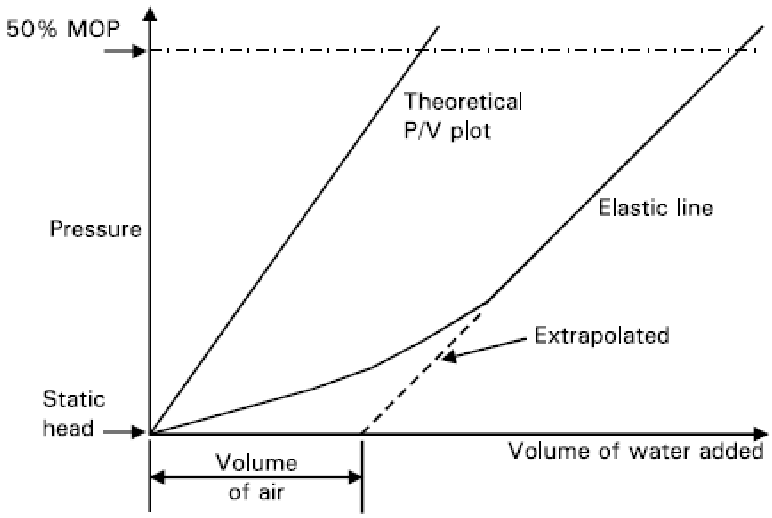


FIGURE 9 - MEASUREMENT OF AIR CONTENT

Note: The air content is determined by constructing a P/V plot from static head pressure into the linear section of the P/V plot curve and extrapolating back to the axis. The volume of air is then read directly from the horizontal axis and compared with the total volume of the test section.

8.5.2 Temperature variations

Variations in temperature during the test shall be considered.

Note 1: Changes in temperature above or below ground, during a test, will affect the test pressure and make assessment of the soundness of the test impossible unless the changes are taken into account.

Note 2: The various temperature/pressure corrections provided in Appendix 5 indicate the change in pressure versus change in temperature for most sizes of pipe used in the gas industry.

8.5.3 Test acceptance

The relevant procedure for test acceptance criteria shall be as given in Appendix 5.

8.6 SAFETY – GENERAL

8.6.1 The safety of personnel and the general public is of paramount importance and measures to ensure safety shall be specified/included in the test procedure.

Safety precautions must comply with statutory and other relevant Regulations. The precautions should be approved.

Note: HSE Guidance Note GS4 (Fourth Edition) provides guidance on addressing safe systems of work.

8.6.2 Prior to testing, all personnel engaged on testing or associated work shall be aware of the possible consequences of failure of a test or test fitting under pressure conditions and the hazards associated with the energy stored within a test section, particularly when it contains water and/or a gas.

8.6.3 All personnel engaged in pigging operations shall be instructed on the precautions necessary to ensure the safe operation and reception of pigs.

8.6.4 The test area shall be specified, approved and defined clearly to all personnel (see clause 8.7.4).

8.6.5 During testing and subsequent pressure-reducing operations, all construction or operational work in the test area or on the pressurised sections shall cease and all persons not involved directly should be evacuated from the test area.

8.6.6 Test equipment shall be situated in a safe location, away from public highways, other inhabited areas, depots and sites.

8.6.7 A certain amount of noise is inherent in all testing operations. Best practice should be employed to minimise noise emissions to levels acceptable to site personnel and the general public.

Special consideration shall be given to:

- siting and possible screening of plant and equipment
- use of acoustically treated power tools, compressors and generators
- avoidance of operations outside normal working hours
- the use of a silencer to decrease noise levels during venting operations.

8.6.8 Suitable precautions shall be taken to protect any adjacent pipework or equipment from the potential effects of failure of the pipework under test.

8.6.9 During testing using media other than air or water, precautions shall be taken to prevent personnel from entering areas, for example pump pits, where dangerous concentrations of nitrogen or other test fluids may be present.

8.7 SAFETY - PIPELINES

8.7.1 Testing shall not commence until confirmation has been received from the appropriate authority, in writing, that the following precautions have been taken:

- prior notification of testing has been given, in writing, to persons in the vicinity of the pipeline or installation.

  An individual assessment should have been made for persons who will be resident near the pipeline or installation during the period of the test
- prior notification of testing has been given to the local Police and other authorities who may be affected
- protective walls, constructed of sand bags, earth bunds or other methods, have been placed in agreed locations
- Safety distances for the pipeline and for above and below ground pipework have been confirmed e.g., in accordance with HSE Guidance Note GS4.

Particular attention shall be paid to blanked or capped ends of pipes and any adjacent operational pipework.

8.7.2 If testing is extended, additional notification to those specified in clause 8.7.1 shall be given.

8.7.3 Warning notices, stating “WARNING – PIPEWORK UNDER TEST”, “NO PARKING”, “NO ACCESS”, “RESTRICTED ACCESS” AND “ACCESS BY PERMIT ONLY” shall be placed at appropriate locations, for the duration of the test.

The boundaries of the test area shall be defined using marker tapes, or a fence and at night, lighting shall be provided at appropriate locations.

8.7.4 It shall be ensured that, from the start of pressurisation, during the test period and until de-pressurisation, no person approaches within the following safety distances from the test section:

- for a test pressure equivalent to a design factor not exceeding 0.45, a distance of 30 m
- for a test pressure equivalent to a design factor exceeding 0.45, a distance of 100 m.

If it is necessary, because of site restrictions, for personnel to approach nearer than these distances, a suitable protective wall shall be constructed (see clause 8.7.1).

Note 1: For a test pressure not exceeding a design factor of 0.45, the 30 m safety distance may be reduced, after taking into account the proposed test pressure and the design pressure of the test section.

Note 2: It may be impractical to apply these safety distances to points of access to the general public, for example roads. In these instances, all reasonable measures need to be taken to ensure that the public do not dwell at these locations, by way of "NO PARKING" signs and regular patrols (see also clauses 8.7.3 and 8.7.5).

8.7.5 Patrols shall be provided to watch special points of hazard during the test, in particular road, rail and water crossings and other points of public access.

8.7.6 Standby emergency crews shall be available to deal with washouts or other damage.

8.7.7 The test pressure shall be reduced to a safe level before any work is permitted within the safety distance. The safe pressure level shall be not greater than static head plus 1 bar, unless specified otherwise in Appendix 5.

8.7.8 Hoses shall be anchored securely using an approved method to reduce the risk of injury to personnel in the event of failure.

8.7.9 High-pressure test hoses shall be:

- visually checked for damage prior to use
- certified within a 6 month period preceding the test.

8.8 SAFETY - SMALL BORE PIPEWORK ON PIPELINES (PNEUMATIC TESTING)

8.8.1 Potentially, pneumatic testing is a more hazardous operation than hydrostatic testing at the same pressure, in that any failure is likely to result in more serious consequences.

There shall be appropriate consultation at the pipework design stage on the adequacy of the safety precautions proposed.

8.8.2 Safety precautions shall be subject to written approval before any testing work takes place, with particular reference to the following:

- adequacy of protection of any adjacent pipework or equipment
- extent of the area cleared for test purposes (see clauses 8.6.6 and 8.7.4)
- adequacy of any applicable NDT carried out before the test, including testing previously carried out by others
- procedures to prevent local chilling during filling and emptying
- extent of remote monitoring provided during the test.

8.8.3 All personnel engaged in the test shall be instructed fully regarding the possible hazards involved in pneumatic testing.

8.8.4 Attention shall be paid to preventing whip in small bore pipes following failure.

Hoses shall be anchored securely using an approved method to reduce the risk of injury to personnel in the event of failure.

8.8.5 High-pressure test hoses shall be:

- visually checked for damage prior to use
- certified within a 6 month period preceding the test.

8.8.6 The test area shall be clearly defined. It shall include all enclosed areas through which the pipework runs and local access ways.

The boundaries of the test area shall be defined by marker tapes and purpose-made warning notices stating "WARNING – PIPEWORK UNDER TEST", which shall be displayed at all points where access may be gained to the test area.

8.8.7 As the pressure of the test medium is reduced from high pressure storage, its temperature will fall. The test arrangements shall be such that the temperature of the medium entering the pipework under test is not lower than the agreed test temperature.

In order to prevent condensation within pipework, the temperature of the test medium shall not be allowed to fall below the dewpoint at the corresponding test pressure.

8.9 TEST SECTIONS

8.9.1 Pipelines

The pipework test sections may be made as long as is practical, provided the maximum variation in altitude in each section does not exceed 60 m.

The test sections shall be determined in advance of construction or re-testing giving due regard to the following:

- availability and disposal of water for testing
- topography

  Note: In mountainous terrain or for long HDD sections, where strict compliance with the 60 m altitude limitation would unduly restrict test lengths, consideration may be given to a relaxation of this limit, providing that over or under-stressing of the pipework test section does not occur at the elevation extremes.

- impact of test failures where washout may give rise to a hazardous situation
- access to test points for tie-in and reinstatement works
- for re-testing existing pipelines or installations, the time scale that the pipeline or installation can remain out of commission, given the impact of a rupture
- potential damage to orifice plates, metering equipment, unidirectional valves and the like, that have been tested independently in accordance with IGEM/TD/13 or IGEM/GM/8 Part 3 and where removal of part of all of the item may be necessary.

  Spool pieces or blind flanges may be inserted where items have been removed or omitted, provided these are designed and constructed to a standard of at least that of the permanent pipework
- all small bore pipework, such as impulse and instrumentation lines, need to be disconnected and approved plugs or blind flanges installed
- testing against closed valves is not appropriate
- all below-ground pipework needs to be backfilled so far as is practical

- all underground connections prone to leakage, such as flanged joints and drain points, valve spindles and the like, need to be left exposed fully for inspection during the test
- consecutive sections of pipework need to be constructed so as to overlap such that the tie-in can be made with a single weld (see clause 7.28.1)
- all pipework is supported adequately to take the additional load imposed by the weight of the test water
- at installations, the pipework test sections may be combined and tested together
- all connections to lower design pressure systems are capable of being positively isolated
- annuli of ball valves are pressurised, where necessary by means of temporary connections from the annulus vent to the test section pipework, or by closing the valve by approximately 50%. The manufacturer's instructions for testing shall be observed.

8.9.2 Pre-testing of pipes, fittings and fabrications

8.9.2.1 Pipes to be pre-tested shall be assembled into strings, with a maximum of 4 strings per test and a maximum of 12 pipes in each string.

Note: Where a string fails or half strokes occurs before reaching the required test pressure (see Tables 10 and 11), this string may be isolated, and the remaining strings tested with minimum delay.

Pipe which has not been affected by nor identified as contributing to the string failure, may be suitable for use in the main pipeline but shall not be used at locations in the higher risk areas.

8.9.2.2 Pipe strings shall be at a minimum spacing of 5 m and supported by an approved method which is designed specifically to provide a sufficient regular gradient to ensure that air can be vented readily.

8.9.2.3 Due regard shall be paid to ground conditions when designing pipe supports, in particular when an increase in support height is required to accommodate pipework gradients.

8.9.2.4 Where ground conditions make a regular gradient impractical or potentially dangerous, pigs or other means shall be employed to achieve a satisfactory fill.

8.9.2.5 Each pipe or fitting that has been pre-tested shall be identified clearly as such, together with the relevant test pressure.

8.9.2.6 Details of the pipes or fittings shall be retained as a permanent record with the test documentation.

8.9.2.7 Fittings for pre-testing shall not be welded directly together.

8.9.2.8 Fabrications which are to be concrete-coated, for negative buoyancy, shall be tested prior to the application of the concrete, in order to prevent fracture or spalling of the concrete.

Note: This test may be additional to any subsequent testing that is carried out once the fabrication is concrete-coated and installed.

8.10 FITTING OF TEST ENDS

8.10.1 Valves shall not be used for isolating test sections.

8.10.2 All test sections shall be sealed by suitable end enclosures, such as blind flanges, specifically-designed spades or purpose-built test ends.

Note: The use of pig traps is not a preferred method of sealing prior to hydrostatic testing.

8.10.3 Welded test ends shall only be fitted by means of an approved welding procedure.

All such fitting welds shall be subjected to full NDT, equivalent to that employed on the pipework section to be tested.

8.10.4 Where appropriate, test ends shall incorporate a device to establish that pigs or spheres have been launched successfully or received.

8.10.5 Where the wall thickness of the test end and the pipeline being tested differ, a compatible sacrificial pipe pup matching the thickness of the test end transitioned to the pipeline wall thickness at the end of the pup shall be used. The transitional pipe pup shall be removed after testing.

8.11 WATER SUPPLY

8.11.1 For the purposes of hydrostatic testing, only approved clean water shall be used.

8.11.2 During the selection of test sections, account shall be taken of the need for consents or licences for the extraction or disposal of water (see Section 4).

8.11.3 Where the water source contains a high degree of solids in suspension, consideration shall be given to the use of filters, settlement tanks or lagoons.

8.11.4 Where there is a possibility of contamination or de-oxygenation of the water during testing, the problem shall be addressed and resolved prior to the commencement of testing operations.

8.11.5 Filling and emptying shall be carried out in accordance with Appendix 6.

8.12 REPAIR OF TEST FAILURES AND LEAKS

8.12.1 Prior to the commencement of any testing works, a comprehensive repair and NDT procedure shall be established.

8.12.2 Materials used for repairs shall be compatible with the existing pipework.

8.12.3 Where a leak is suspected, the test section pressure shall be reduced to the design pressure prior to carrying out a visual examination.

8.12.4 Work to repair any leak or failure shall not be carried out until the pressure has been reduced to a safe level (see clause 8.7.7).

8.12.5 In the event of a test failure, the test section shall be repaired and re-tested as follows:

- where failure occurs prior to the pre-determined test limit, the repair shall be made with pipe which may not have been pre-tested.

  After completion of the repair and refilling of the test section, the test shall be recommenced from the beginning, including a new air content check.

  The records for the test failure shall be retained as part of the permanent record of the pipeline or installation.

  OR

- where failure occurs after the pre-determined test limit, the time under test shall be noted and the repair made using pre-tested pipe.

  After completion of the repair and refilling, the test section shall be subjected to a further air content check.
  The test section shall then be re-pressurised to the test limit attained in the original stage of the test.

  The test shall then proceed for a further period, such that the aggregate time will be at least equal to the required test period.

  Where pre-tested pipe is not available, the test shall be recommenced from the beginning, as in Sub-Section 8.1.

8.13 RECORDING AND DOCUMENTATION

8.13.1 General

8.13.1.1 A documentary record of all tests shall be compiled and retained for the life of the pipeline or installation.

8.13.1.2 Care shall be exercised in the identification of test documentation to ensure that it can be identified accurately in the future.

8.13.1.3 The documentary record shall include:

- test or calibration certificates for all instruments and equipment used in the measurement of the test (see clause 8.13.2)
- the records produced during the test (see clause 8.13.3)
- a test certificate (see clause 8.13.4 and Figure 10).

8.13.2 Test equipment and instruments

8.13.2.1 All instruments and test equipment used for the measurement of pressure, volume and temperature shall be certified for accuracy (see Sub-Section 8.4).

8.13.2.2 The following instruments should, as a minimum, be provided at the test control centre:

- where a P/V plot is specified in the procedure;
  - dead weight tester
  - pressure gauge
  - temperature indicators
  - pressure and temperature recorders
  - duplicate water volume measurement equipment
  - calibrated tanks for volume measurement
  - pump stroke indicator or rev counter.
- where a P/V plot is not specified in the procedure;
  - standard test gauge
  - temperature indicators.
- for small bore pipework subject to a pneumatic test;
  - standard test gauge
  - temperature indicators.

8.13.2.3 Gauges and recorders shall be calibrated within the preceding 12 months and checked for accuracy by comparing gauge readings against a certified test gauge which has been approved by the pipeline operator immediately prior to each pressure test.

Checks shall be carried out to establish that the test gauge has not been subjected to any damage whilst transporting to the site which may invalidate its accuracy prior to use.

8.13.2.4 Dead weight testers shall be certified within the 12 month period preceding the test.

8.13.2.5 Pressurising pump delivery shall be checked by a calibrated tank and verified in writing.

8.13.2.6 A means of measuring accurately any water drained off during the test shall be provided.

8.13.2.7 High-pressure test hoses shall be certified within a 6 month period preceding the test.

8.13.3 Test record

The test record shall, where referred to in the relevant test procedure, contain the following documentation:

- an air inclusion plot, together with all tabulated measurements and calculations
- tabulated measurements and graphical plots of pressure against volume during the pressurisation period, which represents the stress/strain graph for the pipework steel
- tabulated results of pressure against time during the initial decay and test hold period
- volume of water added or drained from the test section once the pressurisation limit is reached
- visual records of pressure and temperature
- tabulated measurements of temperature against time throughout the full duration of the test (see clause 8.4.4 and Appendix 5). Care shall be taken, when measuring water temperature in the test section, to ensure the temperature transducer is correctly located
- identification of any joints or materials that cannot be tested
- details of all pipework tested, including any unique material or fitting identifiers where pre-testing is carried out
- a test certificate (see clause 8.13.4).

8.13.4 Test certificate

On completion of each test, a test certificate shall be compiled which should include, but is not limited to, the following information:

- an accurate description of the pipeline project or installation to which the test relates
- the method statement
- a detailed description of test start and finish points
- details of all pipework tested including diameter, wall thickness, grade, manufacturer and external coating
- the required maximum test pressure in the test section, together with details of its derivation or source

- the test pressure achieved at the maximum, minimum and test control point locations, together with their relative locations
- the procedure, Edition and Section with which the test complies
- date and time of test start and finish.

Note: Figure 10 provides an example of a test certificate.

PRESSURE TESTING CERTIFICATE				
Pipeline:				
Contract:			Test No	of
Contract No:			Years of work	
Contractor:				
Testing contractor:				
Test result:	PASS/FAIL*		Start date:	Time:
Half slope:	YES/NO*		End date:	Time:
Test medium:	PNEUMATIC/HYDROSTATIC*		Test period:	hrs
Test doc:	Section:	Edition:		

1.1 **Test results – required**

Required test pressure: bar Design factor:

1.2 **Test results – achieved**

Elevation at control point m

Pressure at control point bar

Elevation at low point m

Pressure bar Design factor:

Temperature °C

Comments

……

Temperature

……

2.1 **Test limits – pipeline**

From weld……………………………… Section…………………………………… Map No ………………

Grid ref…………………………………… Bar chart No……………………………

To weld…………………………………… Section…………………………………… Map No ………………

Grid ref…………………………………… Bar chart No……………………………

Profile drawing No ……………………

2.2 **Test limits – installation**

Test limit welds Bar chart No ……………………………….…

Isometric or line drawing showing test limits and where applicable all new and existing pipework to be included with all installations.

*** Delete where not applicable**

FIGURE 10 - EXAMPLE OF A PRESSURE TESTING CERTIFICATE (Cont. overleaf)

PRESSURE TESTING CERTIFICATE

3 **Test parameters**

Derivation of test pressure $Pt = \frac{20\ t_n\ s\ f}{D}$

Show test pressure calculation or specify test regulator and pressure

……

……

……

……

4 **Pipework detail**

Diameter	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	mm
Wall thickness	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	mm
Grade	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	
Type	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	
Length	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	m
Manufacturer	1 …………………	2 …………………	3 …………………	4 …………………	5 …………………	

For TYPE specify **ERW** **SAW** **SEAMLESS**

5 **Air content**

Pump calibration: litres/stroke

Vol. Test section: litres

Air content: litres %

6 **Records submitted**

*Instrument certification
*Pressure/temp. record sheets
*Pressure temp. charts
*P / V Plot
*Test limit drawing
*Decay period pressure/temp plots
*Hold period pressure/temp plots
*Air content check
*Comments on leak/failures

All documents to be fully identified and certified by the test engineer

Test engineer signature …………………………………………………………………… Date……………………

Name ………………………………………………………… Title ……………………………………………………………

Responsible engineer signature ……………………………………………………………………………………

Name ………………………………………………………… Title ……………………………………………………………

*** Delete where not applicable**

FIGURE 10 cont. - EXAMPLE OF A PRESSURE TESTING CERTIFICATE

SECTION 9 : COMMISSIONING OF PIPELINES

This Section entirely addresses commissioning of pipelines. For associated installations, relevant requirements apply as for pipelines.

9.1 GENERAL

9.1.1 When a pipeline is to be brought into service following construction, it shall be purged of air using an approved direct or indirect process prior to gas being transmitted.

Measures shall be taken to prevent the formation of methane hydrates in methane-rich transmitted gases caused by water which remains after hydrostatic testing (see Sub-Section 9.4).

Note: Other hydrocarbon gases can also form hydrates.

Tests shall be carried out to monitor any odorant level when a pipeline is put into service.

Note: A possibility exists, particularly if there has been a significant lapse of time between gassing up the pipeline and putting it into service, that the odorant level of the gas may be affected adversely.

9.1.2 Prior to gassing up, a new pipeline shall undergo hydrostatic testing (see Section 8). Although preliminary pigging runs may appear to be effective in removing water from the pipeline, a certain volume inevitably remains on the inner surface. In order to effectively dry a pipeline, the maximum possible amount of free water shall be removed by multiple pigging runs. Water also gathers at low points and in the body cavities of ball valves.

Note 1: The presence of water in a gas transmission pipeline can result in the formation of solid hydrate or contamination of the product. Water may also cause very serious operational difficulties.

Note 2: It is considered that dewpoints at or below −20 °C, will provide the necessary dryness and are attainable with standard desiccant dryers, which will output air at −40 °C dewpoint at atmospheric pressure.

Note 3: Where vacuum drying is used, the value of −20 °C is equivalent to a saturation vapour pressure of 1.032 mbar, which is attainable by the use of vacuum pumps of a reasonable capacity, on a normal pipeline system.

The dewpoint required should be decided at the design stage and stated in the specification for commissioning.

9.1.3 The choice of method for the removal of water, to be followed by gassing up of a pipeline, should be made following consideration of the proposed timing of the operations, the nature and characteristics of the gas to be transmitted and the design, operation and maintenance criteria for the particular pipeline system.

Note 1: The principal circumstances which may occur are:

- *a dry pipeline, which can be commissioned straight to gas. Refer to IGE/SR/22*
- *a wet pipeline which is dried prior to gassing up*
- *a wet pipeline which is dried and gassed up simultaneously.*

Note 2: The methods available for drying are:

- *using super-dry air or dry inert gas, where an air-drying plant and compressor produce dry oil-free air to push a series of pigs through a pipeline, collecting water until the required dryness is achieved*
- *vacuum drying, where evacuation of a pipeline causes water to boil off at the ambient temperature of a pipeline, the vapour formed being drawn off until the required dryness is achieved*

- *operational drying, where a pipeline may be purged using an inert gas and then gassed up and operated at a pressure where hydrate formation will not occur at ambient temperatures. When checks prove an acceptable dewpoint is achieved, the pipeline may be elevated to its full operating pressure. In this case, care is needed to ensure water does not collect in pipework on installations and subsequently freeze due to the Joule Thompson effect*
- *where none of the above are practicable, by methanol swabbing.*

Combinations of the above methods, except operational drying, can be used for particular circumstances or conditions.

Note 3: Gassing up may be carried out immediately after any of the above drying operations. Guidance on commissioning is given in IGE/SR/22. For vacuum drying, consideration may be given to the direct injection of gas into the vacuum created in the pipeline.

9.2 PRELIMINARY ARRANGEMENTS

9.2.1 Planning

9.2.1.1 A detailed programme of operations and procedures shall be prepared, circulated and approved in advance of the operation. The programme should nominate a person to be in sole charge of operations. The programme and procedure(s) shall define clearly all stages of the commissioning operations, together with the duties and responsibilities of the personnel involved, incorporating an appropriate permit to work system. The authorised procedure should also detail initial and final valve positions and movements.

9.2.1.2 Advance consultations, to agree the timing of the operations, shall take place with the appropriate control centre operators. These should also agree the daily volume and rate of flow of gas to be used. Similarly, advance consultation shall take place with the nominated person responsible for safety concerning the precautions which shall be observed and drawn to the attention of all personnel.

9.2.1.3 Before commissioning, a certificate of compliance shall be handed to the pipeline operator. Commissioning shall not take place until all operating, maintenance and emergency procedures are established and in place.

9.2.1.4 Upon completion of commissioning, a formal handover shall ensure that all records of design, construction, and testing are given to the pipeline operator.

9.2.2 Safety and welfare

9.2.2.1 S*tatutory Regulations*

In the UK, all aspects of the commissioning and pressurisation of a pipeline are subject to HSWA and other appropriate Legislation as listed in Appendix 2.

Arising from HSWA, an employer must ensure that all personnel are made fully aware of the relevant safety aspects, including the dangers of toxic materials.

Necessary safety precautions must be taken for the protection of personnel, members of the public and property that might be affected by the works.

9.2.2.2 *Safety and welfare equipment*

Safety and welfare equipment shall be available on site. Personnel must wear appropriate personal protective equipment (PPE) during all operations.

9.2.2.3 *Notification to relevant authorities*

The police, fire and civil aviation authorities, as well as other interested parties, should be given advance notice of the date on which commissioning is to be carried out.

9.2.2.4 *Safety training*

Employers must provide such instruction, training and equipment as is necessary to ensure, as far as it is reasonably practicable, the health and safety at work of all personnel.

Note: A high concentration of nitrogen can cause asphyxiation.

9.2.3 **Attachments**

Attachments, for example pig signallers, vents, pressure gauges and recorders, should be fitted at both launch and reception points on the line, together with valved attachments to facilitate the injection and reception of nitrogen. In addition, suitable gas sampling points shall be considered.

The methanol injection point or vacuum connection shall be downstream of the launcher trap isolation valve and should be not less than 50 mm diameter.

Pig launchers, pig launcher cradles, pig receivers and pig receiver cradles shall be bonded to unloading equipment.

9.2.4 **Access to launch and reception sites**

9.2.4.1 *Road access*

A suitable hard surface access road and hard standing should be provided. The road surface should be at least reasonably level.

Adequate clearance beneath overhead obstructions should be available to allow free access and operation for plant vehicles.

9.2.4.2 *Access to valves*

Facilities shall be provided to enable site personnel to gain access to all valves and equipment in a safe and proper manner.

9.2.5 **Site security**

Site security shall be ensured with adequate security fencing. If this is not possible, the site should be manned continuously.

Suitable notices must be displayed prohibiting access by unauthorised persons and "NO SMOKING" and "NO NAKED LIGHTS" notices must be displayed prominently. Where other operations are proceeding on the site, an area for each operation shall be defined clearly by physical barriers with additional appropriate warning notices displayed around the perimeter.

Sources of ignition shall not be sited within 15 m of any point of possible leakage of gas or flammable liquid.

9.2.6 Lighting at terminals, etc.

Floodlighting, suitable for Zone 1 in accordance with an appropriate standard, shall be considered at both launch and reception sites and any other locations as necessary, for example at block valves.

9.2.7 Monitoring of pigs

Listening points should be provided at suitable intervals along the pipeline so that the progress of pigs can be reported.

Note: Block valve installations can be used for this purpose as, normally, facilities exist at these points for fixing pressure gauges which will give a positive indication of the passage of pigs.

Arrangements shall be made for listening observers to be in communication with both launch and reception terminals and any other manned locations.

Note: Alternative methods of detection, using proprietary tracking/listening devices, can be considered.

9.2.8 Pre-commissioning inspections

Before operations commence, all installations shall be inspected to confirm that:

- all valve attachments, actuators, pig signallers and pig trap doors are operational
- all valves are operational and maintained
- all necessary vents, drains, test gauges etc. are in position and functional
- all valves, pig signallers, etc. are identified and referenced correctly and are in their correct position in accordance with the approved procedure
- all other preliminary requirements are satisfied
- warning notices, fire-fighting equipment and barriers are sited as appropriate
- reception and storage tanks, vehicles or other equipment are not placed in direct line with, and sited at least 15 m away from, the pig trap door
- communication systems are operational.

A certain amount of noise is inherent in all commissioning operations. The precautions outlined in clause 7.4.2 shall be applied during commissioning.

9.3 PRELIMINARY PIGGING

The entire pipeline shall be swabbed thoroughly and satisfactorily gauged in a preliminary pigging operation.

Note: This may have been carried out during the testing procedure (see Section 8).

Several pigging runs will be necessary to remove as much water as possible from the line. Consideration shall also be given to the use of magnetic pigs/geometric pigs/gauging pigs and cleaning pigs. After pigging, precautions shall be taken to prevent the ingress of water and foreign matter into the pipeline.

Particular attention shall be given to clearing water from ball valve bodies.

9.4 DRYING, PURGING AND GASSING UP

A pipeline should be commissioned by one of the following procedures:

- super-dry air/nitrogen followed by gas
- vacuum drying followed by purging and gassing up
- where neither of the above is practicable, by methanol swabbing.

9.4.1 **Super-dry air/nitrogen followed by gas**

The optimum length of pipeline for drying by this method is approximately 30 km. Normally, lengths greater than this are avoided to prevent abrasion of the pig material.
This method utilizes an air-drying unit and compressors to produce dry, oil-free air or a dry inert gas which is used to propel pigs through the pipeline. These pigs absorb water, remove pools of water at low points and distribute any residual water as a thin film on the internal pipe wall to facilitate faster evaporation. On completion of the drying/purging operation, the pipeline can be gassed up immediately or sealed off for gassing up at a later date.

Alternatively, a pipeline can be simply dried by passing super dry air or gas through the pipeline after the free water has been removed by multiple pigging runs.

In order to minimise the time required for an air-drying operation, it has to be recognised that a given mass of air can take up only a limited amount of water vapour, the precise amount being calculable from the initial dryness and the temperature with reference to saturation tables. Thereafter, the larger the throughput, the shorter will be the drying time. However, the rate at which water molecules are transferred from the pipe wall to the free stream is, in part, dependent on a coefficient which is proportional to pressure and temperature. The pressure in the drying medium needs to be kept low.

In order to determine the dryness of the pipeline, the moisture content of the air at the discharge end of the section is measured by recording the dewpoint temperature. The moisture content of the discharged air can be obtained by reference to the dewpoint temperature in standard saturation vapour pressure tables.

Where multiple valves and offtakes are included in the section to be dried, the number of test locations should be sufficient to adequately demonstrate the whole system is dry e.g., on AGIs.

9.4.1.1 *Operational equipment*

(a) Super-dry air

The air-drying/super-dry air equipment should be located at the launching end of the pipeline and connected to allow the repeated dispatch of pigs during the operation. The air-drying unit should have sufficient capacity to suit the pipeline size and be able to achieve a dewpoint temperature below that specified. The unit should have two absorption vessels with fully automatic change over facilities for regeneration to allow for continuous working. Dewpoint temperature measuring instrumentation should be installed at both the pig launching and receiving stations to allow continuous monitoring to take place. This should be calibrated and checked in accordance with an agreed procedure and check list.

(b) Inert gas

The equipment and instrumentation for inert gas should be located and operated as for the super dry air method. Sufficient capacity should be available to suit the pipeline size and dewpoint temperature required.

Note: The gas may be supplied in a gaseous form from bottles or be a direct supply pipeline or be in liquid form in tankers, in which case a vaporiser will be required of sufficient capacity to suit the speed of supply.

9.4.1.2 *The drying operation*

As soon as the first pig has been despatched, the instrumentation at the launching end should be checked to ensure the air-drying unit is attaining the required dewpoint temperature.

Pigs should be discharged at regular agreed intervals, established from calculations based on the length and internal condition of the pipeline, as well as the ambient temperature of the ground and dewpoint temperature to be achieved.

Instrument readings at the receiving end should commence when there are no further signs of moisture being expelled or when the pipe begins to discharge dust.

Note: The mechanism of air-drying is such that the exhausted air will be saturated until very close to the end of the operation. If the dewpoint sensors come into contact with free water, they will take a considerable time to recover and, if contaminated by particulate matter, will need to be replaced.

9.4.1.3 *Completion of the drying cycle*

Shortly before drying is concluded, the block valve cavities should be purged with dry air/nitrogen by closing partially the mainline valve and venting to atmosphere. The pipeline can be considered to be dry along its whole length when the required dewpoint has been reached at the receiving end. Upon reaching a dewpoint throughout the system better than –20 ºC the system shall be isolated and initial readings taken from the end locations. Following a soak period of 12 hours minimum dewpoint measurements should be taken from the same end locations. Air should be vented at the measurement point for a minimum period of 5 minutes before a measurement is taken. The dewpoint should remain equal to or less than –20 ºC but should not have reduced by more than 5 ºC or 20 % of the original readings. All dewpoint readings should be taken at or around atmospheric pressure. The line should then be closed off and the air-drying equipment removed.

9.4.1.4 *Gassing up*

The pipeline should be commissioned in accordance with IGE/SR/22. If gassing up is to take place sometime in the future, the pipeline should be secured in dry air or an inert gas. When gassing up is due to take place, the dewpoint should be re-checked prior to introduction of the gas behind pigs and an inert gas slug.

9.4.2 **Vacuum drying followed by purging and gassing up**

The temperature at which water will undergo a change of state from liquid to vapour is dependent on its pressure. At normal atmospheric pressure, this change of state occurs at 100 ºC. This is known as the “saturation vapour temperature”. If the pressure is reduced, the change of state will occur at a lower temperature. Thus, at a pressure of 10 mbar, water will evaporate at 7 ºC, and it is this vapour which is extracted by the vacuum drying process.

Note 1: Typically, a dewpoint of –20 ºC is equivalent to a saturated vapour pressure of 1.032 mbar.

Note 2: For accuracy, dewpoints are to be measured at or around atmospheric pressure.

The method may take longer than drying with air or nitrogen but, when fuel costs are taken into account, vacuum drying may prove cost effective.

9.4.2.1 *Operational equipment*

The vacuum plant should be installed at the agreed location and run for a specified period against closed connections to ensure that leaks associated with the temporary connection have been minimised and that the agreed minimum pressure can be achieved.

The pumping equipment should have sufficient capacity to suit the pipeline volume and be able to achieve a dewpoint temperature below that specified, but care should be taken to regulate the flow during evaporation to avoid over-rapid cooling of the free water during evaporation. Certified vacuum gauges and temperature measurement instrumentation should be installed at both ends of the pipeline to allow continuous monitoring to take place.

Dewpoint temperature measuring instruments will be accurate to +/-2 ºC and the instrumentation should be calibrated and checked.

9.4.2.2 *Personnel*

Personnel should be available for each location of equipment and/or instrumentation, in sufficient numbers to allow for continuous working over a number of days.

9.4.2.3 *Evacuation*

The pressure of the system is reduced to the point where the water in the pipeline is able to boil at the temperature of the pipeline surroundings. At a pressure of between 200 and 300 mbar, an evaluation of the system in-leakage should be made by temporarily ceasing drawdown and isolating the system for a set period, usually 12 hours, quantifying the air in-leakage. If the air in-leakage is large, remedial measures should be taken to locate and reduce the leakage. After a successful leak check, the vacuum plant should be brought back online and pressure reduction continued until the specified pressure is reached.

9.4.2.4 *Evaporation*

Evaporation of free water will commence nearest the vacuum pump(s) and will move away from the pump(s) as the process progresses.

Given a constant temperature and a frictionless system, the pressure will be constant throughout and evaporation will take place simultaneously along the length of the pipeline.

However, a dynamic pressure gradient will exist within the pipeline due to the frictional effects on the flow of vapour. While evaporation will take place at a relatively constant pressure, the pressure seen at the pump suction will be lower than that seen where evaporation is taking place. Therefore, the distance from the vacuum pump(s) of the area being dried will increase with time and will be characterised by pressure at the pump suction falling, with consequent reductions in the quantity of vapour pumped.

Evaporation will continue until all free water is evaporated. The pipeline will now contain water vapour at low pressure.

9.4.2.5 *Gassing up*

The pipeline should either be gassed up immediately into vacuum or packed with dry air or nitrogen for gassing up at a later date.

If gassing up is to take place immediately on completion of vacuum drying, this can be undertaken directly into vacuum with vacuum pumps at the remote end drawing off vapour to prevent water drop out due to the effects of over compression. The discharge from the pumps should be monitored to detect the presence of gas. When gas is detected at the remote end, the pumps should be shut down and the gas taken to vent until the dewpoint specified for the gas is achieved. Gas injection should continue until the agreed commissioning pressure is attained.

When gassing up into dry air or nitrogen, the dewpoint temperature should be re-checked before the introduction of gas.

9.4.3 **Final drying**

The water vapour in the pipeline should be removed and the system pressure reduced to a level where the pipeline is at or below the saturated vapour pressure.

Having established that all the water vapour has been removed, pressure should be reinstated to atmospheric pressure + 1 bar with a dry medium, and a "soak test" should be conducted following system isolation, to monitor any decay in the dewpoint over an agreed period, up to 24 hours.

If the values obtained indicate the required dewpoint in the system has not been achieved, the drying process should be repeated until the agreed dewpoint level has been reached.

Following a successful soak test, the line should be re-evacuated to the ultimate level achievable and the system made ready to commission.

Where dewpoints drier than -20 ºC are specified, it may be necessary to investigate a dry air or nitrogen purge. This requires dry air, having a dewpoint of -40 ºC or less or nitrogen to be introduced at one end of the pipeline section while drawing through the section using vacuum plant at the remote end, thus preventing water "dropping out" of the vapour on to the pipe wall through the effects of over compression.

The air purge should be maintained at a constant level until the required dewpoint is reached. Subsequently, the line should be re-evacuated to the ultimate level achievable and the system made ready to commission.

9.4.4 **Methanol swabbing**

Pipelines may be dried by methanol swabbing whenever the methods outlined in clauses 9.4.1 or 9.4.2 are not practicable. Methanol swabbing is recommended only as a last resort. Swabbing shall be carried out in accordance with Appendix 9.

9.5 **PRESSURISING**

9.5.1 **Preliminary works**

All valves shall be positioned to allow the pressurisation of flanges and fittings. Any leakage shall be reported.

Consideration shall be given to the use of a flow meter in the gas admission line. All valves shall be checked for their positions, in accordance with the authorised procedure.

9.5.2 **Pressurisation**

9.5.2.1 *Pipelines*

Gas should be admitted via the control valve, ensuring that the maximum permitted flow rate agreed with the control centre is not exceeded. All flanges and fittings shall be checked for leak tightness at 7 bar intervals. Any leakage shall be reported immediately.

The means of rectification shall be authorised.

During pressurisation, the pressure gradient along the pipeline shall be monitored and recorded, using gauges connected direct to the pipeline at bridles, valves, pressure reduction station inlets and the terminal ends.

On reaching the full pressure, all valves on the system shall be checked to ensure they are in their correct positions in accordance with the authorised procedure.

The pipeline may now be considered operational and maintenance procedures instituted.

9.5.2.2 *PRIs*

All PRIs fed from the pipeline shall be brought into operation and monitored regularly for gas dewpoint and performance.

If the PRI inlet dewpoints are not satisfactory, consideration shall be given to the following:

- use of low outlet flow rates
- gas pre-heating
- regulator small bore pipework heating.

If the gas is odorised, the odorant level shall be checked at the PRI outlets. If necessary, the odorant level shall be corrected by odorant injection at the new systems source.

On completion, all sample points, temporary pressure connections etc., shall be removed and the fittings plugged.

SECTION 10 : PROTECTION AGAINST CORROSION

This Section applies entirely to pipelines.

10.1 GENERAL

10.1.1 Provided the quality of the NG as described in Section 6 is maintained and is dry, it is not expected that a pipeline will suffer internal corrosion (but see clause 10.3.1).

External corrosion of a buried pipeline may arise from the nature of the surrounding ground, from contact with other buried metallic structures or from the pickup and discharge of stray DC electric earth currents, such as may occur with DC operated electric traction systems, HVDC power systems, solar farms or incorrect operation of DC welding equipment, or by AC discharge due to low frequency induction with overhead powerlines.

Prevention of external corrosion shall be achieved by a combined system of coating and CP. An external coating alone should not be considered adequate corrosion protection.

10.1.2 Reference should be made to the relevant parts of the appropriate standards for guidance on the selection of coating materials and requirements for their application, for example BS EN ISO 12944 for above ground pipe and pipework. Coating of buried pipelines shall be in accordance with the relevant part of BS EN ISO 21809.

10.1.3 All internal and external painting and coatings systems shall be in accordance with a recognised standard e.g., BS EN ISO 12944 or an approved specification. The coatings should be tested for physical durability, cathodic disbondment and the resistance to chemical attack.

10.1.4 Consideration shall be given to the temporary protection of weld preparation areas during transport, handling and storage, guidance on which is provided in IGEM/TD/1 Supplement 1.

10.2 SPECIAL SITUATIONS

10.2.1 Avoidance of known corrosion hazards

At the route planning stage, consideration shall be given to the avoidance of the more obvious corrosion hazards, for example by routing to avoid:

- stray DC current areas
- groundbeds associated with CP systems of other buried assets
- paralleling of high voltage AC/DC overhead or buried power lines
- electricity towers (pylons)
- wind farms
- Solar farms
- DC traction systems
- contaminated ground
- naturally aggressive ground, for example peat
- rock or other ground conditions which may limit CP current.

Note: Further information on interference from solar farms on CP systems is given in UKOPA/GP/014

Where it is not possible to avoid such hazards, appropriate consideration shall be given to the effectiveness of CP and the risk of stray current interaction both in terms of transient fault events and normal operation.

10.2.2 Pipelines operating at elevated temperatures

Where a pipeline or section of pipeline operates at an elevated temperature, for example immediately downstream of compressors, the coating material shall be suitable for service in such conditions.

Note: Such suitable materials include thermosetting powders and liquids and three layer systems with a polypropylene or polyethylene outer sheath.

10.2.3 External stress corrosion cracking (SCC)

Use of appropriate high quality coatings such as fusion bonded epoxy (FBE) will, normally, protect the pipeline against SCC which is associated with cyclic stress, temperature and soil pH. Field joint coatings shall comply with the requirements of BS EN ISO 21809-3.

Note: SCC may occur under disbonded coatings at elevated temperatures (generally greater than 30^{o}C), where effective CP at adjacent coating damage provides the causative chemical environment. It may also occur at normal temperatures, where mildly acidic ground water is present under the disbonded coating, in the absence of effective cathodic protection, due to the shielding effect of the coating.

If a pipeline is considered to be at risk of stress corrosion cracking (SCC) an assessment of the risk should be carried out in accordance with a recognised standard e.g., NACE (National Association of Corrosion Engineers) SP 0204. Further information on managing SCC is provided by UKOPA/GPG/009 'Near Neutral pH and High pH Stress Corrosion Cracking'.

10.2.4 Effects of CP interaction on buried metallic structures

Consideration shall be given to the effects of CP interaction on adjacent buried metallic structures. The locations of CP current sources should be sited such that the buried metallic structure is not situated between the current source and the pipeline that it is protecting.

10.3 COATINGS

Wherever possible, coatings for pipes and fittings should be factory-applied. Materials used for coating on site shall be compatible with any factory applied coatings.

In selecting suitable materials, consideration shall be given to the operating regime and the eventual siting of the component, for example buried or above ground, and the temperature range likely to be experienced.

Note 1: Some coating materials could, for example, be affected adversely by solar heating or exposure to ultra violet radiation.

Note 2: Where a reinforced thickness dual layer system is employed, in addition to adhesion testing to the substrate, consideration needs to be given to intercoating adhesion testing and adhesion testing of field joint coating overlay.

10.3.1 **Internal pipe coatings**

10.3.1.1 Notwithstanding the non-corrosive nature of dry Natural Gas, pipes should be internally coated to prevent rusting during transit and storage.

Note 1: The presence of rust could give rise to problems of internal dust and blockage of filters, etc. during operation.

Note 2: In certain circumstances, it may be advisable not to use an internal coating, for example when the pipeline is carrying gas laden with hydrocarbon condensate.

10.3.1.2 A further advantage of internal coating is the reduction of friction losses within the pipeline.

Note: Normally, the internal coating system would be epoxy based, and be applied to a surface blast cleaned to an approved standard and profile or to a surface which has been chemically cleaned, phosphated and thoroughly washed in accordance with an approved specification.

10.3.1.3 The thickness of the coating material shall be selected to match the duties required, for example expected duration of storage, ability to withstand pigging, etc.

10.3.2 **External pipe coatings**

10.3.2.1 *Factory-applied coatings*

Factory-applied external coating systems shall be such as to provide long term electrical and mechanical characteristics, which are suited to the diameter and operating conditions of the pipe and the nature of the environment. The coatings shall adhere strongly to the pipe and have a sufficient resistance to cathodic disbondment.

The coating shall be applied to a clean, dry surface.

Note: Blast cleaning to the required surface profile is the preferred method of cleaning.

The coating system should be applied with minimum delay after surface preparation and in accordance with a recognised specification.

Note: The coating material may be FBE, asphalt, extruded high density polyethylene, a 3 layer system with a polypropylene or polyethylene outer sheath, a multi-component liquid, or other material of proven performance in accordance with appropriate specifications e.g., ASTM.

If pipes are to be installed by a trenchless crossing technique which may increase the risk of coating damage e.g., HDD, thrust or auger boring, appropriate coatings shall be used. A reinforced thickness dual layer system should be employed to provide increased resistance to mechanical damage and a suitable wear resistant field joint coating system with a proven track record for use in trenchless crossings should be employed.

A current drainage test shall be conducted in accordance with an agreed procedure on all new trenchless crossing sections before they are tied into the remainder of the pipeline to confirm the extent of coating damage and that current density necessary to achieve CP is within defined limits. Care should be taken to ensure that the pipeline is fully contained within an effective conductive electrolyte during testing.

Where pipework extends above ground, coatings specified for below ground applications shall not be used. The first 500 mm of pipework emerging from the ground shall be given additional protection, for example with a multi-component liquid, to provide a satisfactory transition between the pipeline coating and the paint system. For pipes other than vertical, this measurement should be to the nearest surface of the pipe to above and below ground level (see Figure 11).

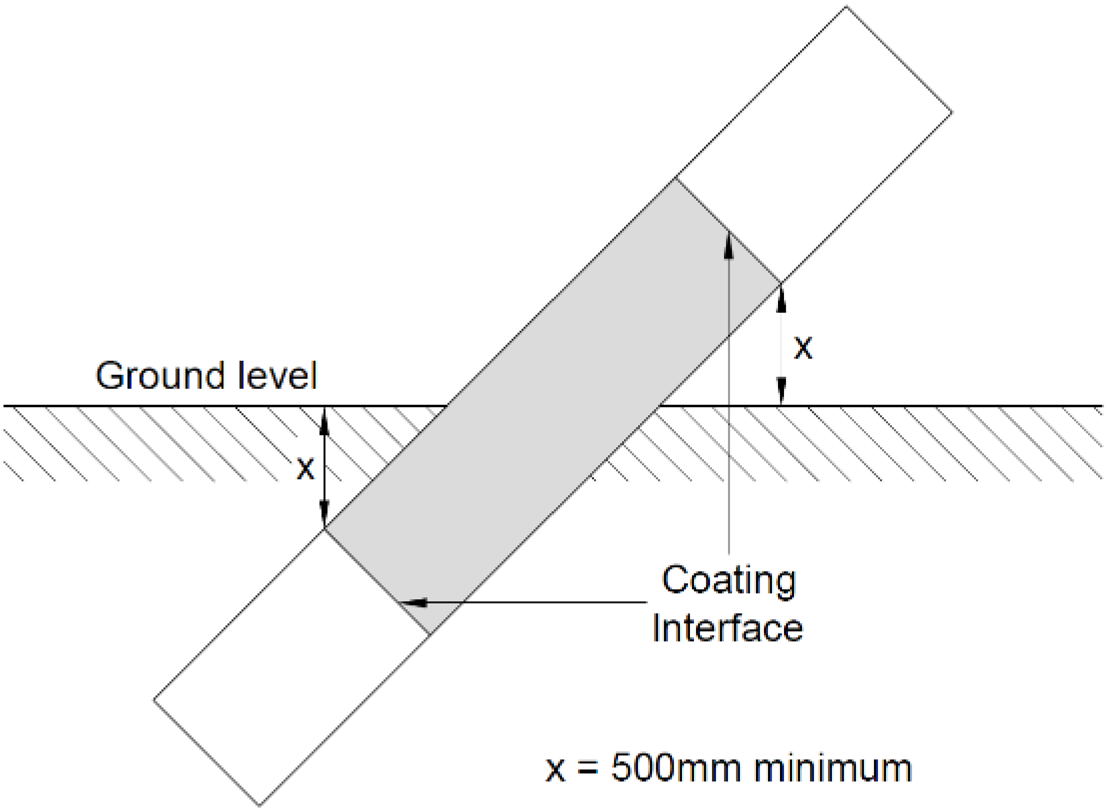


FIGURE 11: EXTENT OF COATING FOR PARTIALLY EXPOSED PIPE

Similarly, consideration shall be given to suitable enhanced corrosion protection systems at other locations where there is a possibility of moisture entrapment e.g., pipework entry into buildings, valve pits, pipe saddles and pipe supports.

Special attention shall be given to the areas of the structure that are covered with lagging and which may, therefore, be subject to an additionally corrosive environment.

Note: Grease-based paints are not considered appropriate for application under lagging.

10.3.2.2 *Field-applied coatings*

Field-applied coating systems shall be selected and applied in accordance with an appropriate procedure to reproduce, and be compatible with, the factory-applied coating.

Note: In some situations, for example where the factory-applied coating is extruded polyethylene, the use of compatible, spirally applied wrapping tape or compatible shrink materials may be acceptable.

In all cases, the pipe should be blast cleaned in accordance with a recognised standard e.g., BS EN ISO 8501-1 to the required level of cleanliness and the selected coating system should be applied in accordance with a recognised specification.

Note: There may be occasions when it is desirable to apply a second protective coating to factory-coated pipe, for example to improve mechanical features of the coating in rocky ground, or as a further safeguard at particularly hazardous points.

Additional protection may be required to prevent migration of objects within the ground. This may involve containment of selected fill around the pipe or use of membranes or barriers, in order to ensure effective operation of the CP systems.

Following welding and weld inspection, the pipe coating shall be completed at joint areas. While the requirements of clause 10.3.2.2 apply, particular care shall be taken to ensure that the materials chosen are compatible with, and adhere strongly to, the factory applied pipe coating. An adequate overlap by the field-applied material shall be provided on to the original cleaned pipe coating.

Note: Since this work will, normally, be carried out in the field, it is particularly important to consider the suitability of the coating material for the site and climatic conditions and its ease of application.

All field coating operations shall be witnessed and inspected by a suitably qualified inspector.

10.3.3 Coating of other below-ground components

All below-ground components, forming part of a cathodically protected pipeline, shall be coated to a common standard. Valves, etc., sited below ground level, shall be so coated even when housed in chambers.

The complex shape of some components may require consideration of coating materials other than those used for pipes. All coating employed shall be resistant to mechanical damage, particularly where there is a likelihood of personnel accessing pits, etc.

10.4 CATHODIC PROTECTION (CP)

10.4.1 General

CP shall be applied to the pipeline in accordance with BS EN ISO 15589-1. CP may be applied either by means of sacrificial anodes or by the impressed current method.

The CP system shall be designed to ensure that the minimum protection criteria defined in BS EN 12954 for the soil conditions are achieved. For aerobic soil conditions the required polarised potential should be -0.85 V vs $Cu/CuSO_4$ and for anaerobic soil conditions the required polarised potential should be -0.95 V vs $Cu/CuSO_4$.

The requirements for the following activities are given in the standard BS EN 12954:2019:

- the need for electrical insulation joints at offtakes and other installations
- other forms of electrical isolation
- the provision of permanent monitoring facilities
- possible secondary effects such as coating disbondment or electrical interference with adjacent buried structures
- the possibility of DC and AC stray current interference
- the protection of sleeves (see Sub-Section 6.12)
- the need to avoid inadvertent earthing of the CP system through such items as pipe supports, instrument connections, electrically operated valve actuators, reinforced concrete piles remaining after construction, connection to reinforced concrete or site earthing systems etc.

A CIPS of the entire pipeline shall be undertaken after the CP system has had sufficient time to polarise and as soon as possible after complete commissioning of the CP system, in order to fully validate the CP system performance and provide a baseline record of the CP system. Appropriate alternative techniques (e.g., current attenuation) shall be applied to HDDs, tunnels and sleeves or road, rail or river crossings.

As part of the commissioning process for areas where it is not possible to conduct a CIPS e.g., motorways, special crossing, railways, rivers etc., due consideration shall be given to employing alternative techniques to provide assurance of effective protection i.e., current gradient survey, diver towed reference electrode surveys etc.

On all new pipelines an approved coating defect survey shall be conducted along the entire pipeline length following backfill.

Temporary CP arrangements should be made where the commissioning of the permanent CP system is delayed or advanced works, for example crossings, are undertaken prior to the main pipeline construction. The criteria for assessing requirements for temporary CP are defined in BS EN ISO 15589-1.

If AC interference mitigation is deemed necessary, this shall be installed and connected as soon as practicable after pipe installation.

The design, installation and monitoring of CP systems should be carried out by personnel having the necessary level of competency defined in BS EN ISO 15257, or equivalent CP certification schemes or the pipeline operator's internal verification and training processes.

10.4.2 CP Monitoring

Due consideration shall be given to ensuring that appropriate CP monitoring facilities are installed at regular intervals along the pipeline route so as to ensure that routine maintenance and inspection can be conducted to confirm the effectiveness or otherwise of the level of CP current being applied. Consideration shall be given to providing a sufficient number of monitoring facilities to ensure that CIPS and other trailing wire surveys can be conducted along the entirety of the pipeline with particular attention being paid to the risk of stranded sections i.e., physical barriers where a wire cannot be trailed across e.g., rivers, railways, motorways. Due consideration shall be given to the installation of AC and DC coupons at pipe level to provide additional information.

Pipework extending from below ground to surface shall be backfilled to ensure CP e.g., including valve actuator stems and vent riser by a suitable surround e.g., sand.

10.4.3 AC corrosion

When pipelines are routed parallel to overhead high voltage power lines, voltages and current can be induced into the buried pipeline. Long parallelisms with overhead power lines of 132 kV or greater should be avoided or at least minimized.

- separation distance > 500 m should be maintained for parallelisms > 3 km
- separation distance > 200 m should be maintained for parallelisms ≤ 3 km.

These separation distances are minimum distances and specialist advice should be sought to ascertain whether AC interference may occur in a given situation and regardless of distance.

The guidance on the measures to evaluate the risk of AC corrosion on buried pipelines given in BS EN ISO 18086 shall be followed. Additional guidance on assessment of AC corrosion risk is provided in UKOPA/GPG/027 'AC Corrosion'.

Where AC corrosion has been identified as a risk the protection criteria to mitigate the AC corrosion risk defined in BS EN ISO 18086 shall be adopted.

Case studies indicate that, where the AC discharge current density is continuously above 30 Am^{-2} (measured on a 1 cm^2 coupon) for a period of time in excess of 24 hours then there is an enhanced risk of AC corrosion under certain conditions. Where AC corrosion is identified as a risk, suitable coupons should be installed with an exposed surface area of 1 cm^2 so that the AC and DC coupon current density can be recorded.

The DC pipe to soil potential, DC current density, AC current density and AC pipe to soil potential can all affect the AC corrosion risk and the methods of assessment and protection criteria defined in BS EN ISO 18086 should be applied to mitigate the AC corrosion risk.

The first step in mitigating the AC corrosion and safety risk is to ensure that the rms AC voltage on a pipeline is less than 15 Vrms, and then ensuring the AC current density is less than 30 Am^{-2} over a 24 hour period and that the DC current density is 1 Am^{-2} if the AC current density is in excess of 30 Am^{-2}, or maintaining the AC to DC current density ratio on a 1 cm^2 coupon to be less than 5.

It should be noted that in low resistivity soils, even at very low AC pipe to soil potentials of less than 4 V, AC corrosion can occur. Thus, the AC voltage on a pipeline system should be as low as possible and should not exceed the value at which the AC current density can exceed the criterion stated in BS EN ISO 18086.

The AC current density variations will be time dependent and should be evaluated using a data logger.

10.4.4 Mitigation measures

10.4.4.1 *AC Interference*

Specialist modelling software packages may need to be applied at the pipeline design phase on new pipelines or if AC interference is detected on existing pipelines. The software packages will be used to identify the areas on the pipeline system where there may be high AC discharge current densities and where additional earthing may be required to discharge the AC current to earth. Guidance on relevant calculations is given in BS EN 50443 and BS EN ISO 21857 Part 1.

An empirical approach may sometimes be adopted where earthing locations are selected based upon experience of AC interference in similar situations. Where such an approach is conducted, testing shall always be carried out to confirm that the AC interference levels are within prescribed limits.

Following measurement of the induced current, current densities greater than 30 Am^{-2} measured on AC coupons will require mitigation measures to be undertaken.

Earth gradient wires, installed as part of an AC mitigation scheme, should be connected to the pipeline via solid state DC decoupling devices irrespective of the gradient wire material. In the event of failure of the decoupling device then the earth gradient wire material shall not have a detrimental effect on the levels of CP afforded.

Note: In certain instances where the earth wire is compatible with the pipeline CP system e.g., zinc, it can be connected directly to the pipeline and not via a decoupling device. However, the latter arrangement may affect the ability to perform accurate ON/OFF CIP surveys.

1 cm^2 coupons should be installed at fixed test posts along the parallelism in addition to the usual corrosion coupons to facilitate subsequent monitoring of the AC current density. Data logging should be considered over representative periods of time not less than 24 hours to determine the variation of AC pipe to soil and AC discharge current density over time.

Note: Guidance is provided in UKOPA/GPG/027.

Where AC mitigation earth gradient wire is installed, due consideration shall be given to how effective future monitoring of polarised CP levels is to be conducted as decoupling devices can limit the effectiveness of CIP surveys on pipelines.

10.4.4.2 *DC Interference*

DC interference can result in high rates of corrosion on cathodically protected pipelines. During the design of a pipeline CP system, the risks of DC interference should be considered and the guidance given in BS EN ISO 15589-1 and BS EN ISO21857 Part 1 followed. It is particularly important to identify the location of third party groundbeds along a new pipeline route to ensure that the pipeline is not routed in close proximity to these.

The effect of a new pipeline CP system on third party pipelines shall be considered at the design phase, and details of the pipeline CP system should be advised to third party pipeline or metallic structure operators at an early stage. The requirements for stray current interference testing shall be agreed with the third party operator.

Sources of stray DC current should be identified and where appropriate suitable mitigation and monitoring measures implemented. Sources of DC stray current interference include DC traction and DC transit systems, DC welding systems, third party pipeline CP systems, HVDC transmission systems, DC operated solar farms and battery storage sites.

Note: Guidance is provided in BS EN ISO 21857-1 and UKOPA/GPG/031.

10.5 RECORDS

Permanent records shall be maintained of all corrosion control measures. These should include:

- type of internal coating
- types of external factory/field applied coating
- disposition and type of CP components and bonds
- current drain test results
- CP monitoring results
- state of interference bonds and shared schemes
- stray current interaction testing results of inspection surveys, for example DCVG, CIPS, ACVG, nitrogen sleeves etc.
- AC corrosion monitoring and mitigation systems
- short term AC interference events
- results of inspection surveys, for example DCVG, ACVG, CIPS, nitrogen sleeves etc.
- remedial work carried out
- sleeve protection details, including any auxiliary anodes.

Note: An integrated computer/pipeline management system may require additional specific information.

SECTION 11 : ASSOCIATED INSTALLATIONS

11.1 GENERAL

In general, an installation on a pipeline comprises one or more of the following:

- compressor station
- line valve
- branch connection to an adjacent installation
- meter installation (see also IGEM/GM/8 or IGEM/GM/4, as appropriate)
- multi-junction station with or without in-line metering and which may include pig traps and/or line valves
- overhead pipe crossing
- pigging station
- PRI controlling gas flow and/or pressure from one system to another
- terminal
- other offtakes.

Note: Branch connections involving a minimum connection to an underground pipeline are to be designed in accordance with Section 6.

The design of line valves, overhead pipe crossings and pigging stations is covered in Section 6. The pipework and component design, selection, layout, supports, stress analysis and other mechanical, civil, and E&I requirements on all of the above installations shall be in accordance with IGEM/TD/13 Section 7. Compressor installations shall be designed in accordance with appropriate industry standards such as BS EN 12583.

11.2 PIPELINE – INSTALLATION DEMARCATION

The point of demarcation between the standards IGEM/TD/1 and IGEM/TD/13 shall be selected by the designer, taking full account of the requirements of IGEM/TD/1, IGEM/TD/13 and IGEM/TD/12, and ensuring that:

- all joints between the pipeline and the first valve off the pipeline shall be welded to restrict the potential for leakage which cannot be isolated by closure of the valve
- buried flanges are avoided, or the number is minimised to the lowest practicable level.

Note 1: Exceptions to the above include flanged connections associated with under-pressure connections.

Note 2: The designer is cautioned that the standards IGEM/TD/1 and IGEM/TD/13 are not design handbooks, and competent engineering judgement is to be applied.

SECTION 12 : OPERATION AND MAINTENANCE OF PIPELINES

Certain parts of this section apply to the operation of pipelines constructed before the publication of this edition of IGEM/TD/1. Details of the application of specific editions of IGEM/TD/1 to the operation of pipelines are considered in Sub-Section 12.4.

12.1 GENERAL

All diversions, modifications and repairs of existing pipelines shall be in accordance with all sections of this, the latest edition of IGEM/TD/1. In addition, reference shall be made to IGEM/GL/5.

12.2 MANAGEMENT

12.2.1 Administration

12.2.1.1 A system of surveillance, inspection and maintenance shall be established for all high pressure pipelines and their ancillary equipment. A pipeline integrity management system shall specify the operational surveillance, inspection and maintenance required. It should set out schedules, procedures and instructions under which these activities should be carried out.

Such schedules, procedures and instructions shall embrace all aspects, including liaison with other departments, third parties and those responsible for gas movement or control. Such arrangements should be reviewed and updated as appropriate.

12.2.1.2 A separate Emergency Procedures Manual (EPM) shall be provided to deal with situations which necessitate emergency actions (see clause 12.2.3.8). The EPM should include details of the organisational response to emergencies, the safety precautions to be observed in preventing loss of life, injury and damage to property and the means of resourcing specialist services and equipment. The preparation of the EPM shall take account of local authority emergency plans.

Note: Guidance on emergency planning and testing is given in UKOPA/GPG/010, 011 and 012, guidance on pipeline hazard distances is given in UKOPA/GPG/016, guidance on information to be provided to local authority emergency planner sis given in UKOPA/GPG/029.

12.2.2 Legal and allied considerations

The requirements of Section 4 shall be observed. All work must be in accordance with the relevant legal requirements and shall be in accordance with safety codes and recommendations of appropriate bodies.

12.2.3 Safety management

If it is decided to use discretion in the application of this Standard, the risks associated with any variation shall first be considered (see also IGEM/G/7).

12.2.3.1 *Emergency contacts*

Arrangements shall be made for the receipt of reports of gas escapes by correspondence and in person, at company premises occupied during normal working hours. Adequate publicity should be given to the methods of reporting gas escapes.

Contact telephone numbers for use by the general public shall be publicised widely, and adequate telephone answering facilities shall be manned at all times in order to receive calls reporting gas escapes. Reference should be made to IGEM/SR/29 for further guidance.

12.2.3.2 *Training*

Personnel engaged in activities on high pressure pipelines shall be adequately and regularly trained. The training shall cover all aspects of safety and emergency procedures and equipment, as well as technical matters concerning the operation and maintenance of high pressure pipelines and associated equipment.

12.2.3.3 *Equipment*

Personnel engaged in activities on high pressure pipelines shall be issued with suitable protective clothing and equipment and, where necessary, emergency rations. Vehicles used shall be equipped with all necessary communication and safety equipment. Measures shall be taken to ensure that safety equipment is used whenever necessary.

12.2.3.4 *Permit to work system*

A documented permit to work system shall be in place to supplement other job instructions when the work is non-routine, may be potentially hazardous and a risk to personnel and others, or could damage plant or equipment.

An authorised person shall determine which activities require a permit to work by taking into consideration the potential hazards associated with the work activity. Attention shall also be given to factors which may change, requiring the issue of a new permit to work.

A permit to work system shall have the following features:

- clear identification of who may authorise particular work activities and who is responsible for specifying the necessary precautions.
- training and instruction in the use of permits
- site specific risk assessments and method statements
- competency requirements
- monitoring and auditing to ensure that the permit to work system operates as intended.

Note 1: Alternative permit systems may be available to operators.

Note 2: Guidance is given in HSG 250.

12.2.3.5 *Non-odorised gas*

Particular attention shall be given to enclosures, confined spaces and public reported gas escapes (PREs) where systems transport non-odorised gas.

12.2.3.6 *Inspection and routine work*

The following requirements provide a general guide when carrying out routine pipeline maintenance, including the physical inspection of exposed pipelines (which does not involve mechanical damage assessment).

- appropriate communication routes shall be established between the site and the operational control centre
- before starting work, the site shall be examined for gas leakage. If a significant gas presence is found, the remaining procedures of this clause, and those of clauses 12.2.3.7 and 12.2.3.8 shall be put in hand. In these circumstances, a working area, based on gas concentration measurements, shall be established and monitored to ensure a safe working environment
- smoking, naked lights and other sources of ignition shall not be allowed in the vicinity of the work and prohibition notices to this effect should be displayed.

Fire-fighting equipment should be available on site. The positioning of powered plant shall be considered carefully, as such equipment can be a source of ignition

- entry shall not be made to any building, trench or other confined space where gas may be trapped or which may be oxygen deficient, until the space has been ventilated and the atmosphere checked, particular regard being paid to the danger of asphyxiation and explosion. Monitoring shall be carried out during the operation to ensure a continuing safe environment
- a final leakage check shall be carried out on completion
- the necessary equipment shall be available to ensure safe access to, and egress from, the work area and the necessary precautions shall be taken to exclude non-essential personnel and the general public.

12.2.3.7 *Non-routine works*

Before carrying out non-routine works, written procedures shall be prepared and clause 12.2.3.4, concerning permits to work, followed.

When carrying out non-routine major works, additional precautions to those provided in clause 12.2.3.6 apply:

- at least two operatives shall be present

  Note: Under certain circumstances, extra operatives may be required, for example when entering and working within deep pits.

- sufficient sets of breathing apparatus shall be available on site
- where deep pits and confined spaces are involved, safe means of access shall be provided, harness and life-lines shall be available and at least one operative shall be detailed to observe others working in such space
- at least one member of the team shall be experienced in first aid and rescue operations
- where it is necessary to cut into a commissioned or decommissioned pipeline, cold cutting equipment shall be used until it has been confirmed that there are no hazardous substances present.

12.2.3.8 *Emergency procedures*

The following requirements are provided as a general guide with respect to emergency procedures and reference should be made to IGEM/SR/29:

- both operative and supervisory staff level shall be adequate at all times to handle reported escapes. Procedures shall be established in order to ensure that there is a system in place which can identify the likely source of escapes and will enable mobilisation of the appropriate resources as soon as is reasonably practical
- emergency procedures shall be established and all operational personnel shall be made aware of them including any requirement of themselves under such procedures
- emergency procedures shall be reviewed periodically and updated as changes in circumstances occur.

12.2.3.9 *Venting gas*

The venting of gas shall be minimised in order to reduce environmental impact. Reference should be made to IGE/SR/23.

12.2.3.10 *Electrical continuity*

When making a break in a pipeline or dismantling associated equipment, a temporary continuity bond shall be fitted across the intended break. The continuity bond shall be securely connected to the pipeline each side of the intended separation location and the bond cable should have sufficient flexibility to ensure that it does not break or disconnect if pipeline movement occurs as that may create an incendive ignition risk. Wherever possible, maintenance should be carried out without breaking the CP system. When this is not possible, the CP system shall be restored as soon as the work is complete.

Note: Attention is drawn to the possibility of induced AC currents being present which are independent of CP systems e.g., long line AC currents. In addition, CP systems can take time to depolarise after isolation and some stored energy may be present. It is advisable to allow 24 hours after isolation of a CP system for all stored energy to dissipate. Therefore, prior to disconnection of pipework, the risk of both AC and DC current flow creating a spark hazard on disconnection is to be considered. On cross country pipelines the magnitude of the long line AC could exceed that of the DC.

12.2.3.11 *Noise abatement*

A certain amount of noise is inherent in operation and maintenance activities. The best practicable methods should be employed to minimise noise emission, to protect site personnel and the general public. Any relevant legal requirements must be applied. Reference should be made to IGEM/TD/13.

Consideration shall be given to:

- provision of suitable ear protection to site personnel
- siting and screening of plant
- use of acoustically-treated power tools compressors and generators
- the timing of all operations and maintenance activities, which shall take into account the impact on the environment.

12.2.4 **Surveillance, inspection and maintenance frequencies**

12.2.4.1 Provided that appropriate data is available, frequencies may be determined by a risk-based approach and the use of software tools where appropriate.

Frequencies that have been determined using a risk-based approach should be reviewed periodically. Such a review should take account of the results of previous surveillance, inspection and maintenance.

12.2.4.2 A risk-based approach shall take into account a complete inventory of existing equipment and a comprehensive history of all occurrences and work undertaken on the equipment in question.

Note: It may be necessary to justify a risk-based approach to a regulatory body. Guidance on risk assessment techniques and criteria is given in Appendix 3 together with examples. Further guidance is given in IGEM/G/7, also HSE RR823 Managing Ageing Plant.

12.2.4.3 A risk-based approach shall take into account those factors which influence the probability and consequences of failures occurring in pipelines. The following shall be taken into consideration:

- age and standard of construction of the pipeline
- design assumptions for pipelines having a design factor exceeding 0.72
- previous surveillance, inspection and maintenance
- the results obtained from CP monitoring
- any evidence of ground movement
- ground conditions

- operating temperature history of the pipeline
- implications of loss of gas supply
- density of population surrounding the pipeline
- manufacturers' recommendations.

12.2.4.4 If there is not sufficient data to support a risk-based approach, a prescribed frequency shall be used as identified in the appropriate clause (see Table 14).

12.3 RECORDS

12.3.1 General

12.3.1.1 Records shall be readily available and continually updated, categorised under the following headings:

- fixed data
- surveillance
- inspection
- maintenance
- operation.

Note: Records may be held in hard copy, for example paper, microfilm, etc., or electronically, for example digital computer records.

12.3.1.2 An administrative procedure, preferably with a document flow diagram to suit the needs of the particular organisation, shall be defined to initiate and control the modification of records. The procedure should indicate the method of re-issuing plans, drawings or documents and include details of interested parties who have a specific requirement for detailed records, for example local Police and Fire authorities.

12.3.1.3 The number of persons holding records shall be strictly limited and indicated clearly on a distribution list for documents. Previous records should be destroyed, unless required for archival purposes in which case they should be marked as superseded.

12.3.1.4 A review of the accuracy of records shall be made at intervals not exceeding four years as part of the audit required for affirmation of pipeline MOP (see clause 12.4.2.1).

12.3.2 Fixed data

12.3.2.1 The following fixed data shall be retained:

- design records
- construction records
- any other relevant documents.

12.3.2.2 The route of a pipeline should be recorded on maps to a scale of 1:10,000, along with detailed maps to a scale of not less than 1:2500.

12.3.2.3 In addition to other information deemed necessary, the 1:10,000 maps should show the boundaries of all environmentally-sensitive areas, in order that appropriate advice may be sought prior to working within, or adjacent to, such an area.

12.3.2.4 Hard copy or electronic maps should show relevant construction data for the pipeline as identified in clause 4.1.4, including location of the pipe, reference to owners and occupiers, and any modifications to the pipeline.

12.3.2.5 Detailed drawings shall include:

- all installations forming part of, or attached to, the pipeline
- special crossings
- the location of other services
- pipeline profile.

The drawings should include unique identifiers for all valves and other equipment shown on the drawings.

12.3.2.6 Full details of any addition, diversion, modification or permanent decommissioning of any section of the pipeline shall be recorded at the time and subsequently included in the fixed data.

12.3.2.7 Records shall be maintained of all attachments to the pipeline, including under-pressure connections, hot taps and stopples and these should be integrated into the fixed data.

12.3.2.8 Records shall be maintained of all repairs carried out and these should be integrated into the fixed data.

12.3.3 **Surveillance**

12.3.3.1 All information arising as a result of surveillance activities shall be used to confirm or update existing records. Updating should take place as soon as practical after the event.

12.3.3.2 Records shall be kept of the surveillance carried out on the pipeline. These should be in such a form that encroachments can be readily recorded and monitored.

12.3.4 **Inspection**

12.3.4.1 Detailed records of inspections carried out shall be recorded against an item of plant or location or section of pipeline, so that defect trends can be readily identified.

12.3.4.2 Results shall be stored for the life of the pipeline.

12.3.5 **Maintenance**

12.3.5.1 All information arising as a result of maintenance activities shall be used to confirm or update existing records. Updating should take place as soon as practical after the event.

12.3.5.2 Records shall be kept of the maintenance carried out. These should be in such a form that the recurrence of faults can be readily detected. Damage and interference by third parties, together with the remedial action taken, should also be recorded.

12.3.6 **Operation**

12.3.6.1 A record shall be kept of pressures to which the pipeline is subject to facilitate the calculation of stress cycles and the affirmation of MOP.

12.3.6.2 Records of pipeline temperature shall be maintained, as appropriate, to determine that it remains within design limits.

12.4 OPERATIONAL PRESSURE LIMITS

12.4.1 MOP

12.4.1.1 In considering operational limits, it is necessary to decide to which Edition of IGEM/TD/1 the pipeline is operating. The operating edition shall be determined by confirming:

- the pipeline fully meets the requirements of Edition 6
- any infringements can be justified for operation to Edition 6.

If the pipeline MOP complies with Edition 6, the operating edition for the pipeline should be redeclared. If the pipeline does not fully meet the requirements of Edition 6, the operating edition for the pipeline should be confirmed and any infringements shall be identified using the BPDs given in Figures 5 and 6 of Edition 6, and continued operation justified for the appropriate Edition. Figure 12 shall be used when considering uprating a pipeline.

The Type R and Type S Area design factors and BPDs are unchanged from those in Edition 3. Edition 1 BPDs are based on blast and overpressure only. Edition 2 requires that pipeline design pressures between 7 and 19 bar should have a design pressure of 19 bar and BPDs for this pressure. These requirements were revised in Edition 3 and have remained constant in all subsequent Editions.

12.4.1.2 If a pipeline does not comply with an edition of IGEM/TD/1, and if it cannot be upgraded to meet this edition of IGEM/TD/1 or a specific risk assessment carried out to confirm acceptability, the pipeline shall be downrated to below 7 bar operation or taken out of service.

12.4.1.3 MOP of a pipeline shall be in accordance with this or previous editions of IGEM/TD/1. MOP may become limited by the following:

- the design section of the particular edition of IGEM/TD/1 to which the pipeline is being operated
- infrastructure or other adjacent development
- the materials used for the construction and the most recent in-service performance of these materials
- the pressure rating and acceptability of any equipment added since construction
- the most recent pressure test data, inspection results, condition monitoring results or risk analysis
- the requirements of clause 12.4.2
- any significant changes to the parameters used in risk assessments carried out as part of a safety assessment.

Other factors which may limit the MOP of a pipeline are:

- temporary operational constraints
- previous operating conditions
- operating temperature
- ground movement
- fatigue
- interference, in particular the possibility of undetected or un-notified third party interference
- defects
- internal and external stress corrosion cracking
- Legislation.

12.4.1.4 MOP shall be determined and declared annually.

12.4.1.5 The annual declaration of MOP of a pipeline shall be based on the most recent audit (see clause 12.4.2.2), the pressure history (see clause 12.4.2.8) and all information arising from surveillance, inspection, maintenance and operation.

12.4.2 Affirmation of MOP

12.4.2.1 Affirmation of the MOP of a pipeline requires a formal assessment of the integrity of the pipeline and its associated installations, and an assessment of the risks posed on the surrounding population. The objectives shall be to:

- confirm integrity
- identify any development in proximity to the pipeline/associated installation
- assess the population density in Type S area and review any changes within 4 BPD of the pipeline and
- identify any changes along the route that may impact on the risk posed to the surrounding population.

Further guidance on factors that could limit the MOP of a pipeline is provided in clause 12.4.1.3.

Where SRA (see clause 6.7.4.3 and Appendix 4) has been adopted for a pipeline having a design factor exceeding 0.72, the reaffirmation period (see clause 12.4.2.2) may have to be shortened.

12.4.2.2 The first audit shall be carried out 4 years after the commissioning of the pipeline. Except as permitted in the Note below, the affirmation of MOP for a pipeline shall be carried out at periods not exceeding 4 years.

Note: This audit interval may be extended or reduced by the pipeline operator based on the results of an authoritative review of the relevant data given in clause 12.4.1. This review has to be pipeline-specific, taking particular account of the potential for any encroachment. However, in any event, it is recommended that the periodic review interval does not exceed 6 years.

12.4.2.3 Where a SRA (see clause 6.7.4.3 and Appendix 4) has been adopted for a pipeline having a design factor exceeding 0.72, the first pipeline audit should include an audit of the SRA. The actual service performance should be compared with the assumptions used in the SRA. Subsequent pipeline audits should identify any changes in performance which might affect the validity of the assessments performed.

12.4.2.4 Proximity and population density infringements identified during pipeline surveillance should be considered as soon as possible, but the opportunity should be taken to verify compliance as part of the audit.

12.4.2.5 Infringements resulting from changes in proximity, population density, or traffic density shall be evaluated with reference to Sub-Section 6.7 or to Sub-Section 6.10 as appropriate.

When used to assess infringements, risk analyses shall provide:

- quantification of associated individual and societal risks
- data to assist the quantification of potential benefits associated with upgrading and/or risk mitigation measures.

12.4.2.6 Where the pipeline has been categorised as unpiggable, a review taking into account technology advances shall be carried out to determine whether the pipeline can be modified to be piggable in future.

12.4.2.7 Where necessary, the MOP shall be reviewed and revised.

12.4.2.8 Where the maximum pressure experienced by a pipeline during any period of five consecutive years has been 7 bar or more below the declared MOP, a formal MOP Affirmation statement confirming the pipeline/associated installations are fit for operation at the declared MOP, and that all measures required to detect and control external interference are in place, shall be prepared and certified by the responsible engineer. This statement shall be supported by the results of the pipeline audit and confirmation that the inspection and condition monitoring results for the installations are acceptable. Where such a statement cannot be prepared and certified, the MOP shall be re-declared at the highest level of pressure actually experienced during that period.

Where the pipeline is operating at a pressure below the declared MOP and a valid MOP Affirmation statement is in place, the pressure may be increased to the declared MOP in accordance with the requirements specified in clause 12.4.3.

Measures to detect and control external interference are:

- ensuring the pipeline route is clearly marked, the markers are visible and include contact information for the responsible operator
- regular contact with landowners and contractors working in the area is maintained
- reports of contractors working in close proximity to the pipeline are immediately investigated
- aerial survey sightings are investigated, and activities which may cause damage to the pipeline are stopped or supervised
- reports of damage or leaks made by landowners, members of the public, police etc. are promptly investigated
- observations of potential damage are made during pipeline maintenance and patrol activities are investigated promptly
- faults recorded during CIPS and coating damage indications on the top of the pipe recorded by DCVG surveys are investigated and repaired as required
- metal loss and dent features detected on the top of the pipe (8 o'clock to 4 o'clock) by ILI are investigated and repaired as required.

12.4.2.9 Where monitoring of the fatigue usage of the pipeline is required by Sub-Section 6.6, the life consumed since the last revalidation shall be checked at intervals which should not exceed 10% of the most recent estimate of the total pipeline fatigue life.

Where SRA (see clause 6.7.4.3 and Appendix 4) has been adopted for a pipeline having a design factor exceeding 0.72, and where the estimated future pressure-cycling (see Sub-Section 6.6) results in a significant probability of failure within twice the identified design life of the pipeline, the pipeline shall be monitored to establish the actual cyclic loading experienced by the pipeline.

12.4.3 Restoring MOP to a previously declared level, up to the original design pressure

12.4.3.1 The revised MOP shall be specified clearly. Irrespective of the construction date of the pipeline, care shall be taken to ensure that all the requirements of clause 12.4.1 are satisfied before the existing MOP is increased to a higher level. The revised MOP shall not exceed that calculated from the design criteria set out in Section 6 and the previous hydrostatic test shall meet the criteria set out in Section 8.

Where SRA (see clause 6.7.4.3 and Appendix 4) has been carried out for a pipeline having a design factor exceeding 0.72, but the MOP has subsequently been reduced and re-declared, then prior to restoring MOP to a level giving design factor exceeding 0.72, consideration shall be given to the continuing validity of the data, models and assumptions used in the SRA assessments.

12.4.3.2 Reference shall be made to the records of design, construction, testing, modifications, subsequent operation, maintenance and any other works carried out. This review should include a detailed survey of PRIs, associated installations and any other attachment to the pipeline.

12.4.3.3 The pipeline shall be examined for structural faults using either internal inspection (see clause 12.8.3.3), external inspection (see clause 12.8.3.4) or hydrostatic testing (see Section 8) to a level suitable for the revised MOP.

Where such an examination has taken place within the previous 5 years, consideration shall be given to the subsequent operating environment and to the extent of the proposed increase in MOP. Where considered necessary, a further internal inspection or hydrostatic test should be undertaken.

12.4.3.4 Where physical or gas supply constraints prevent structural examination using either internal inspection or hydrostatic testing, consideration shall be given to the use of external inspection techniques (see clause 12.8.3.4). These shall be used only where it can be demonstrated that the associated risk is acceptable. If adopted, the highest standard of external inspection should be carried out within 12 months of the proposed pressure increase.

The time interval between any inspection and the restoration of MOP shall be minimised.

12.4.3.5 If acceptable after consideration of clauses 12.4.3.3 or 12.4.3.4, the pressure shall be raised in accordance with the following:

- immediately prior to raising MOP, the pipeline is surveyed to ensure that no operations are being carried out in the immediate vicinity
- the pressure is raised in appropriate incremental steps taking into account jointing methods and construction standards
- the pressure is held after each incremental step to allow sufficient time for the pipeline to be surveyed for any sign of leakage. This shall incorporate the whole length of the pipeline, with particular regard being given to those lengths which are subjected to routine leakage survey (see clause 12.7.5)
- consideration is given to carrying out a leakage survey at the locations of all mechanical joints after 1 month of operating at the higher pressure.

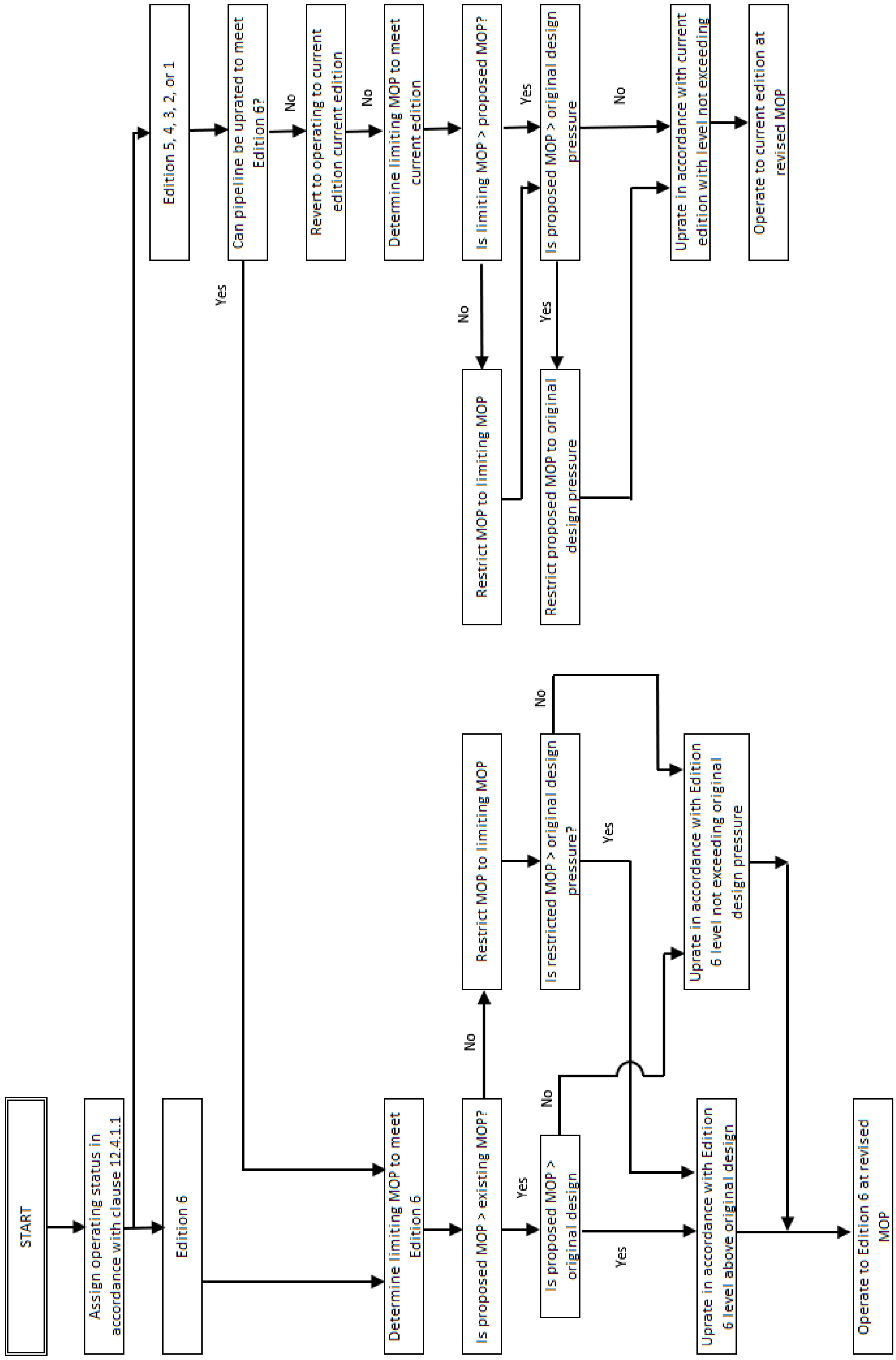


FIGURE 12 - DECISION ALGORITHM FOR UPRATING MOP OF A PIPELINE

12.4.4 Uprating MOP to a level above the previous design pressure

12.4.4.1 *General*

The uprating of a pipeline to a pressure level above the previous design pressure shall be controlled in accordance with formal procedures. The following control stages shall be adopted:

- viability – identification of any fundamental characteristic which may prevent uprating
- acceptability – completion of design review and identification of all modifications necessary
- assessments – completion of specialist studies to confirm the risk and integrity and safety margin of the uprated pipeline
- revalidation – confirmation that the condition is acceptable for the proposed MOP
- modification – completion of all necessary modifications
- pressure raising – increasing the pressure and confirmation of gas tightness.

Note: Figure 13 shows an overview of the uprating procedure.

12.4.4.2 *Viability*

To determine whether a proposed uprating is viable, the records, physical characteristics and original design features shall be examined to assess whether the increase in pressure may be acceptable.

12.4.4.3 *Acceptability*

To determine whether a proposed uprating is acceptable, exhaustive examinations of the records, physical characteristics and original design features shall be made.

The following shall be considered in assessing the viability of uprating a pipeline/associated installation:

- original design criteria
- construction standards and procurement details
- previous test results
- metallurgical details of all pipeline materials and those of the attachments to it
- operational records, including:
  - modifications since construction
  - repairs
  - condition monitoring results and actions
  - pressure cycling/fatigue history
  - service history
  - CP history
  - proximity and population density infringements and area classification.
  - operating temperature history
  - products carried previously in the pipeline
  - susceptibility to stress corrosion cracking
  - residual construction and operating stresses, including those due to ground movement particularly associated with deep mining, quarrying and landslips
  - stress analysis of any associated installation and components included in, or attached to, the pipeline
  - proximity of third party equipment
  - special crossings and the requirements of rail, river or road authorities.

12.4.4.4 *Assessments*

Once a proposed uprating has been determined to be viable, the following must be completed to confirm the risk and integrity and safety margin of the uprated pipeline:

(a) a complete survey of the pipeline for any infringements of this Edition at the proposed revised MOP, and risk assessment of any recorded infringements

(b) the information gathered under clause 12.4.4.3 and above against Sections 5, 6, 7 and 8, for the proposed revised MOP

(c) a stress analysis, if necessary, of associated installations and components included in, or attached to, the pipeline for revised operating pressure. Any changes to operating temperature which are likely to result from the proposed uprating shall be taken into account.

Any infringement of this Edition may be identified at this stage. A risk analysis of the infringements shall be carried out, for the proposed revised MOP, in accordance with Sub-Section 6.8. If required by Legislation, the level of risk must be agreed between the pipeline operator and the regulatory authority, taking into account the requirements of Section 6.

Note: Guidance on managing infringements is given in UKOPA/GPG/015.

The results of all assessments shall be considered and all modifications necessary for the proposed revised MOP should be determined.

12.4.4.5 *Revalidation-condition assessment for uprating*

Revalidation of the pipeline shall be carried out by:

- an internal inspection using an appropriate standard of internal inspection (see clause 12.8.3.3) taking into account the proposed revised MOP. Internal inspection is preferred, where this is not practicable, a justification for using external inspection (see clause 12.8.3.4) may be possible. Any features should be further analysed for growth potential using appropriate fitness-for-purpose techniques
- a hydrostatic test when internal inspection is not practicable and external inspection cannot be justified. Any features previously identified should be reassessed for the proposed hydrostatic test pressure, using appropriate fitness for purpose techniques.

When a pipeline is suitable for uprating with modifications, the modifications should be carried out before any hydrostatic test is undertaken.

Where a hydrostatic test is to be carried out, this shall be consistent with the revised MOP and in accordance with Section 8.

12.4.4.6 *Modifications*

When all the requirements of clauses 12.4.4.2, 12.4.4.3 and 12.4.4.4 have been taken into account and a pipeline is suitable for uprating with modifications, such modifications shall be carried out before any pressure increase is allowed.

It may be necessary to carry out repairs, replace components, relay or divert sections or carry out protection measures.

12.4.4.7 *Raising the pressure to the revised MOP*

If it is determined that a pipeline is suitable for uprating, having carried out the appropriate requirements of this section, the raising of the pressure should be in accordance with clause 12.4.3.5.

If required, any changes to MOP shall be notified to the appropriate regulatory authority.

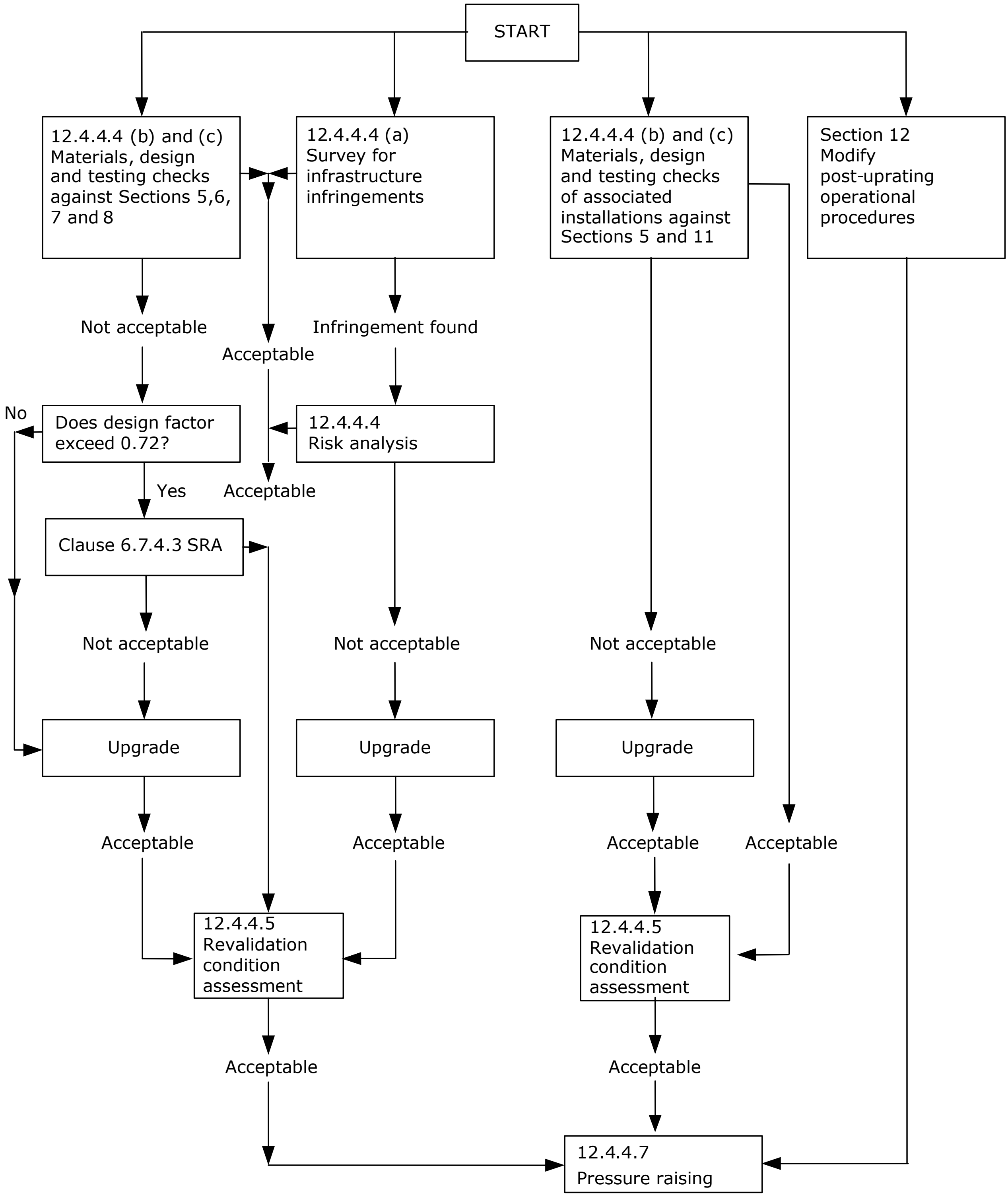


FIGURE 13 - OVERVIEW OF UPRATING PROCEDURE

12.5 Overpressure

12.5.1 The sustained operating pressure of a pipeline system shall be the MOP.

Note 1: This sustained operating pressure is the maximum set pressure for the pressure regulating devices. However, when operating at or near MOP, this pressure may be exceeded by no more than 2.5% of its value due to the variations of pressure regulating devices (see Figure 14 and IGEM/TD/13).

Note 2: The maximum sustainable operating pressure is subject to operational requirements and may be less than the declared MOP.

Note 3: Pressure variations are caused by the characteristics of automatic control systems. The relevant characteristics are:

- *steady oscillation which occurs when a pipeline system is in a steady state and the pressure deviation oscillates equally about the set pressure*
- *overshoot which occurs when a pipeline system is not in a steady state and the pressure regulating system is caused to take correcting action which results in a maximum pressure deviation.*

12.5.2 An incidental pressure rise is admissible, but facilities shall exist to limit automatically, by relieving or shutting off, maximum incidental pressure (MIP) to 10% above MOP and provided, when it occurs, it does not endure for more than 5 hours in excess of MOP at any one time or for more than 20 hours per year.

Note: Determination of the duration of an incidental pressure rise may exclude the duration of acceptable pressure deviations.

Where a SRA (see clause 6.7.4.3 and Appendix 4) has been adopted for a pipeline having a design factor exceeding 0.72, MIP shall have been determined as part of the design.

Note: This value may need to be less than 10% above MOP.

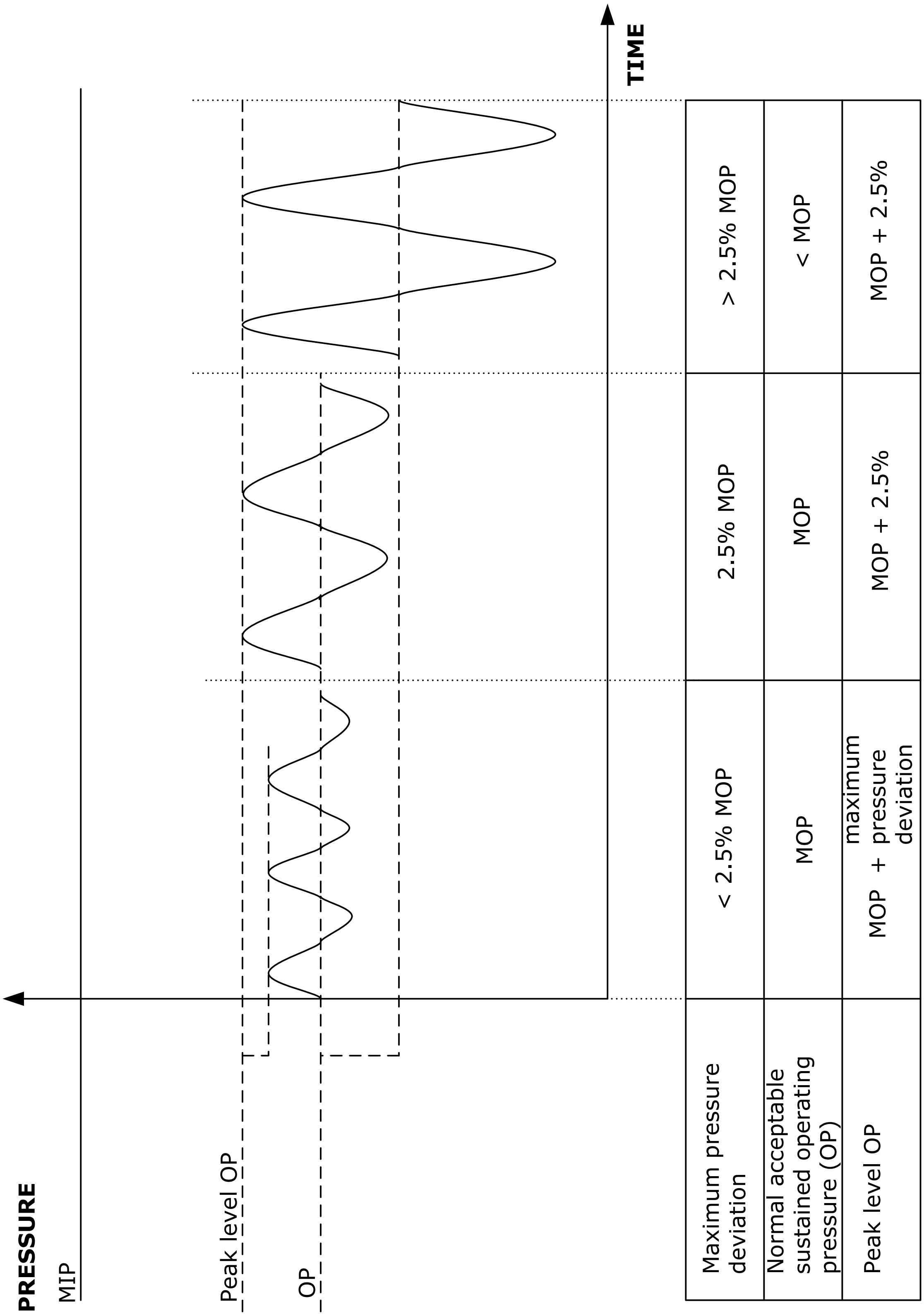
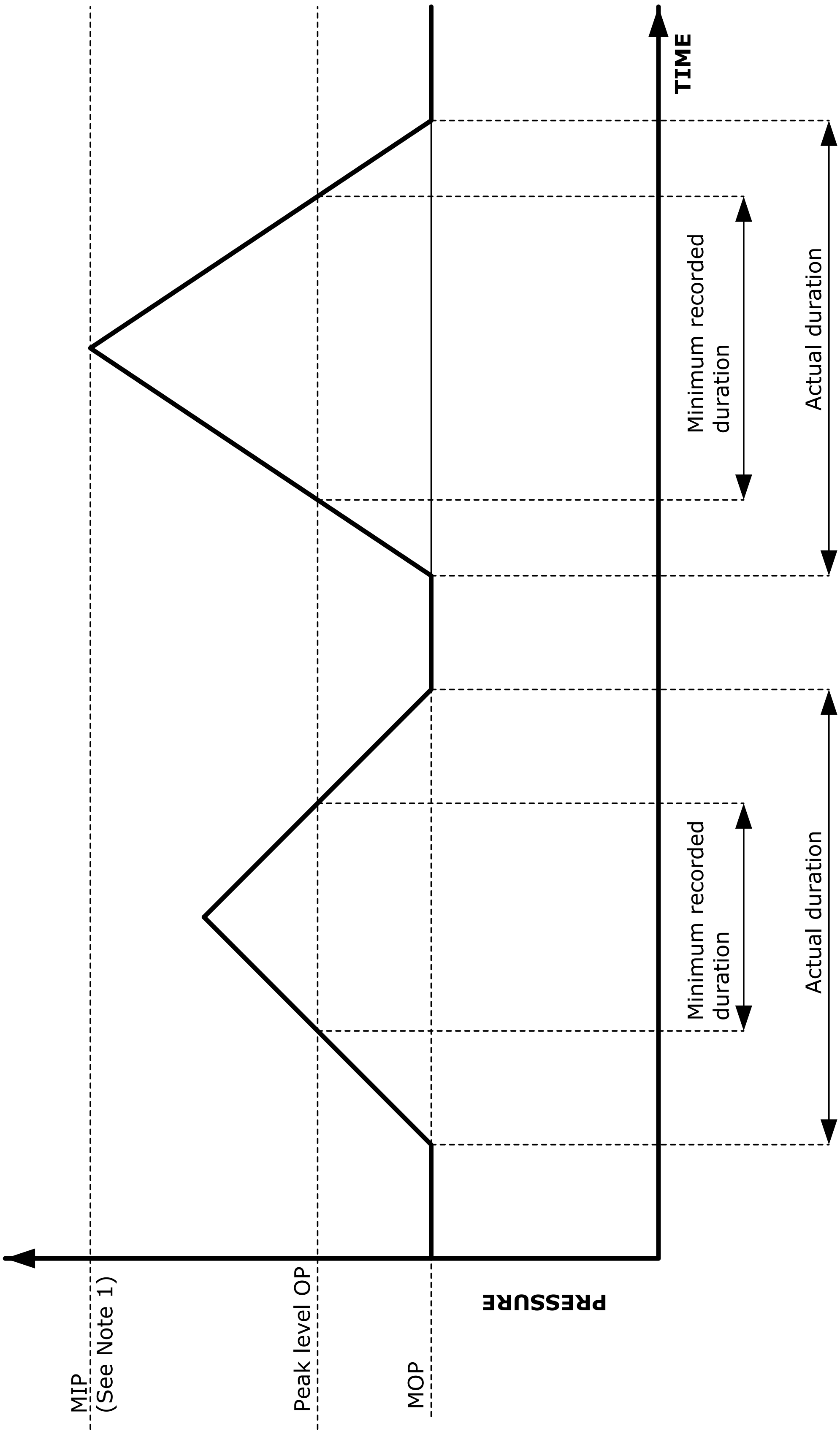


Figure 14(a) - Sustained operating pressure

FIGURE 14 - PIPELINE MOP EXCURSIONS (cont'd overleaf)



Note 1: MIP = MOP + 10% (can be less for pipelines of design factor > 0.72).

Note 2: Duration not to exceed 5 hrs for any single pressure excursion and not to exceed 20 hrs cumulative per annum.

Figure 14(b) - Incidental pressure rises

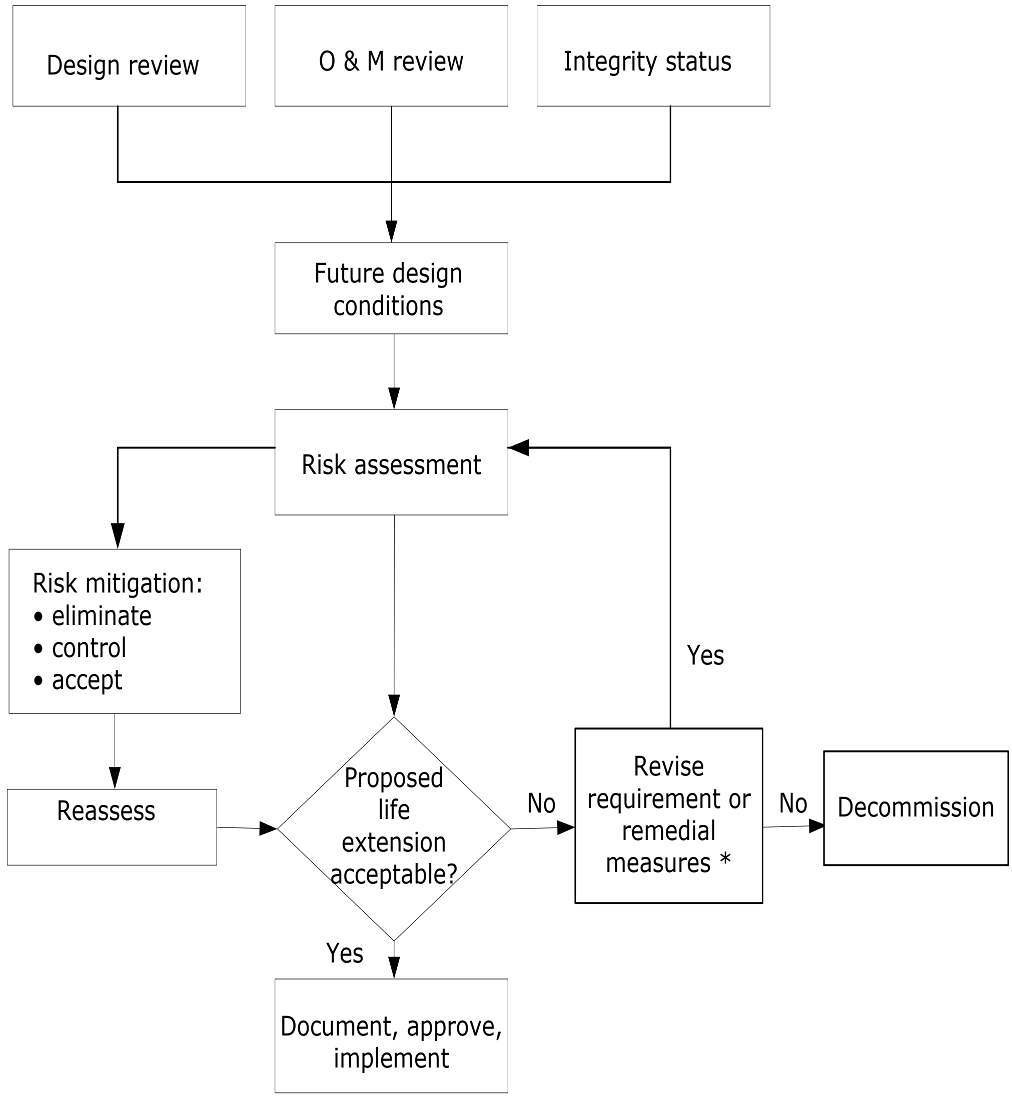
FIGURE 14 (cont'd) - PIPELINE MOP EXCURSIONS

12.6 REASSESSMENT OF DESIGN LIFE

The process applied to the reassessment of design life shall be carried out prior to the end of the original design life of the pipeline in accordance with UKOPA/GPG/018 'Remaining Asset Life Assessment Guide'. The reassessment shall include all activities detailed under clauses 12.4.3 and 12.4.4. In addition, formal reviews shall be undertaken of the condition and remaining life expectancy of CP systems; the condition of ancillary systems and equipment obsolescence. Specific consideration shall be given to the assessment of the remaining fatigue life of the pipeline, and the identification of any locations of active corrosion and the assessment of the rate of corrosion growth at such locations. Where necessary, plans for remedial/rehabilitation/replacement actions shall be developed and progressed. An overview of the process is given in Figure 15.

Note 1: In assessing the fatigue life of pipelines containing dent features, reference is to be made to the UKOPA/GPG/004 'Managing Pipeline Dents'.

Note 2: Guidance on Life Extension of Pipelines and Associated Installations is given in UKOPA/GPG/018.



*For example, reduce MOP; reduce pressure cycling; repair.

FIGURE 15 - REASSESSMENT OF DESIGN LIFE

12.7 SURVEILLANCE

12.7.1 General

12.7.1.1 Reasonable precautions should be taken to reduce the risk of damage to the pipeline. Surveillance activities should be completed in accordance with this edition to minimise the likelihood of damage by external factors and third parties, and also to determine where the environment in which the pipeline is situated has altered.

12.7.1.2 The frequency of surveillance activities should be set by a risk-based approach (see clause 12.2.4). If this is not practicable, the frequency should be prescribed as identified in the relevant clause (see Table 14).

12.7.1.3 The type and frequency of surveillance activity should be determined for each pipeline section taking into consideration a range of factors, including:

- location
- depth of cover
- design of pipeline (wall thickness, operating pressure/stress, attachments etc.)
- historical records
- extent of third party activity
- environmental conditions, including the weather.

12.7.1.4 Where a section of pipeline is operated in accordance with a risk-based design, the level of surveillance shall be appropriate to the location concerned.

Frequencies and levels shall be reviewed at regular intervals to determine that they are still appropriate.

12.7.1.5 An effective management structure and arrangements shall be in place to ensure that:

- any encroachment onto the pipeline is reported immediately according to an agreed procedure
- the necessary action is taken to protect the pipeline and that the pipeline is monitored from the first notification to final completion.

12.7.1.6 Route plans must be deposited with the relevant authorities in accordance with Legislation or where considered appropriate.

ACTIVITY	REFER TO CLAUSE
Surveillance	
Aerial	12.7.2
Vantage point	12.7.3
Walking	12.7.4
Leakage	12.7.5
Monitoring of Third-party activities	12.7.6
Ground movement	12.7.7
Inspection	
Exposed crossings	12.8.1
Water course crossings	12.8.2
Condition monitoring	12.8.3
Inspection and maintenance frequencies	12.8.4
Corrosion control	12.8.5
Maintenance	
Pipeline and associated equipment	12.9.1
Valves	12.9.2
Valve actuators	12.9.3
Remotely operated valves	12.9.4
Pipework, pig traps and equipment	12.9.5
Land and buildings	12.9.6
Non routine	
Isolation	12.10.1
De-commissioning/re-commissioning	12.10.2
In-line inspection	12.10.3
Pipeline damage and repair	12.10.4
Under-pressure working	12.10.5
Permanent de-commissioning	12.10.6

Note: *The recommended frequencies in the referred clauses will need to be increased in areas of intense third party activity, areas of ground movement, or other circumstances when the integrity of the pipeline could be compromised such as flood conditions for water courses, or where large public gatherings occur adjacent to the pipeline, for example festivals, agricultural shows, etc.*

TABLE 12 - SURVEILLANCE, INSPECTION, MAINTENANCE AND NON-ROUTINE ACTIVITIES

12.7.2 Aerial survey

12.7.2.1 An aerial survey of all pipelines should be undertaken every two weeks unless the frequency is set by a risk-based approach in accordance with clause 12.2.4.

Note: *The purpose of this survey is to report on ground activities which, if allowed to develop, might affect the pipeline.*

12.7.2.2 Pipeline markers or some other effective navigational aid, for example Global Positioning Systems (GPS), should be used to enable accurate surveys to be carried out.

12.7.2.3 Observers should be notified of known encroachments. They should record all encroachments or likely encroachments and report them according to an agreed procedure.

Note: Normally, this activity is completed by an observer from a helicopter but can also be achieved by fixed wing aircraft or by the use of satellites. Still or video photography can aid the process. The primary advantage of helicopters is the ability to land immediately at any perceived high risk situation affecting the pipeline.

12.7.2.4 The chosen method for aerial survey should be capable of reporting on any of the following occurrences which may be taking place in the vicinity of the pipeline:

- work on drainage, ditching, fencing or any other farm activity, with the exception of normal topsoil cultivation
- fires of any description, including straw burning
- civil engineering or building work of any kind
- tree felling and timber transportation
- discoloration of vegetation or other evidence of leakage
- blasting and mineral extraction
- ground movement and changing water courses
- the removal of surface soil and conversely tipping or stacking of materials over the pipeline
- solar farms/battery storage sites
- the condition/presence of aerial and other marker posts
- any temporary sites of public gathering, for example camp sites, festivals, agricultural shows, etc.
- any other unusual feature which may affect the pipeline.

Where a serious infringement is observed, immediate action should be taken, for example by landing to investigate, reporting by radio or returning immediately to base to report.

12.7.3 Vantage point survey

12.7.3.1 As an alternative, or as a supplement, to aerial surveys, a vantage point survey should be carried out. This survey should be undertaken every 2 weeks unless the frequency is set by a risk based approach in accordance with clause 12.2.4. The survey should be undertaken by an observer from pre-determined fixed points along the route, the points being selected to ensure that all relevant parts of the route are visible.

12.7.3.2 The actions taken as a result of the survey should be as those following an aerial survey (see clause 12.7.2).

12.7.4 Full walking survey

12.7.4.1 All parts should be walked at least once every 4 years, unless the frequency is set by a risk-based approach in accordance with clause 12.2.4. If it can be demonstrated that sufficient surveillance takes place during aerial/ vantage/overhead crossing/water course crossing/overline and on-line condition monitoring surveys and liaison activities, then separate walking surveys of all or part of a pipeline may not be required.

12.7.4.2 Where appropriate, notice should be given to the owner/occupier/tenant before a ground patrol enters the land.

12.7.4.3 Suitable precautions, including the use of disinfectant sprays, should be taken where necessary to counter the risk of spreading animal and plant disease.

The walking patrol should observe and report on similar features to those outlined in clause 12.7.2.4 in addition to which the following should be checked and duly reported:

- exposed crossings and installations inspected for security
- the condition of surface boxes, markers posts, etc
- if the pipeline and easement is overgrown, if tree growth is present and/or if there is any invasive or non-native plant species present
- A photographic record of pertinent features not limited to but including crossing points of any kind should be taken.

Note 1: Guidance is given in UKOPA/GPG/017 'Line Walking Surveys'.

Note 2: It is essential to clear enough vegetation to prevent re-growth during the interval between inspections. 1 metre of clearance is required, where practical, around marker and CP posts to ensure that they do not become obscured before the next inspection.

12.7.5 **Leakage survey**

12.7.5.1 If a leakage survey programme is deemed appropriate, the frequency should be set by a risk-based approach in accordance with clause 12.2.4. If this is not possible:

- for pipelines conforming to and operating to IGEM/TD/1 Edition 6, a leakage survey should be carried out annually at:
  - sleeve ends not fitted with rigid end seals
  - points where impact protection has been provided
  - those sections of pipelines which cannot be inspected by on-line pigging or a suitable overline survey technique.
- for pipelines not conforming to but operating in accordance with earlier editions of IGEM/TD/1, the above survey frequency should be carried out quarterly at the stated locations
- where sections of the pipeline have infringements resulting from changes in proximity, population density or traffic density, the survey frequency should be carried out quarterly at the infringement locations.

Note: Leakage surveys have been shown to be of limited benefit except in circumstances at a specific location where a survey is deemed appropriate.

12.7.5.2 Where a leakage survey is to be carried out at points of proximity or other infringements or where impact protection has been installed, the length of pipeline to be surveyed should include the section of the infringement or the protection concerned plus the proximity distance for the pipeline at either end of the section concerned.

12.7.6 **Monitoring of third party activities**

12.7.6.1 *General*

A system should be established to collect information on third party activities and assess the impact of such activities on pipelines. This may include "one call systems", information exchange agreements between parties, "dial before you dig" arrangements, etc. Monitoring procedures should be established in accordance with IGEM/SR/18.

12.7.6.2 *Liaison with owners/occupiers, tenants and other authorities*

Regular contact should be maintained with owners/occupiers and tenants on the land through which a pipeline passes. This can best be achieved by regular correspondence which shall include;

(a) Annually depositing with the occupiers, a plan showing the pipeline

(b) The obligations under the deed of grant

(c) Guidance as to the type of activities pipeline operators should be notified of

(d) The requirement to give notice of any work likely to affect the pipeline

(e) A short questionnaire to determine:
- The accuracy of existing owner / occupier records (changes of ownership, tenancy etc).
- That the existence of the pipeline is known to the occupier.
- Confirmation the information provided is understood.
- Whether any work in the vicinity of the pipeline is planned in the future.

If the owner/occupier fails to acknowledge the annual reminder letter or return a completed questionnaire, then alternative methods of communications should be used to confirm contact.

Note: Alternative methods of communication may include a phone call and / or a physical visit taking account of responses obtained from the owner/occupier to the annual reminder letter.

Operator visibility and contact should also be maintained through periodic presence on land during maintenance activities such as Line Walking, CIPS (Close Interval Potential Surveys), CP inspections and pipeline remedial activities.

Where an operator is made aware of a new Landowner/Tenant then a physical visit should be offered to discuss the pipeline route through the land and the obligations laid out in the annual letter.

12.7.7 **Ground movement**

12.7.7.1 *Sources of Ground Movement*

Deep Mining

(a) If mining activities are carried out in the vicinity of pipelines, an assessment should be made of the likely effect on the pipeline of any resultant ground movement so that protective measures can be implemented.

(b) Communication should be maintained with mining companies so that they are fully aware of the pipeline route and protection requirements.

(c) Details should be obtained from the mining company of the type of mining, the scheduled extraction period, the panel dimensions and location, any significant geological features such as structural faults and any adjacent or previous mining in the area.

(d) Predicted ground subsidence profiles along the pipeline route should be obtained and this should include both the horizontal and vertical movement components.

Other Sources of Subsidence

(e) Other sources of 'controlled' subsidence that affect pipelines include the placement of surface loads (for example embankments), the extraction of fluids or the creation of salt cavities. The protection of the pipeline can follow a similar approach to 'Deep Mining' in clause 12.7.7.1 through consultation with the scheme developer to quantify the expected subsidence profile and calculation of the effects on the pipeline following clause 12.7.7.2

Note 1: Uncontrolled subsidence can occur in areas underlain by some types of historical coal mine workings and areas containing soluble rocks. An assessment of the effects on the pipeline will generally involve specialist geological studies to define the likelihood of subsidence and calculations of the loss of bed support.

Note 2: Guidance on managing ground movement is given in UKOPA/GPG/020.

Landslides

(f) The failure of natural slopes can present a serious threat to pipeline integrity and will generally involve a detailed assessment of the pipeline condition and implementation of remedial measures (see clause 12.7.7.2).

(g) It is normal practice to re-route the pipeline around landslide areas, however in some situations pipelines are maintained within landslides where movements are slow, and the risks are clearly recognised, particularly the potential for accelerated movement. This approach requires a robust monitoring strategy with clearly defined limits for intervention.

12.7.7.2 *Assessment and Control of Ground Movement*

(a) Calculations of pipeline stresses (Section 6.5) should be made using a stress analysis procedure, taking account of the predicted ground movement, soil properties, the pipeline geometry and the operating loads. The predicted stresses should be assessed against limiting criteria to prevent tensile fracture or local buckling.

(b) Monitoring of ground displacements is normally required where a pipeline is affected by ground movement. This should involve accurate survey methods and the monitored section should include the full movement zone and the monitoring point density should increase where high gradients of differential movement are expected or are identified during the monitoring period.

(c) Where ground movement loads in the pipeline are predicted to be significant, or there is uncertainty over the development of the ground movement loads, the pipeline should be monitored by appropriate means, such as strain gauges. The positioning of strain gauges should take account of the results of pipe stress analysis. Consideration shall be given to measurement of the pre-existing stress state in the pipeline where previous ground movement loads may have developed.

Note 1: There is no existing guidance on the definition of significant ground movement loads in this context and therefore it is largely a matter of judgement based on the nature of the loading and certainty of the calculation inputs.

Note 2: An example definition may involve ground movement loads that contribute more than 50% of the performance limit (clause 6.5.3) or where the total loads (including ground movement loads) increase to within 20% of the performance limit.

(d) Remedial measures should be carried out where unacceptable stresses occur. These include the controlled exposure of the pipeline, realignment vertically or horizontally, cutting the pipeline, replacement of the backfill by low friction material or low density material, or insertion into the pipeline of bellows or sliding joints.

(e) If the pipeline is to be exposed, due consideration shall be given to any adverse effect on security and the environment.

(f) Specialist advice should be sought before remedial actions are carried out.

Note 1: The response of a pipeline to changes in restraint or operating loads during remedial works needs to be fully understood to ensure that more adverse or potentially damaging loads do not develop.

Note 2: The possibility of sudden uncontrolled movement of the pipeline occurring during remedial work needs to be considered and measures taken to ensure safety.

12.7.7.3 *Pipelines subject to SRA*

Where a SRA (see clause 6.7.4.3 and Appendix 4) has been adopted for a pipeline having a design factor exceeding 0.72 and ground movement occurs or is predicted to occur, the assessment of the continuing fitness for purpose of the pipeline in the vicinity of the ground movement should take cognisance of the SRA assessments performed. The acceptability of any increase in failure probability in the vicinity of the ground movement should be considered when deciding upon remedial actions.

12.7.8 Engineered Slopes (Quarries)

(a) Engineered slopes typically cover mineral extraction in quarries but also include the creation of earthworks or cuttings for example associated with road schemes. Quarry slopes are generally temporary however other forms of slope can be permanent.

(b) If quarrying or surface (opencast) mining activities are to be carried out in the vicinity of a pipeline an assessment should be made of the threat from slope instability so that protective measures can be implemented.

(c) Communication should be maintained with quarry operators so that they are fully aware of the pipeline route and protection requirements.

(d) Details should be obtained from the operator of the type of mineral to be extracted, the scheduled extraction period, the planned extent of the operations, how the mineral will be extracted, whether there are any planned crossing points over the pipeline, the geotechnical assessment of the site and the restoration plan.

(e) For all engineered slopes, a stand-off and safe slope angle should be agreed which protects both the pipeline and easement from potential instability in the engineered slopes and provides suitable access to the pipeline if maintenance is required.

Note: The stand-off is defined as the distance between the centreline of the pipeline and the closest point of the engineering slope.

(f) The pipeline route, stand-off and agreed slope angle should be inspected at a suitable frequency in relation to the risk and extraction schedule, but not less than every four years for quarry slopes. Routine inspection of permanent slopes is generally not necessary.

12.8 INSPECTION

Inspection of any pipeline shall be carried out to ensure that deterioration is not occurring.

12.8.1 Exposed crossings

Exposed crossing points shall be inspected for security, mechanical defects, condition of supports and associated structures/foundations, paintwork, protective wrap and guards. Concrete parts of pipe supports shall also be inspected for any degradation, for example cracking or powdering of the concrete caused by an alkali-silica reaction. Refurbishment shall take place as necessary. The frequency of inspections should be set by a risk-based approach in accordance with clause 12.2.4. If this is not practicable, the inspections should be at least annually.

Note: Where the crossing is the subject of vandalism or other adverse conditions, more frequent inspections may be justified.

For corrosion control of exposed crossings, reference should be made to clause 12.8.5.2.

12.8.2 Water course crossings

12.8.2.1 *General*

The profile of the pipeline beneath any water course shall be determined.

Surveys shall be carried out to allow the identification of changes from the original state of both the pipeline and its immediate surroundings, for example, riverbeds, riverbanks and landfalls, and to provide sufficient information to be able to demonstrate the continued integrity of the pipeline and its fitness for purpose.

12.8.2.2 *Frequency of surveys*

The frequency of surveys should be set by a risk-based approach in accordance with clause 12.2.4. If this is not practicable, the frequency should be in accordance with Table 15. In addition to the items identified in clause 12.2.4, a risk-based approach shall take into account:

- regulatory requirements
- the nature of the water course, seasonable variations and severe weather patterns
- the stability of the riverbed
- the activities of other parties, for example, dredging
- previous inspection history
- the results of studies to evaluate the risks to the pipeline integrity.

	Depth of cover (m)			
	≤ 0.5	> 0.5 ≤ 1.2	> 1.2 ≤ 4	> 4
	Survey interval (years)			
Major water course tidal	1	1	1	1
Major water course (navigable)	2	3	5	15
Minor water course	5	5	5	Not required
Other water course (generally wadeable)	During external condition monitoring or close interval potential survey of the pipeline. Additional inspections where the local situation requires.			

Note 1: *Tidal water course crossings can be subject to extensive and rapid erosion. This may result in loss of cover making the pipeline vulnerable to impact or vortex-induced vibration.*

Note 2: *Where the depth of cover is greater than 1.1 m, the survey interval may be established using a risk-based assessment of previous results and environmental conditions.*

Note 3: *Guidance on managing depth of cover is given in UKOPA/GPG/001.*

TABLE 13 - FREQUENCY OF WATER COURSE CROSSING SURVEYS WHERE RISK ASSESSMENT IS NOT CARRIED OUT IN ACCORDANCE WITH CLAUSE 12.8.2.2

12.8.2.3 *Minor water courses*

Surveys shall be carried out of river crossing points and other locations affected by adverse water and associated ground conditions.

Surveys shall be tied into a recognised geographical grid and shall determine the position of the pipeline, in both plan and elevation, in relation to the riverbed.

Liaison with the controlling water authority shall form an essential part of the survey.

12.8.2.4 *Major water courses*

Pipelines which cross busy navigable water courses, estuaries or large expanses of water such as lakes or lochs, shall be surveyed to ensure that any condition or event likely to be detrimental to the integrity of the pipeline or the safety of others is discovered as soon as possible.

Note: *These types of pipeline crossings are susceptible to third party interference from shipping as a result of collision or grounding and to damage caused by anchors and trawl boards. Additionally, high water currents may cause erosion of the landfall section or disturbance of the material placed over or around the pipeline.*

Scouring of material from beneath the pipeline can result in free spanning in extreme cases, which can grow in length and, unless checked by remedial action, may result in damage to or failure of the pipeline length.

Spanning may also subject the pipeline length to fatigue damage if vortex induced vibration of the span occurs. Such fatigue damage is likely to affect girth welds and requires specialist assessment; the requirements of Sub-Section 6.6 are not appropriate for this case.

12.8.2.5 *Scope of surveys*

When determining the scope of the survey, the following shall be considered:

- size and nature of the water course
- pipeline crossing design specification and method of construction
- local environmental constraints
- information required
- type of features to be identified
- mechanical damage to the pipeline and its corrosion protection coatings
- CP
- changes in position of the pipeline or signs of movement in any direction
- location of sand and mud banks including details of drift
- extent of any loss of cover along buried or protected sections
- condition of weight coating and the extent of any loss of coating
- debris in close proximity to the pipeline which may become a danger to its integrity
- condition of riverbanks or landfall sites

  Note: *Based on the initial and any subsequent surveys of major water courses and trends in seabed movement, exposure and burial can be determined and any areas of concern highlighted for further monitoring.*

- results of studies to evaluate the risks to the pipeline integrity.

12.8.2.6 *Selection of survey techniques*

Information necessary to ascertain the applicability of a specific survey method shall include:

- width and depth of crossing
- water flow rate (tidal or constant)
- pipeline exposure or burial
- strategic importance of the pipeline
- navigability, volume and type of shipping
- necessity to monitor known damage and/or remedial works.

Note: *Further information on the selection of suitable techniques, depending on different water depths and their application, is provided in Appendix 8.*

12.8.2.7 *Survey operations*

A detailed programme of operations shall be prepared and agreed with affected parties. The programme shall define individual and functional responsibilities as well as safety procedures.

Reference should be made to Appendix 8 for further information on survey procedures.

12.8.2.8 *Survey results*

The results of surveys shall be reported in a suitable format to enable both the location and significance of features to be readily determined, and to provide a comparison with previous survey results. Reference should be made to Appendix 8 for further information on the content of survey reports.

The results from each survey shall be examined as soon as possible and appropriate integrity analysis and remedial work initiated as required to ensure the continued fitness for purpose of the pipeline and the safety of others, for example those involved in fishing activities in the vicinity of pipe spans.

12.8.3 **Condition monitoring**

12.8.3.1 Appropriate inspection shall be carried out for any new pipeline, as soon as practicable following commissioning, to provide baseline inspection data for comparison with future inspection results.

Note 1: The engineering standards and specifications used in the design and construction of pipelines, combined with the various non-destructive inspections and hydrostatic tests immediately following construction, ensure the eradication of critical defects at that time.

Note 2: Baseline inspection of a recently tested pipeline informs the assessment of features reported by future inspections. It enables the avoidance of unnecessary risks arising from the excavation and examination of original, benign, features which were subject to a pre-commissioning hydrostatic test.

12.8.3.2 The condition of any pipeline shall be established periodically. The condition monitoring regime shall be determined following consideration of factors such as relevant Legislation, performance of corrosion prevention measures, operation of the pipeline under pressure cycling or at elevated temperatures, and trend analysis of deterioration. Specialist advice should be sought for each of the potential damage mechanisms.

The condition of a pipeline shall be established by:

- the use of internal inspection devices on those pipelines which can be monitored using such devices
- the use of approved external inspection techniques on those pipelines or sections of pipelines which cannot be monitored using internal inspection devices. On pipelines which can be monitored using internal inspection devices, external inspection techniques can be used to provide additional intermediate inspections as necessary

Note 1: Guidance for in-line inspection requirements and the reporting of results is available from the Pipeline Operators Forum document "Specifications and requirements for in-line inspection of pipelines" and UKOPA/GPG/021.

Note 2: Guidance on the qualification of in-line inspection systems is available from API 1163.

Note 3: Qualification and certification requirements for personnel who provide in-line inspection services are available from ANSI/ASNT-ILI-PQ.

(a) Reference should be made to clause 12.10.3 for details of how to carry out internal inspection by means of on-line pigging.

(b) In selecting internal inspection systems, consideration shall be given to the following system characteristics:

- feature detection, classification and sizing capability, which is appropriate for the quantitative assessment of the structural integrity of the pipeline and associated repair policy
- feature location accuracy to minimise subsequent excavation
- the use of hydrostatic testing on those pipelines or sections of pipelines not suitable for either of the options above.

Note: Guidance on the verification of features identified by In Line Inspection is given in UKOPA/GPG/026.

12.8.3.3 *Frequency*

The frequency of condition monitoring activities should be set by a risk-based approach in accordance with clause 12.2.4. If this is not practicable, the frequency should be in accordance with that prescribed in Table 14.

TYPE OF MONITORING	MAXIMUM INTERVAL BETWEEN MONITORING
Internal	Not to exceed 10 years
Above-ground a. For pipelines subject to internal inspection b. For pipelines not subject to internal inspection	 Not to exceed 10 years to be carried out mid-way between internal inspections. Not to exceed 5 years
Hydrostatic test	Not to exceed 20 years

TABLE 14 - FREQUENCY OF CONDITION MONITORING WHERE RISK ASSESSMENT IS NOT CARRIED OUT IN ACCORDANCE WITH CLAUSE 12.2.4

12.8.3.4 *Internal inspection*

Methods of internal inspection are subject to continuing development and may be modified as new, different or improved information on the significance of defects is obtained. A proven method should be used for monitoring the condition of the pipeline using internal equipment under on-line conditions. Additional steps should be implemented where necessary.

To obtain satisfactory results from an in-line inspection programme, a comprehensive inspection plan should first be prepared. The inspection plan should include:

- the damage types to be detected
- the required detection limits & tolerances
- the typical operating conditions.

The inspection plan should provide a basis for:

- selection of an inspection system
- implementation of inspection
- monitoring of inspection activities
- assurance of inspection results.

Note 1: Satisfactory performance of in-line inspection depends upon the complete inspection system including hardware, software, procedures, data analysis and qualified personnel.

Note 2: Additional guidance for planning, organizing, and executing an in-line inspection programme is available from NACE SP 0102.

Note 3: Guidance for in-line inspection requirements and the reporting of results is available from the Pipeline Operators Forum document "Specifications and requirements for in-line inspection of pipelines".

Note 4: Guidance on the qualification of in-line inspection systems is available from API 1163.

Note 5: Qualification and certification requirements for personnel who provide in-line inspection services are available from ANSI/ASNT-ILI-PQ.

(a) Reference should be made to clause 12.10.3 for details of how to carry out internal inspection by means of on-line pigging.

(b) In selecting internal inspection systems, consideration shall be given to the following system characteristics:

- feature detection, classification and sizing capability, which is appropriate for the quantitative assessment of the structural integrity of the pipeline and associated repair policy
- feature location accuracy to minimise subsequent excavation
- measurement resolution, which should be consistent with requirements for subsequent analysis, for example calculation of dent strain
- requirements for comparison of the results with those from previous inspections, for example to estimate corrosion growth rates
- the purpose of the inspection. The following list may not be exhaustive as internal inspection is the subject of continuing development:
  - inspection for pipe deformation e.g., dents, wrinkles and ovality
  - inspection for metal loss resulting from, e.g., corrosion and mechanical damage
  - inspection for SCC and other forms of cracking, e.g., construction defects or fatigue cracking
  - inspection for exposure, loss of weight coating and free spanning, in major water course crossings
  - inspection to determine the pipeline location (XYZ data) to estimate bending strain due to, e.g., ground movement.

(c) The results of an inspection shall be reported in a suitable format to enable both the location and significance of defects to be readily determined, and to provide a comparison with previous inspection results. The pipeline operating conditions at the time of inspection shall also be reported.

(d) The results of an inspection shall be examined as soon as possible, and remedial work initiated to ensure the continued fitness for purpose of the pipeline. Where external corrosion is found, an investigation of the CP system shall be undertaken.

(e) Any previously unreported dent and/or gouge features identified on the top of the pipeline shall be risk assessed and investigated as potential unnotified or undetected third party interference, as required by clause 12.4.2.8.

12.8.3.5 *External inspection*

(a) These techniques shall be used on installations and on those pipelines (or sections of pipelines) which cannot be monitored using internal inspection devices and to provide additional intermediate inspections where necessary on pipelines normally monitored using internal inspection devices.

For the types of inspection techniques, reference shall be made to BS ISO 15589-1. Further guidance on direct and indirect assessment is given in NACE SP0502.

Note: *Impact protection can affect the efficiency of above ground surveys, such as DCVG and CIPS.*

(b) Survey procedures shall be adopted to assess the effectiveness of the CP system and to detect areas of mechanical damage where appropriate.

(c) For any pipeline having a design factor not exceeding 0.3 or pipelines of nominal wall thickness 19.1 mm or greater at a design factor not exceeding 0.5 which are not internally inspected, the following monitoring methods shall be used:

- a CIPS carried out over the entire length of pipeline being monitored. Where the polarised potential does not meet the criteria for effective CP, as specified in BS EN 12954, a DCVG or similar survey for any coating defects shall be carried out
- where electrical interference makes CIPS inaccurate, a separate, simultaneously recorded static data logger shall record the pipe-to-soil potential at an appropriate point on the pipeline and located at least 3 km from the section being surveyed to determine and calculate the compensation required in the CIPS data for the amount of interference
- where a pipeline is protected by sacrificial anode groups, a CIPS measuring "on" pipe-to-soil potentials may be used where it is not practical to switch off all anode current sources, and supported by polarised potentials measured from buried coupons at test points.

Note: This will enable a polarised potential profile to be estimated for the pipeline.

Consideration shall be given to excavating all locations of coating defects where the CP is not effective and to carry out external pipe wall inspections. Following any repair work and after consolidation of the backfill, necessary remedial action should be taken to ensure that the pipeline meets the criteria for effective CP.

(d) For any pipeline having a design factor exceeding 0.3, or pipelines of nominal wall thickness 19.1 mm or greater operating at a design factor exceeding 0.5, the following monitoring methods shall be used:

- a CIPS carried out over the entire length of pipeline being monitored
- a DCVG or similar coating defect survey for coating defects carried out over the entire length of pipeline being monitored which is not internally inspected, and at specific locations where defects are indicated for pipelines which are internally inspected
- where electrical interference makes the polarized potential survey inaccurate, a separate simultaneously recorded pipe-to-soil potential at an appropriate point on the pipeline should be used to calculate a compensation for the amount of interference
- where a pipeline is protected by sacrificial anode groups, a CIPS measuring "on" pipe to soil potentials may be used where it is not practical to switch off all anode current sources, and supported by polarised potentials measured from buried coupons at test points.

Note: This will enable a polarised potential profile to be estimated for the pipeline.

Consideration shall be given to excavating all locations of coating defects identified by the coating defect survey and to carry out external pipe wall inspections.

Where the potential survey data does not meet the criteria for effective CP specified in BS EN 12954, remedial action shall be taken.

(e) Any previously unreported or investigated CP faults or coating defects identified on the top of the pipeline shall be risk assessed and investigated as potential unnotified or undetected third party interference, as required by clause 12.4.2.8.

(f) Other survey methods shall be considered where particularly difficult faults are unable to be resolved by normal survey procedures.

- Current attenuation survey

Similar to the Pearson survey this detects loss of an injected AC signal through measurements of the magnetic field with pairs of coils. The method will also identify the current strength and direction of current flow and is a useful technique in locating uninsulated contacts as well as coating defects. This is referred to as the Alternating current voltage gradient (ACVG) technique There is another similar technique termed Alternating current attenuation (ACCA) survey which uses a low frequency (4Hz) signal to identify current loss locations associated with coating defects.

- Direct current voltage gradient (DCVG)

  The voltage gradient that exists at coating defects is measured between two reference electrodes using a voltmeter with an accuracy of +/- 10 mV as the pipeline is traversed. This method will provide information on the relative sizes of coating defects and other sources of current loss but will not determine whether the applied CP is effective.

  The DCVG technique can be used in areas where measurements may be susceptible to AC interference. The DCVG survey technique can also, in some circumstances, determine the shape of a coating defect (from which a cause may be inferred e.g., backfill or mechanical damage), the location of the defect on the pipeline (top, bottom or side) and whether the defect is actively corroding.

The following alternative survey techniques may be considered for application in place or in addition to CIPS.

- Current drainage test (CDT)

  Coating defects can often be introduced during the construction process. At some locations, such as trenchless crossings, these defects will not be detected by over the line coating defect surveys. A current drainage test at these locations can give a qualitative assessment of coating quality from the determination of the current density necessary to achieve CP and an indication of whether additional cathodic protection will be required at the location. In the context of managing CP systems, CDT is also employed to provide an indication of coating quality, for the identification of shorted insulating joints/flanges, pipeline to sleeve shorts, and to confirm cathode faults.

  The principle of a CDT is to use an external power source to provide current to the pipeline and coating defects on the pipeline/pipework via a temporary groundbed and to measure the current required to achieve CP along the length of pipeline under test. Although the current required to achieve CP can be calculated for new systems, this can be unreliable for existing systems, where the level of coating breakdown is unknown or other current drain sources exist. In such cases, the current requirement can be accurately determined by the application of a CDT.

- Electromagnetic current attenuation surveys

  The electromagnetic current attenuation survey technique can be used to indicate where buried steel pipework is free from significant coating defects in a situation where a complete CIPS is not possible. CIPS can be especially difficult where pipes are laid below concrete, tarmac etc., making it impossible to obtain reliable pipe to soil potential readings due to either poor ground contact of the reference electrodes or at locations such as railways, busy road crossings and in towns and cities where the safety of the public and CIPS operatives due to the use of trailing cables can be compromised.

The technique can also locate cathode faults on cathodically protected pipelines. A cathode fault is present when the current demand to achieve CP is excessive due to an inadvertent contact with another metallic structure such as a cast iron water main, concrete reinforcing bar contact or an insulation joint failure.

The technique requires an AC signal to be applied between the coated pipe and remote earth by means of a battery-powered transmitter connected between the pipe and one or more earth spikes. The strength of the AC signal is measured along the pipe with an antenna (not connected to the pipe). A coating defect or metal to metal contact with a foreign structure can be identified through an observable drop in the signal gradient.

- Long range ultrasonics (LRUT)

  LRUT or Guided Wave Ultrasonic Thickness (GWUT) is based on guided ultrasonic waves which are transmitted along a section of pipe to detect metal loss. Typically, it is used where it is difficult to gain access to pipework or pipeline sections, for example road crossings.

  The reliability of LRUT is not established, and the user should ensure the technique is suitable for their particular application and materials.

  Note: When carrying out an inspection of below-ground pipework which has a coal tar coating, the wave strength may diminish rapidly. Similarly, some soils may have the same effect.

  In addition, the image may be affected by wave background noise for areas of inspection within 1 metre of the transmitter contacts. The presence of bends on pipeline sections can also affect the suitability of the technique.

12.8.4 **Inspection and maintenance frequencies**

12.8.4.1 Provided that appropriate data is available, then, as a first preference, frequencies should be determined by a risk-based approach and the use of software tools where appropriate. Frequencies that have been determined using a risk-based approach should be reviewed periodically.

Such a review should take account of the results of previous inspection results.

12.8.4.2 A risk-based approach requires a complete inventory of existing equipment and a comprehensive history of all occurrences and work undertaken on the equipment in question.

During the planning phase of the on-line inspection, consideration shall be given to the implications of the loss of gas supply should the device get stuck and appropriate contingency plans put in place to mitigate this.

Note: It may be necessary to justify a risk-based approach to a regulatory body.

12.8.4.3 A risk-based approach shall take into account those factors which influence the probability and consequences of failures occurring in pipelines. The following shall be taken into consideration:

- age and standard of construction
- design assumptions for pipelines having a design factor exceeding 0.72
- previous inspection results
- the results obtained from CP monitoring
- any evidence of ground movement
- ground conditions

- operating temperature history of the pipeline
- density of population surrounding the pipeline
- pipeline sleeves.

Note: Reference to UKOPA/GPG/005 'Managing Pipeline Sleeves' is recommended.

12.8.4.4 If there is not sufficient data to support a risk-based approach, a prescribed frequency should be used as identified in the appropriate clause (see Table 14).

12.8.4.5 *Inspection feature investigation and remedial works*

Inspection features, reported as a result of condition monitoring operations, shall be inspected and repaired in accordance with clause 12.10.4.

Note: For the investigation of dent features, reference to UKOPA/GPG/004 is recommended.

12.8.5 **Corrosion control**

12.8.5.1 *CP monitoring and maintenance work*

(a) The continued effective operation of a CP system is totally dependent upon a satisfactory level of monitoring and maintenance and shall form part of the pipeline management system.

(b) Due regard shall be taken of the possible ageing effects on the pipeline coating systems and on locations where the integrity of the CP system may become increasingly vulnerable.

(c) The periods of monitoring and the continuing suitability of the representative test locations shall be periodically reviewed and changed as required.

(d) AC corrosion monitoring and mitigations systems shall be checked to confirm that the pipeline is not exposed to an enhanced stray current corrosion risk.

(e) Suitable procedures can be found in BS EN ISO 15589-1. The following minimum routines shall be considered:

(i) for sacrificial anode systems, pipe/soil potentials at representative points and points of low protection should be checked at 6 monthly intervals. For impressed current systems, a status check should be made monthly where there is just one T/R unit or three monthly where there are a number of T/R units to establish that the CP system power source(s) are functioning within limits that have previously been shown to give the required levels of protection throughout the system. Checks should also be made on the integrity and accessibility of the means of electrical isolation.

(ii) pipe/soil potentials should be measured, and surface components examined to a schedule such that, in general, all points considered to be critical to the effectiveness of the system are checked annually.

(iii) after the commissioning period, and where practicable, a CIPS and DCVG survey should be carried out over the total length of the pipeline at a risk based frequency determined by the pipeline system and its performance. The CIPS frequency should not exceed the ILI frequency. Ideally CIP surveys should be conducted at the midpoint between in-line inspections.

(iv) crossing points with other cathodically protected structures (whether bonded or not) and any other interference bonds, should be tested at the frequencies identified in BS EN ISO 15589-1 to ensure that no adverse changes have occurred.

Note: Guidance on the management of AC corrosion is given in UKOPA/GPG/027, and on the management of DC corrosion in UKOPA/GPG/031.

12.8.5.2 *Inspection of above-ground components of the pipeline system*

(a) Exposed pipe shall be inspected for areas where undue corrosion might occur, for example any fabrication where there are crevices open to the atmosphere, or areas of metal where painting is made difficult due to the design of the structure. Particular attention shall be paid to pipe corrosion hidden by supports.

(b) The paint coating system on atmospherically exposed pipe shall be examined on a planned and regular basis and rectified as necessary in an approved manner.

(c) Special attention shall be given to the areas of the structure which are covered with lagging and which may, therefore, be subject to an additionally corrosive environment.

(d) Special consideration shall also be given to the condition of any electrical insulation where deterioration could adversely affect the CP system.

12.8.5.3 *Corrosion protection of sleeves*

(a) Schedules for pipeline inspection shall include appropriate checks on sleeves and attachments, for example resistive bonds.

Note: Information on sleeve/carrier pipe eccentricity can be gained from suitable carrier pipe internal inspection vehicles.

(b) Pipelines designed, constructed and maintained to either Edition 1 or Edition 2 of IGE/TD/1 may have sleeves that were constructed to give additional protection either to the public, or to the pipeline, from third party activities. These sleeves were built to either Class 1, 2 or 3 standards and shall be maintained depending upon their type.

For NG pipelines designed to IGE/TD/1 Editions 1 and 2, the following sleeve classifications were used:

- Class 1 - Sleeves required to protect the public, or judged desirable to protect some other installation, from the consequences of failure of the carrier pipe. They also serve to protect the carrier pipe from outside interference.
- Class 2 - Sleeves provided in order to protect the carrier pipe from outside interference.
- Class 3 - Sleeves installed only to facilitate the construction of the carrier pipe.

Note: Audits are carried out periodically to reaffirm the MOP and the edition of IGEM/TD/1 to which a pipeline operates (see clause 12.4.2.1). Sleeve classifications may be re-designated as part of these surveys.

(c) Pipelines designed, constructed and maintained to IGE/TD/1 Edition 3 or Edition 4 may have sleeves built to provide protection to the carrier pipe. Where these sleeves are steel, they should be maintained depending upon their type.

Note: Guidance on corrosion management in sleeves is given in UKOPA/GPG/005.

(d) The carrier pipe shall always be cathodically protected, even if, as a result, the sleeve potential fails below the protection criteria.

Note: Lack of sleeve protection is an acceptable risk when corrosion of the carrier pipe would be the unacceptable alternative.

(e) All Class 1 sleeves shall be cathodically protected. Nitrogen-filled Class 2 and Class 3 sleeves shall also be cathodically protected, to prevent loss of nitrogen through corrosion damage and the consequent loss of protection to the carrier pipe within the sleeve.

(f) Unprotected Class 2 and Class 3 sleeves shall be maintained in a condition that does not affect adversely the CP system of the carrier pipe.

(g) All metallic sleeves shall be fitted with test facilities.

(h) For nitrogen-filled sleeves, CP shall be effected from the main carrier pipe protection system, either by virtue of welded/forged end seals or via a direct cable bond surface facility where epoxy grouted end seals are installed.

Note: For either of these situations, the CP system of the pipe and sleeve may be augmented locally where damage to the sleeve coating causes reduction of CP.

(i) Protection of the section of carrier pipe within grouted sleeves will only be effective if the annual space is filled completely with a conductive material, if there is no metallic contact between the sleeve and the carrier pipe and if the carrier pipe is free from significant coating damage.

- Grouted Class 1 sleeves
  - where the annular space between the sleeve and carrier pipe is filled with a conductive material, including normal cementitious grouting materials, the external surface of the sleeve may be protected by the main carrier pipe CP system. The use of separate CP on the sleeve should be avoided since accelerated corrosion of the carrier pipe can result
  - CP of the external surface of the sleeve may occur, due to the interception of current from the carrier pipe CP system. Where measurements of sleeve to soil potential indicate that protection does not occur by interception, a resistive device should be fitted between the carrier pipe and sleeve
  - the resistive device should ensure that the current drained provides a sleeve to soil polarised potential in the range –0.85 V to –0.95 V vs $Cu/CuSO_4$. However, the carrier pipe to soil polarised potential should be at least 0.1 V more negative than the sleeve to soil polarised potential
  - consideration shall be given to protecting the resistive device from electrical surges. When the CP system has stabilised, both the pipe to soil and sleeve to soil "ON", potentials should be recorded, for use as a basis for comparison in future monitoring routines.

- Grouted Class 2 and Class 3 sleeves

  Although there is no requirement to cathodically protect grouted sleeves in these categories, they shall be constructed and maintained in a condition that does not adversely affect CP of the carrier pipe.

  Note: Further guidance is given in UKOPA/GPG/005.

12.8.5.4 *Pipeline coatings*

A comparison of the predicted and actual performance of the pipeline coating shall form part of pipeline audits (see clause 12.4.2.1).

Consideration shall be given to the actual performance of the coating under stress corrosion cracking conditions.

In assessing the susceptibility to SCC, account shall be taken of the types of coating used on the body of the pipe and at field welds and their influence on SCC of the pipeline.

Where a pipeline coating is susceptible to disbondment, for example coal tar or polyethylene (PE) tape wrapping, and CP shielding, and the pipeline operation involves stress cycling and temperatures greater than 30°C, any indicated areas of disbonded coating shall be investigated for the possible initiation of stress corrosion cracking or bacterial induced corrosion and general corrosion under disbonded coating.

12.9 MAINTENANCE

An effective system of preventative maintenance shall be instituted on pipelines and associated equipment. In preparing maintenance schedules, due account shall be taken of the latest information on equipment faults and other defects and their frequencies. Maintenance schedules shall be updated in the light of the latest information on asset performance. Asset defects shall be rectified as soon as possible.

Note: The following outlines the maintenance of pipelines and associated equipment.

12.9.1 Pipelines and associated equipment

12.9.1.1 *Aerial markers and pipeline marker posts*

Aerial markers and pipeline marker posts shall be maintained to ensure that they are visible. The information contained thereon shall be verified, updated and checked for legibility.

12.9.1.2 *CP systems*

Maintenance of CP systems shall be carried out in accordance with clause 12.8.5.

12.9.1.3 *Nitrogen-filled steel sleeves*

(a) The frequency of pressure checks on nitrogen-filled sleeves shall be set by a risk-based approach in accordance with clause 12.8.4. If this is not practicable, the pressure shall be recorded annually. If the pressure decreases, then more frequent visits may be required. Remote monitoring may be used to record the nitrogen pressure.

(b) If a serious loss of fill pressure is sustained, investigation shall be made as to its cause. In the event of the leakage being from the sleeve pipe or attachments, necessary repairs shall be carried out. If the leak is from a flexible end-seal and satisfactory sealing is not practicable, consideration shall be given to replacing the end-seal with a rigid end-seal or fully grouting the sleeve.

A check for electrical shorts should be carried out and any identified shorts remedied prior to grouting.

(c) In the event of a marked increase in fill pressure, it shall be assumed that a leakage exists in the carrier pipe and action taken accordingly. Chemical analysis of the fill gas shall be carried out at the first step in determining the cause of the pressure increase.

(d) Where vents have been fitted, the frequency of checks of the pressure relieving device should be set by a risk-based approach in accordance with clause 12.8.4. If this is not practicable, checks should be carried out annually. Remote monitoring may be used to record the nitrogen pressure.

12.9.1.4 *Grouted steel sleeves*

(a) For cementitious and other fills, a visual inspection of the end-seals and annular fill shall be made, if the opportunity arises.

(b) In the event of an electrical short being confirmed, it shall be considered that the carrier pipe is not protected. In such cases, the electrical short should be removed. If this is impractical, the sleeve may be fitted with end-seals, so that annular voids can be nitrogen-filled. However, where such nitrogen-filling is considered not to provide corrosion protection throughout the sleeve length due to the nature of the annular fill, replacement of the sleeved section may be required.

12.9.2 **Valves**

12.9.2.1 The frequency of valve maintenance and operation should be set by a risk-based approach in accordance with clause 12.8.4. If this is not practicable, valves should be maintained, operated fully and their seals proved at least annually.

In maintenance operations involving the movement of a valve, due regard shall be given to the monitoring of pressures on both sides of the valve.

12.9.2.2 In the exceptional circumstance where the system does not allow for complete valve closure, the valve shall be moved off the seat and closed partially. Due account shall be taken of the permissible pressure drop across the valve.

12.9.2.3 Where possible, valve body vents should be installed with the vent valve located immediately off the valve.

Note: For buried valves, an extension may be fitted at ground level and a further valve fitted where it may be operated safely.

12.9.2.4 Special consideration shall be given to the maintenance of valves which are normally-closed for operational purposes.

12.9.2.5 Unless adequate precautions have been taken against corrosion, maintenance schedules shall include a visual inspection of the valve body, accessible moving parts and associated pipework.

Visual inspection of the valve body should include small bore vent and sealant lines, with particular attention to locations where these may be prone to corrosion, e.g., where they are clipped to the valve body.

12.9.2.6 Where valves are located in unfavourable conditions, such as in valve chambers subject to flooding or general dampness, consideration shall be given to increasing the maintenance frequencies to take account of these conditions.

12.9.2.7 Covers on valve chambers shall be maintained, to ensure that they can quickly be removed.

Checks shall be made to ensure that there is no gas build up in valve chambers.

12.9.3 Valve actuators

12.9.3.1 The frequency of maintaining and proving all actuators should be set by a risk-based approach in accordance with clause 12.2.4. If this is not practicable, actuators should be maintained and proved at least annually. For remotely operated valves, reference should be made to clause 12.9.4.3.

12.9.3.2 Inspection and maintenance of electrically-operated actuators shall ensure that the installation is electrically sound. Electrical inspection and maintenance shall be carried out in accordance with BS 7671.

12.9.3.3 For gas storage cylinders not connected to the pipeline, the bottle pressures shall be recorded and topped up, as necessary, at intervals of not more than monthly.

12.9.3.4 The maintenance schedule shall include for any statutory requirements for testing/revalidation of pressure vessels associated with valve actuators.

12.9.4 Remotely operated valves and pipeline protection devices

12.9.4.1 Remotely operated valves shall be maintained in accordance with clause 12.9.3. In considering a schedule of maintenance operations, account shall be taken of the need to test the equipment by remote operation or by simulating line-break conditions. For remotely operated block valves, an inspection and testing schedule should be carried out at a frequency set by a risk-based approach in accordance with clause 12.8.4. If this is not practicable, they should be inspected and tested annually.

12.9.4.2 Operations involving the closure of block valves by remote operations and by simulation techniques shall be a co-ordinated exercise with all relevant parties, for example control room, operators of other parts of the system, etc.

12.9.4.3 The cyber security risk posed by existing remotely operated valves shall be assessed, and controls introduced to manage the risks.

12.9.5 Pipework, pig traps and equipment

Pipework shall be visually examined to assess:

- paint condition
- any evidence of corrosion
- condition at the air to soil interface
- mechanical damage
- any evidence of leakage
- any evidence of displacement
- condition of supports.

Where necessary, insulation should be removed to assess the condition of paint/coating and any evidence of corrosion.

12.9.5.1 Maintenance of all components of pig traps, including end closure seals, bleed locks, electrical bonds, locking rings, pig signallers and fasteners, shall be undertaken just prior to use, after painting and at a frequency set by a risk-based approach in accordance with clause 12.8.4.

If it is not practicable to use a risk-based approach, maintenance shall be carried out at least every 10 years.

12.9.5.2 In addition to clause 12.9.5.1, temporary or removable pig traps shall be inspected before use for any mechanical damage due to handling.

12.9.5.3 A record shall be kept of the pressure cycles sustained by pig traps, including portable pig traps.

12.9.5.4 Maintenance of equipment associated with the pipeline and installations shall be carried out in accordance with the manufacturer's instructions, or a frequency set by a risk-based or reliability approach.

12.9.6 Land and buildings

12.9.6.1 The maintenance of sites shall include any buildings, access roads, drains and cable ducts. Attention shall be paid to the provision, location and maintenance of fire-fighting equipment, in accordance with statutory requirements.

12.9.6.2 Attention shall be paid to the condition of fences, all components affecting safe access and egress, including all gates and locks, hedgerows and ditches, weed control, grass cutting and general control of vegetation.

12.10 NON-ROUTINE ACTIVITIES

12.10.1 Isolation

12.10.1.1 The isolation of a pipeline, or part of a pipeline, shall be carried out to ensure that the appropriate level of safe isolation from all sources of danger is achieved. The risks of any uncontrolled release of gas shall be reduced to a minimum.

12.10.1.2 Attention shall be paid to the disconnection and isolation of associated electrical and gas power sources, instrumentation and control equipment, CP systems, etc. Power gas storage systems shall be depressurised. Attention shall also be given to drains, valve body cavities, instrumentation piping and "dead legs" in pipework systems.

12.10.1.3 Procedures shall be established for pipeline isolation using techniques outlined in HSG253.

12.10.1.4 When deciding on the isolation method, the following constraints shall be taken into account:

- the requirement to keep the rest of the pipeline system operating while working on an isolated section
- the requirement to remove safely flammable gas, vapours and other fluids
- the duration of the work activity
- the need for "redundancy" in the isolation system
- the effect on pipeline materials.

12.10.1.5 Isolation procedures shall:

- consider all reasonably foreseeable risks
- take into account the nature of the work to be undertaken, for example hot tapping, dismantling, etc.
- ensure that the level of isolation is satisfactory and secure, for example, physical disconnection, double block and bleed, locking of valves (especially those which are remotely operable), etc. The aim should be to achieve as a minimum a double block and bleed isolation. Main line block valves may have bypass schemes around them to allow pressure equalisation, maintain pipeline flow during main valve isolation, etc. When a main line valve is used for isolation, the bypass shall be shut down and a comparable standard of isolation (i.e., double block and bleed isolation) applied
- specify the requirements for testing and proving the adequacy of the isolation
- specify monitoring arrangements
- require that valves and other plant be identified properly and labelled
- specify suitable means of communication, especially between work sites and control centres
- reference the permit to work system and other procedures, for example hot work certificates.

12.10.1.6 Procedures shall be used to return the pipeline to its original safe condition on completion of works. Special attention shall be given to ensuring that the work activity has been carried out and completed satisfactorily.

12.10.2 **De-commissioning and re-commissioning**

12.10.2.1 *General*

A detailed programme of works and procedures shall be prepared and followed for all pipeline de-commissioning and re-commissioning operations. Purging shall be carried out in accordance with IGE/SR/22.

12.10.2.2 *De-commissioning*

Pipelines and/or pipeline sections that are to be taken out of service for modification works, maintenance or repair shall be de-commissioned to remove gas and other hazardous substances.

The pipes shall be cleared and purged of flammable gases, vapours and residues. Reference should be made to IGE/SR/23 when gas is to be vented.

Pipeline surveillance shall continue to be applied after a pipeline is taken temporarily out of service. The CP system shall be maintained.

Consideration shall be given to de-commissioning pipelines and pipeline sections that may not be used to flow gas for an extended period of time.

12.10.2.3 *Re-commissioning*

Prior to re-commissioning any pipeline or pipeline section, particularly those that have been de-commissioned for extended periods of time, measures shall be taken to establish the integrity of the pipeline to ensure that it continues to be fit for its intended purpose.

For any pipeline that has been de-commissioned for modifications or other work activities, all work shall be verified as having been completed and correctly executed prior to re-commissioning. Special attention shall be paid to NDT results and integrity of the pipeline prior to any pressure testing or the introduction of gas. During re-commissioning, the rate of fill shall be controlled and the pressure not allowed to exceed permitted limits.

Leakage checks shall be carried out periodically during the filling and pressurisation process. Pipeline external coating integrity and CP effectiveness shall be established according to the requirements of clause 12.8.5.

12.10.3 In-line inspection

12.10.3.1 An assessment of the pipeline shall be undertaken by the examination of records and as-laid information, plus site visits and site inspections, to confirm that the pipeline is piggable. Items that should be checked include the radius of bends, the length of the pig trap oversize pipework, the offtake tee sizes and configurations and whether offtake tees greater than 50% of the mainline diameter are fitted with guide bars of adequate design and construction.

Note: Guide bar requirements can vary, e.g., depending on pig design, branch orientation and gas flows. Requirements for new construction are given in clause 6.14.5 and for new under-pressure connections in clause 12.10.5.2.

12.10.3.2 Launch and receive facilities shall be built or modified to ensure that they will accept the pigs which it is proposed to run. All other pipeline equipment shall be modified as necessary, to ensure the free passage of the pigs.

Note: Launch and receive arrangements suitable for in-line inspection are identified in Sub-Section 6.14.

12.10.3.3 The design and manufacture of the pigs shall be to an appropriate standard for the anticipated pipeline operational conditions and the pipe configurations, to avoid damage to the pipeline or the pig. Where considered necessary, the pig shall be designed such that it will allow the passage of gas in the event of it becoming jammed.

12.10.3.4 The design of metal-bodied pigs shall include a means of dissipating any build-up of static charge.

12.10.3.5 Where practical, pigs should be designed to be equipped with a location device.

12.10.3.6 A detailed programme of works and procedures shall be prepared and followed for all in-line inspection operations. Reference should be made to Appendix 7 for further information.

12.10.4 Pipeline damage and repair

Whenever a pipeline is found to be defective or damaged, precautions shall be taken to afford protection to employees, contracted personnel and members of the public as outlined in clause 12.2.3.

12.10.4.1 *Damage types*

When a pipeline defect is found, the type of damage shall be identified.

Note: In general, pipeline damage is of one of the following types:

- *damage caused mechanically by interference which may involve a combination of loss of wall thickness, cracking, spalling, gouging, and denting*
- *cracking caused by stress corrosion or fatigue*
- *general loss of wall thickness by corrosion*
- *damage caused by ground movement which may involve a combination of buckling, denting and cracking*
- *damage caused to protective coating only which will require repair accordance with the procedures set out in clause 10.3.2.2.*

12.10.4.2 *Pipeline damage inspection and repair procedures*

Suitable procedures shall be prepared for the safe inspection, categorisation and repair of damaged or defective pipelines. Specialist advice should be sought when drawing up the procedures.

The procedures shall identify an appropriate number of damaged categories. The definition of each category shall give a clear indication of the level of severity.

For each type of damage considered by the procedures, guidance shall be given on how to allocate a damage category based on actual damage size and required pipeline design and operating conditions.

Based on the damage category, the procedures shall identify safe working practices and appropriate repair methods. The procedures shall identify any subsequent operational restriction which may be caused by a particular repair method.

12.10.4.3 *Safety in incidents where a gas escape is not involved*

Whenever the pipeline is suspected of having been damaged or has become defective, the pressure shall not be allowed to rise above the level at the time the defect was found or first suspected.

Before excavation on the suspected damage or defect, the operating pressure shall be reduced to 85% of the level above.

Note: *Depending on the severity of the damage, and by reference to the procedures defined under clause 12.10.4.2, it may be necessary to reduce the pressure further.*

12.10.4.4 *Safety in incidents where a gas escape is involved*

Careful consideration of the risks associated with pipeline gas escapes shall be undertaken before working on any such escape.

Where a defect or damage is combined with loss of gas, the safety precautions in clause 12.8.4.3 shall be implemented, as a minimum. Further actions shall be regulated by the particular circumstances of the incident. The requirements in clause 12.2.3.7 shall be applied.

Note: *Where the gas pressure, volume of leaking gas, geometry and location of the pipeline allow, a temporary repair may be made by the application of a suitable leak clamp.*

12.10.4.5 *Repair method*

A temporary repair shall maintain the pipeline in a safe condition until a permanent repair can be effected.

Note: *It may also be necessary to reduce the operating pressure of the pipeline until it can be repaired.*

A permanent repair shall ensure the restoration of the damaged section of pipeline to the standard of the original undamaged pipe.

Note: *This may be by replacing the damaged section with a new piece of pipe or installing a shell or other suitable proprietary repair system. Expert assessment may allow minor damage to be repaired by dressing out.*

The method of repair shall be selected with reference to the procedures outlined in clause 12.10.4.2, the type and category of damage, the operating conditions of the pipeline and any requirements to maintain gas supply.

12.10.5 Under-pressure connections, hot taps and stoppling

12.10.5.1 *General*

A detailed programme of works and procedures shall be prepared and followed for all hot tap and stopple operations, in addition to those required under clause 12.2.3.7.

Where a new section of pipeline is to be tied into an existing pipeline, the assessment of the acceptability of the design of the tie-in arrangement and the temporary works arrangement at all stages (including temporary pipework, excavation, equipment loading and pipeline support) shall be included in the design and appraisal for the new pipeline section.

Note: The design may consider alternative tie-in options to reduce construction risks i.e., avoiding under-pressure drilling and stoppling operations.

Mechanical and operational matters will affect the selection of an optimum type of under pressure connection, generally either a welded or grouted encirclement tee. Determination of the optimum connection type should consider the mitigation of operational disruption, standard methods for safe and efficient installation, operational integrity, and the required service life.

12.10.5.2 *Materials and equipment*

The materials, design and construction of hot tap and stopple connections shall be in accordance with appropriate standards, taking into account the design criteria of the pipeline. Care shall be taken to ensure that the equipment is suitable for the operating conditions, i.e., pressure and temperature, the product in the pipeline, the pipe diameter, wall thickness and material.

Where a branch connection diameter exceeds 25 % of the pipeline diameter and is to be included in a pipeline to remain piggable, the connection shall include provision for the setting of a suitable plug incorporating either guide bars or the original pipe coupon.

Design and construction requirements for any guide bar assembly shall be suitable for the required duty.

Critical dimensions shall be maintained during the alignment and mating of under-pressure tees with associated tapping equipment and stoppling equipment. Required tolerances between load bearing members shall be achieved in order to obtain a safe and securely set stopple plugging head.

Note: The alignment and mating of under-pressure tees with associated tapping equipment and stoppling equipment is essential to ensure successful operations, particularly at high pressures.

12.10.5.3 Where a stopple and bypass arrangement is used to tie in a new section of pipeline to an existing pipeline, assessment of the acceptability of the design of the bypass pipework and the temporary works arrangement (including equipment loading and pipeline support) shall be included in the design and appraisal for the new pipeline section.

12.10.5.4 *Preparations and considerations*

Depending on the reason for the stopple operation, the number of positions requiring provision for stopple plugs should be determined. Vertical positioning of stopples and hot taps is preferred, but consideration shall be given to the reduction in ground cover the remaining fittings will incur.

Consideration shall be given to the examination of pipeline welds exposed prior to the stopple operation, to ensure they are adequately sound to meet the stresses resulting from the stopple operation. If defective welds are located by examinations, consideration shall be given to reinforcing the welds by use of appropriate repair methods before any other attachments are made to the pipe.

Pipe wall quality and thickness checks shall be carried out at the point of attachment of the fitting to the pipeline.

Note: Figure 16 shows a typical arrangement for a two-position stopple operation.

Spacings between fittings shall be selected to suit the actual pipeline diameter.

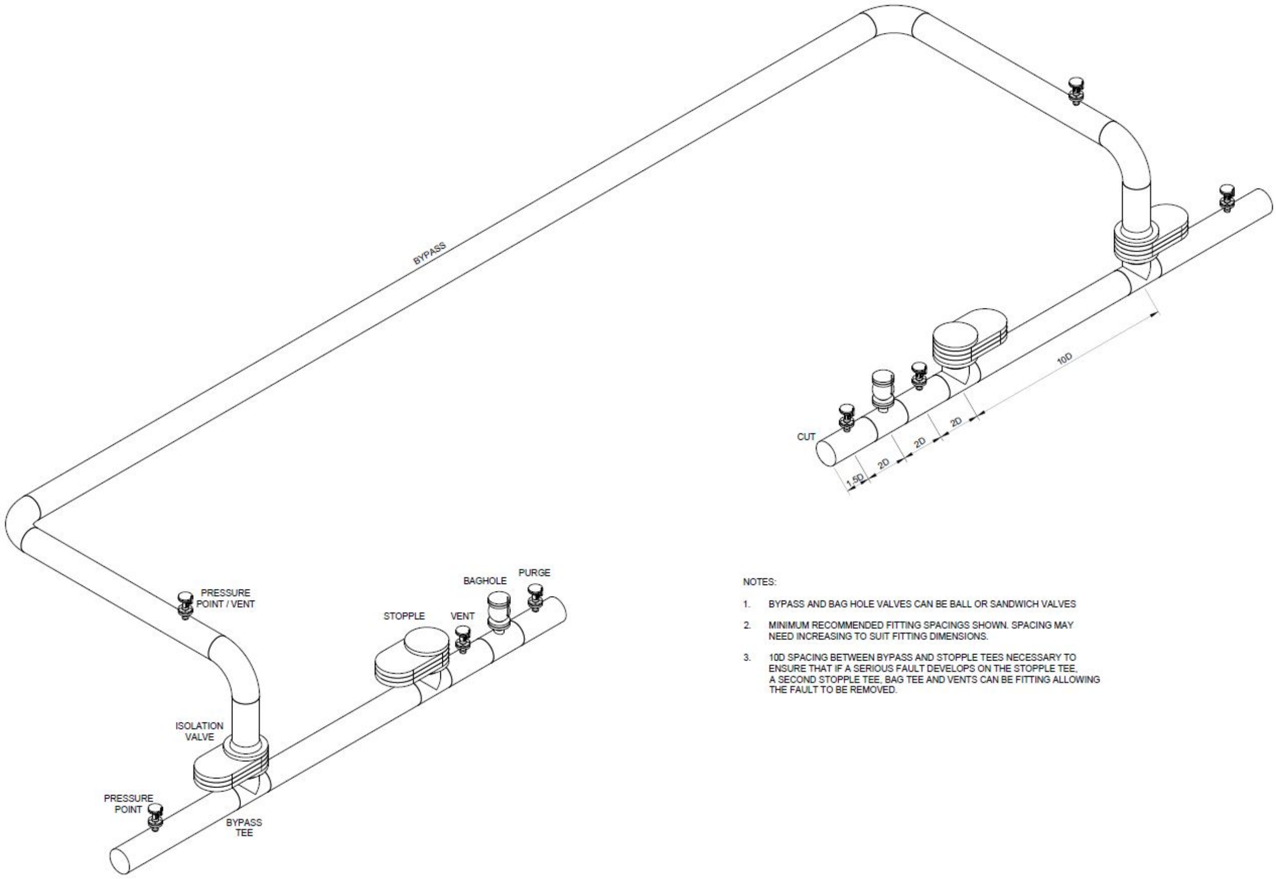


FIGURE 16 - TYPICAL ARRANGEMENT OF A TWO-POSITION STOPPLE WITH BYPASS

12.10.5.5 Excavations for stopple and hot taps shall be substantial, and consideration shall be given to:

- adequate clearance to operate equipment
- easy escape routes
- firm base with provision of a sump for draining
- access to operate equipment.

12.10.5.6 The carrier pipe shall be supported adequately, considering the operation involved.

Note: Attention is drawn to the weight of the drilling and stoppling equipment which can be considerable on large diameters.

12.10.5.7 Welding and weld inspection shall be carried out in accordance with appropriate standards. Consideration shall be given to temperature effects, including the pipe wall ambient temperature, environmental conditions and the effects of cooling due to flowing gas. Where necessary, gas flow requirements shall be specified and pre-heat requirements established to ensure weld cooling rates are controlled. The selection and preparation of the location on the pipeline to accept welded-on fittings shall also be in accordance with appropriate standards.

12.10.5.8 Where works involve the assembly of a series of fittings onto the pipeline or pipework for stoppling with bypass, the initial fitting locations shall be selected so that alternative locations are available between them.

Note: This will allow a new stopple tee to be installed if the initial stopple fail to seal or any other operational problem occur.

12.10.5.9 Before penetration of the pipeline or pipework, the fitting and equipment shall be pneumatically leak tested at a pressure equivalent to the operating pressure at the time.

12.10.5.10 Where sections of pipeline or pipework are to be removed, installed or permanently de-commissioned, the requirements of clause 12.10.6 shall be observed.

12.10.5.11 Following completion of the stopple operation and removal of the stopple, particular attention shall be given when resealing and installing a flange over the stopple tee. The potential requirement to re-enter a stopple tee should be considered, and an appropriate plug gasket used, and if necessary, a suitable method for testing and venting the cavity applied.

12.10.6 Permanent de-commissioning of pipelines and sections of pipelines

12.10.6.1 *General*

A pipeline or pipeline section that is no longer to be used for the conveyance of gas shall be taken out of service, with all hazardous fluids removed and the following options considered:

- use the asset for another purpose or
- remove the asset or
- leave the asset in-situ but rendered permanently safe.

Note: This may involve removing components, for example valves, and capping open ends so as to leave all sections gas tight.

The following factors shall be taken into account when deciding on the most appropriate option:

- public safety
- environmental protection
- future land use
- legal duties and residual liabilities
- practical difficulties and financial considerations
- maintenance requirements, for example to prevent corrosion of the pipeline leading to pipe wall collapse or becoming a channel for the conveyance of water or gases.

12.10.6.2 *Assets left in situ*

Consideration shall be given to residual liabilities with the owner or operator of the assets, which may remain in perpetuity.

Note: There may be a continuing duty to monitor the condition of the pipeline and a requirement for maintenance or remedial action, for example to ensure that the pipeline route remains safe and without danger as a result of decommissioning.

12.10.6.3 *Taking an asset out of service*

The following steps shall be taken when taking an asset out of service:

- consider dismantling and removal – recommended for all above ground sections but economic considerations may limit this option to short sections of buried pipeline
- clear and purge the pipeline of any flammable gases, vapours or residues
- physically separate from other parts of the system and isolate from all possible sources of gas
- if appropriate, fill remaining pipeline sections with non-hazardous material, for example by grouting, especially large diameter pipelines at road and rail crossings or at other locations sensitive to subsidence.

  Note: Practical and economic considerations may limit this to short sections of buried pipeline.

- where it is not practicable to fill a large diameter pipeline section with grout, charge with an inert gas and seal permanently the vent and fill points. Leakage tests should be carried out and pressures checked periodically and re-charged as necessary.

12.10.6.4 *Identification of permanently de-commissioned buried pipelines left in-situ*

The pipeline or pipeline sections shall be identified by suitable markers.

12.10.6.5 *Records of permanently de-commissioned assets left in-situ*

Records of permanently de-commissioned assets left in-situ shall be maintained.

APPENDIX 1 : GLOSSARY, ACRONYMS, ABBREVIATIONS, UNITS AND SYMBOLS

A1.1 GLOSSARY

For the purposes of this Standard, the following definitions apply. The definitions are included as a general guide to terms used and are related to terms found in British Standards, etc.

All other definitions are given in IGEM/G/4 which is freely available by downloading a printable version from IGEM's website, www.igem.org.uk.

Standard and legacy gas metering arrangements are given in IGEM/G/1 which is freely available with copies of IGEM/TD/1 Edition 6.

case length	The axial distance along the pipeline over which the risk is assessed. A length of 1.6 km will encompass most isolated developments and will provide consistency with area classification procedures.
Class rating	A number indicating the pressure strength of a component. *Note: Class ratings are used in ASME standards. See PN for the equivalent European system.*
dense traffic	Generally means traffic on a high density traffic route. However, where specific constraints apply which creates traffic congestion, consideration needs to be given to defining lower traffic densities which result in the road being at full capacity as dense.
design pressure	The pressure on which design calculations are based. *Note 1: Design pressure is the target MOP.* *Note 2: Design pressure will be greater than or equal to MOP.*
event tree	Provides a systematic way of identifying all of the possible outcomes from a hazardous event. In this case, the initial event for a pipeline would be the release itself. The tree is then used to identify the likelihood of leak/rupture, ignition, the possible types of release, etc.
failure cause	The reason for a pipeline reaching a "limit state". Examples are external interference, external corrosion and growth of defects due to fatigue.
failure mechanism	A potential cause of pipeline failure, for example corrosion, external impact, overpressure etc.
failure probability	The likelihood that one or more failure mechanism will occur.
hazard range	A distance from the pipeline beyond which the risk of injury from the worst credible pipeline failure would be of no concern.
high density traffic routes	High density traffic routes include: • All motorways • All roads that carry a volume of traffic totally, in both directions, 2000 vehicles per hour and above, for periods of at least 10 hours per week. The 10 hours may be spread evenly over the week or may be concentrated into set periods. On dual carriageway roads which carry less than this number, consideration needs to be given to future growth.

	• All dual or multi-track rail routes with an average of more than 4 trains an hour, in either direction, measured over the busiest 8 hour period in any one day.
initial defect size	The maximum size of defect (or the distribution of actual sizes of defects) which could be left in the pipeline following the commissioning hydrotest.
limit state	The state of the pipeline when it no longer satisfies a particular design requirement, see "ultimate limit state" and "serviceability limit state".
loads	The forces acting on a pipeline or other components.
maximum incidental pressure (MIP)	The maximum pressure which a system is permitted to experience under fault conditions, limited by safety devices.
maximum operating pressure (MOP)	The maximum pressure at which a system can be operated under normal conditions.
multi-storey	Containing more than one storey, either above or below ground but not including a basement/cellar.
operating pressure (OP)	The pressure at which the gas system operates under normal conditions.
peak level OP	The maximum pressure permitted under normal conditions.
piggable	Capable of passing a pig.
pressure deviation	The difference between the measured pressure and the set pressure.
pressure regulating system	A control system, the purpose of which is to hold pressure constant or to vary it in a predetermined manner.
probability density function	A function which defines the relationship between the value of a parameter and the probability of occurrence of that value.
proximity distance	Minimum distance permissible between the pipeline and any normally occupied building or traffic route as derived from Figure 5 and 6.
resistance	The ability of a pipeline or other component to withstand the forces acting on it.
sensitive locations	Locations at which it may be difficult for people to escape, or which have concentrations of people who would have difficulty in escaping and/or with an increased sensitivity to thermal radiation. Examples of such developments are hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing, schools, colleges, buildings with five or more storeys, large community and leisure facilities, large open-air gatherings (see IGEM/TD/2).
set pressure	The command value to a pressure regulating system.
societal risk	The relationship between the frequency and number of people in a given population suffering a specified level of harm from the realisation of specific hazards.
steady oscillation	An oscillation, the amplitude, period and wave form of which remain unchanged.
steady state	The final state which a pipeline system attains when the effects of external disturbances have ceased.

structural reliability model	A mathematical or statistical model of a failure mechanism.
ultimate limit state	The state of the pipeline when it can no longer contain the gas it is carrying. This limit state has safety and environmental implications. Examples are leaks and ruptures.

A1.2 ACRONYMS AND ABBREVIATIONS

AC	alternating current
ACCA	alternating current voltage gradient
ACVG	alternating current current attenuation
ACoP	Approved Code of Practice
AGA	American Gas Association
AGI	Above Ground Installation
ALARP	as low as reasonably practicable
AMP	arial marker post
ATEX	Atmospheric Explosibles
BPD	building proximity distance
CAD	Chemical Agents Directive
CBA	cost benefit analysis
CDM	Construction (Design and Management) Regulations
CDT	current drain test
CIPS	close interval potential survey
CNE	combined neutral earth
CONCAWE	Conservation of Clean Air and Water in Europe
COPA	Control of Pollution Act
COSHH	Control of Substances Hazardous to Health Regulations
CP	cathodic protection
DC	direct current
DCVG	direct current voltage gradient
DECC	Department of Energy and Climate Change
DEFRA	Department of Environment, Food and Rural Affairs
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
DTLR	Department of Transport, Local Government and Regions
DWTT	Drop Weight Tear Test
EA	Environment Agency
EC	European Community
ECA	engineering critical assessment
EGIG	European Gas Incident Group
EIA	environmental impact assessment
EPA	Environmental Protection Act
EPM	emergency procedures manual
ES	environmental statement
FBE	fusion bonded epoxy
GB	Great Britain
GPS	global positioning system
GS(M)R	Gas Safety (Management) Regulations
GT	gas transporter
GWUT	guided wave ultrasonic thickness
HDD	horizontal directional drilling
HDPE	high density polyethylene
HMSO	Her Majesty's Stationery Office
HSC	Health and Safety Commission
HSE	Health and Safety Executive
HSWA	Health and Safety at Work etc. Act
IET	Institution of Engineering and Technology
IGEM	Institution of Gas Engineers and Managers
LRUT	long range ultrasonic testing
LUP	land use planning

MAPD	major accident prevention document
MHSWR	Management of Health and Safety at Work Regulations
MIP	maximum incidental pressure
MOP	maximum operating pressure
MP	marker post
NACE	National Association of Corrosion Engineers
NDE	non-destructive examination
NDT	non-destructive testing
NRA	National Rivers Authority
NRSWA	New Roads and Street Works Act
NRV	non-return valve
NTSB	US National Transportation Safety Board
OD	outside diameter
OP	operating pressure
OSGB	Ordnance survey GB
PCA	pipeline construction authorisation
PE	polyethylene
PIMS	pipeline integrity management system
PIV	pipeline isolation valve
PME	protective multiple earth
PN	Pressure Number (Pression Nominale)
PPE	personal protective equipment
PPG	pollution prevention guidelines
PRI	pressure regulating installation
PSR	Pipelines Safety Regulations
PSSR	Pressure Systems Safety Regulations
PUWER	Provision and Use of Work Equipment Regulations
PWHT	post weld heat treatment
QRA	quantified risk assessment
SCC	stress corrosion cracking
SEPA	Scottish Environment Protection Agency
SMTS	specified minimum tensile strength
SMYS	specified minimum yield strength
SPIA	soil pipeline stress analysis
SRA	structural reliability analysis
SSV	slam-shut valve
UK	United Kingdom
UKOPA	United Kingdom Onshore Pipeline Operators Association
UHMWPE	ultra high molecular weight polyethylene

A1.3 UNITS

Am^{-2}	ampere per square metre
barg	bar gauge
cm^2	square centimetre
cpm	chance per million
hr	hour
in	inch
km	kilometre
kV	kilovolt
$kW\ m^{-2}$	kilowatt per square metre
$km\ h^{-1}$	kilometre per hour
M	metre
mbar	millibar
mm	millimetre
mV	millivolts
mm^2	square millimetre
$m\ s^{-1}$	metre per second
N	Newton
$N\ mm^{-2}$	Newton per square millimetre

ppm	part per million
secs	seconds
V	Volt
°	angular degree
˚C	degree Celsius.

A1.4 **SYMBOLS**

∅	diameter
C_1, C_2	constants
d	inside diameter of pipe
D	outside diameter of pipe
D_F	damage fraction
f	design factor
kV	measured impact energy
N and n	number of cycles
t	design thickness of pipe (nominal less under-tolerance)
t_{min}	minimum wall thickness
T	wall thickness
P	design pressure at the relevant design temperature
P/V	pressure/volume
s	SMYS
S	constant amplitude stress range
S_p	cross sectional area of test piece
>	greater than
<	less than
≤	less than or equal to
σ_h	hoop stress due to internal pressure
σ_{eq}	Von Mises (equivalent) stress
σ_c	circumferential stress
σ_n	hoop stress due to internal pressure
σ_L	longitudinal stress
σ_a	through wall component of the longitudinal stress
τ	shear stress
Σ	sum of

APPENDIX 2 : REFERENCES

This Standard is set out against a background of Legislation in force in GB at the time of publication. The devolved administrations for Scotland, Wales and Northern Ireland means that there may be variations to the Legislation described below for each of them and consideration of their particular requirements is required to be made. Similar considerations are likely to apply in other countries where reference to appropriate national Legislation is necessary. The following list is not exhaustive.

All relevant Legislation is required to be complied with and relevant Approved Codes of Practice (ACoPs), official Guidance Notes and referenced codes, standards, etc. are to be taken into account.

Where British Standards, etc. are quoted, equivalent national or international standards, etc. equally may be appropriate.

Care is to be taken to ensure that the latest editions of the relevant documents are used.

A2.1 UK LEGISLATION

This Sub-Appendix lists Legislation referred to in this Standard, as well as some Legislation not referred to, but which may be applicable.

A2.1.1 Acts

- Ancient Monument and Archaeological Areas Act 1979
- Animal Health Act 2002
- Control of Pollution Act 1974
- Deer (Scotland) Act 1996
- Environment Act 1995
- Environmental Protection Act 1990
- Forestry Act 1991
- Gas Act 1986 and 1995, as amended
- Health and Safety at Work etc. Act 1974
- Local Government Act 2010, as amended
- Local Government in Scotland Acts 1973, 1975, 1994 and 2003
- New Roads and Street Works Act 1991
- Noise and Statutory Nuisance Act 1993
- Pipe-lines Act 1962
- Pollution Prevention and Control Act 1999
- Protection of Badgers Act 1992
- Protection of Wild Mammals (Scotland) Act 2002
- Town and Country Planning Act 1990
- Town and Country Planning Act (Scotland) 1997
- Transport Act 2000, as amended
- Water Resources Acts 1963 and 1991
- Water Resources (Scotland) Acts 2013
- Wildlife and Countryside Act 1991 as amended
- Wild Mammals (Protection) Act 1996.

A2.1.2 Regulations and Orders

- Borehole Sites and Operations Regulations 1995
- Conservation (Natural Habitats etc.) Regulations (Northern Ireland) 1995, as amended
- Construction (Design and Management) Regulations 2015
- Construction (Health, Safety and Welfare) Regulations 1996
- The Control of Noise at Work Regulations 2005, as amended
- Control of Substances Hazardous to Health Regulations 2002, as amended
- Dangerous Substances and Explosive Atmospheres Regulations 2002
- Electricity at Work Regulations 1989, as amended
- Foot and Mouth Disease Order 2006, as amended
- Gas Safety (Management) Regulations 1996 (and Guidance L80)
- Health and Safety Information for Employees (Amendment) Regulations 2009
- Health and Safety (Safety Signs and Signals) Regulations 1996
- Hedgerows Regulations 1997
- Ionising Radiation Regulations 2017, as amended
- Management of Health and Safety at Work (Amendment) Regulations 1994 (and ACoP L21)
- Manual Handling Operations Regulations 1992
- Noise at Work Regulations 1989, as amended
- Personal Protective Equipment at Work Regulations 1992, as amended
- Pipelines Safety (Amendment) Regulations 2003 (and Guidance L82)
- Pipeline Works (Environmental Impact Assessment) Regulations 2000
- Pressure Systems Safety Regulations 2000 (and ACoP L122 and Guidance HSR30)
- Provision and Use of Work Equipment Regulations 1998, as amended (and ACoP L22)
- Reporting of Injuries, Disease and Dangerous Occurrences Regulations (RIDDOR) 2013 (and Guidance L73)
- The Gas Transporter Pipe-line Works (Environmental Impact Assessment) (Amendment) Regulations 2007
- The Public Gas Transporter Pipe-line Works (Environmental Impact Assessment) Regulations 1999, as amended
- The Town and Country Planning Act (General Permitted Development) Order 1995, as amended
- Town and Country Planning (Environmental Impact Assessment) (England and Wales) (Amendment) Regulations 2000
- Town and Country Planning Act 1962, 1968, 1971, 1990, 1997.

A2.2 EUROPEAN LEGISLATION

- EC Directive 97/11/EC on assessing effects of projects on the environment
- EC Directive 79/409/EEC on the conservation of birds
- EC Directive 92/43/EEC on the conservation of natural habitats of wild fauna and flora.

A2.3 HSE ACOPs and GUIDANCE

• HSE (website)	Reducing Risks, Protecting People
• HSE (website)	Tolerability of risk from nuclear power stations
• HSE	Risk criteria for land use planning in the vicinity of major hazards
• HSG47	Avoidance of danger from underground services
• HSG48	Reducing error and influencing behaviour
• HSG65	Managing for health and safety
• HSG253	Safe isolation of plant and equipment
• GS4	Safety requirements for pressure testing
• GS6	Avoiding danger from overhead power lines
• INDG 163	Risk assessment
• INDG 178	Written schemes of examination
• INDG 229	Using work equipment safely
• INDG 261	Pressure systems
• INDG 291	Providing and using work equipment safely
• INDG 370	Controlling fire and explosion risks in the workplace
• INDG 453	Reporting accidents and incidents at work.

A2.4 BRITISH STANDARDS (abbreviated titles)

• BS 593	Laboratory thermometers
• BS 1041-4	Temperature measurement
• BS 1377	Methods of test for soils for civil engineering purposes. Consolidation and permeability tests in hydraulic cells and with pore pressure measurement
• BS 1640-1	Steel butt-welding pipe fittings (imperial)
• BS 1640-3	Steel butt-welding pipe fittings (metric)
• BS 2633	Class 1 arc welding of ferritic steel pipework
• BS 3293	Carbon steel pipe flanges (over 24 in nominal size)
• BS 3799	Steel pipe fittings, screwed and socket-welding
• BS 4368	Metallic tube connectors. Split collect compression fittings
• BS 4515-1	Specification for welding of steel pipelines on land and offshore. Carbon and carbon manganese steel pipelines
• BS 5228	Noise and vibration control
• BS 5911	Pre-cast concrete pipes, fittings and ancillary products
• BS 5930	Code of practice for ground investigations
• BS 6031	Code of practice for earthworks
• BS 6990	Welding on steel pipelines containing process fluids or their residuals
• BS 7671	IET Wiring Regulations
• BS 7910	Assessing the acceptability of flaws in metallic structures
• BS 8004	Code of practice for foundations
• BS 9295	Structural design of buries pipes

- BS EN 437 Test gases
- BS EN 837-1,2 Pressure gauges
- BS EN 1127 Explosion prevention and protection
- BS EN 1514 Flanges and their joints
- BS EN 1998-4 Design of structures for earthquake resistance
- BS EN 1594 Pipelines for MOP over 16 bar
- BS EN 1759-1,3 Flanges and their joints
- BS EN 1992-1 Eurocode 2: Design of concrete structures. General rules and rules for buildings
- BS EN 10028 Flat products of steel
- BS EN 10029 Hot-rolled steel plates 3 mm thick or above. Tolerances on dimensions and shape
- BS EN 10045 Charpy impact test on metallic materials
- BS EN 10216 Seamless steel tubes for pressure purposes
- BS EN 10217 Welded steel tubes for pressure purposes
- BS EN 10222 Steel forgings for pressure purposes
- BS EN 10255 Non-alloy steel tubes suitable for welding and threading
- BS EN 12007-1 Gas Infrastructure. Pipelines for maximum operating pressure up to and including 16 bar. General functional recommendations.
- BS EN 12954 Cathodic protection of buried or immersed metallic structures. General principles and application for pipelines
- BS EN 13445 Unfired pressure vessels
- BS EN 13509 Cathodic protection measurement techniques
- BS EN 14161 Petroleum and natural gas industries. Pipeline transportation systems
- BS EN 15257 Cathodic protection. Competence levels and certification of cathodic protection personnel
- BS EN 16348 Gas Infrastructure. Safety Management System (SMS) and Pipeline Integrity Management System (PIMS)
- BS EN 50162 Protection against corrosion by stray current from direct current systems
- BS EN 50443 Effects of electromagnetic interference on pipelines caused by high voltage a.c. electric traction systems and/or high voltage a.c. power supply systems
- BS EN 60079 Electrical apparatus for explosive gas atmospheres
- BS EN ISO 3183:2019 Steel pipe for pipeline transportation systems Annex A PSL 2 pipe ordered for European onshore natural gas transmission pipelines
- BS EN ISO 13588 Use of automated phased array technology
- BS EN ISO 15257 Competence level of cathodic protection persons. Basis for certification scheme
- BS EN ISO 18086 Corrosion of metals and alloys. Determination of AC corrosion. Protection criteria
- BS EN ISO 20601: Use of automated phased array technology for thin-walled steel components

- BS EN ISO 21857-1 Prevention of corrosion on pipeline systems influenced by stray currents. Part 1: DC stray current
- BS ISO 21809-1 Petroleum and natural gas industries. External coatings for buried or submerged pipelines used in pipeline transportation systems. Polyolefin coatings (3-layer PE and 3-layer PP)
- BS ISO 21809-2 Petroleum and natural gas industries. External coatings for buried or submerged pipelines used in pipeline transportation systems. Single layer fusion-bonded epoxy coatings
- BS ISO 21809-3 Petroleum and natural gas industries. External coatings for buried or submerged pipelines used in pipeline transportation systems. Field joint coatings
- BS EN ISO 2813 Paints and varnishes
- BS EN ISO 5167 Measurement of fluid flow
- BS EN ISO 9001 Quality Management Systems
- BS EN ISO 12944 Corrosion protection of steel structures by protective paint systems
- BS EN ISO 16708 Reliability-based limit state methods
- BS ISO 15589-1 Petroleum, petrochemical and natural gas industries. Cathodic protection of pipeline systems. On-land pipelines
- PD 5500 Unfired fusion welded pressure vessels.
- PD 8010-1 Steel pipelines on land
- PD 8010-2 Subsea pipelines.

A2.5 **EUROPEAN STANDARDS (abbreviated titles)**

- prEN17649 Gas Infrastructure - Safety Management System (SMS) and Pipeline Integrity Management System (PIMS) – Functional requirements.

A2.6 **INTERNATIONAL STANDARDS (abbreviated titles)**

- ISO 3419 Non-alloy and alloy steel butt welding
- ISO 3183 Steel pipe for pipeline transportation systems
- ISO 13623 Pipeline transportation systems
- ISO 14313 Pipeline transportation systems. Valves
- ISO 13847 Pipeline transportation systems. Welding
- ISO 15590-1,2,3 Induction bends, fittings and flanges for pipeline transportation systems.

A2.7 OTHER STANDARDS (abbreviated titles)

• AGA 3	Orifice Metering of Natural Gas and other related hydrocarbon fluids
• API 5L	Linepipe
• API 6D	Pipeline and Piping Valves
• API 1163	In-line Inspection Systems Qualification
• ASME VIII-1	Construction of Pressure Vessels
• ANSI/ASME B16.5	Flanges and flange fittings
• ANSI/ASME B16.9	Factory made wrought steel butt/welding fittings
• ANSI/ASME B16.28	Wrought steel butt/welding elbows and returns
• ANSI/ASME B16.47	Large diameter steel flanges
• ANSI/ASME B31.3	Process piping
• ASME B31.8	Gas transmission and distribution piping systems
• ANSI/ASME B31.8S	Managing System Integrity of gas pipelines
• ANSI/ASNT ILI PQ	In Line Inspection Personnel Qualification and Certification Standard
• ASTM A53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
• ASTM A105	Carbon steel forgings for piping applications
• ASTM A106	Seamless carbon steel pipe
• ASTM A234	Piping fittings of wrought carbon steel and alloy steel. High and moderate temperature
• ASTM A312	Austenitic stainless steel pipes
• ASTM A333	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service
• ASTM A420	Piping fittings of wrought carbon steel and alloy steel
• ASTM A671	Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
• ASTM A672	Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
• ASTM A860	Wrought high strength, low alloy steel butt welding fittings
• ASTM E1049	Standard practices for cycle counting in fatigue analysis
• DNVGL-RP-F110	Global buckling of submarine pipelines
• DNVGL-ST-F101	Submarine pipeline systems
• Energy Institute	Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework. 2 ed. 2008
• MSS SP-6	Standard finishes for contact faces of pipe flanges
• MSS SP-44	Steel pipeline flanges
• MSS SP-75	High test wrought butt welding fittings
• NACE SP0102	In-Line Inspection of Pipelines
• NACE SP0204	Stress Corrosion Cracking (SCC) Direct Assessment Methodology
• NACE SP0502	Pipeline External Corrosion Direct Assessment Methodology.

A2.8 MISCELLANEOUS

- EEMUA Publication 224, A guide to risk-based procurement
- GIS/CW6:2020 Guidance on the specification for the external protection of steel line pipe and fittings using fusion bonded powder and other coating systems
- GIS/DAT/6 2019 Guidance on standard sizes of carbon steel and carbon manganese steel for operating pressures greater than 7 bar
- GIS/P16:2020 Guidance on weld ends
- GIS/VA1:2019 Actuators
- GIS/VA2 Actuators
- GIS/V6:2019 Guidance on weld ends
- RR319 HSE Research Report Safer foundations by design
- Pipeline Operators Forum - Specifications and requirements for in-line inspection of pipelines.

A2.9 **IGEM**

- IGEM/TD/1 Supplement 1 Edition 2 — Handling, transport and storage of steel pipe bends and and fittings
- IGEM/TD/2 Edition 2 — Assessing the risks from high pressure Natural Gas pipelines
- IGEM/TD/3 Edition 5 — Steel and PE (polyethylene) pipelines for gas distribution
- IGE/TD/4 Edition 4 — PE and steel gas services and service pipework
- IGE/TD/9 (obsolete) — Offtakes and pressure-regulating installations for inlet pressures between 7 and 100 bar
- IGEM/TD/12 Edition 3 — Pipework stress analysis for gas industry plant
- IGEM/TD/13 Edition 2 — Pressure regulating installations for transmission and distribution systems
- IGEM/GL/5 Edition 3 — Procedures for managing new works, modifications and repairs
- IGEM/SR/18 Edition 3 — Safe working practices to ensure the integrity of gas assets and associated installations
- IGE/SR/22 — Purging operations for fuel gases in transmission, distribution and storage
- IGEM/SR/23 — Venting of Natural Gas
- IGEM/SR/25 Edition 2 — Hazardous area classification of Natural Gas installations
- IGEM/SR/29 Edition 2 — Dealing with gas escapes
- IGEM/G/7 — Risk assessment techniques
- IGEM/GM/4 Edition 3 — Flowmetering practices. Inlet pressure exceeding 38 bar and not exceeding 100 bar
- IGEM/GM/5 Edition 3 — Selection, installation and use of electronic gas meter volume conversion systems

- IGEM/GM/7A Edition 2 — Electrical connections for gas metering equipment
- IGEM/GM/7B Edition 2 — Hazardous area classification for gas metering equipment
- IGEM/GM/8 Parts 1 to 5 Edition 2 — Non-domestic meter installations. Flow rate exceeding 6 $m^3 h^{-1}$ and inlet pressure not exceeding 38 bar.

A2.10 **UKOPA**

- UKOPA/GPG/001 Managing Pipelines with Reduced Depth of Cover
- UKOPA/GPG/003 Pipeline Safety Monitoring
- UKOPA/GPG/004 Managing Pipeline Dents
- UKOPA/GPG/005 Managing Pipeline Sleeves
- UKOPA/GPG/006 Impact Protection Slabs
- UKOPA/GPG/009 Near Neutral pH and High pH Stress Corrosion Cracking
- UKOPA/GPG/010 Major Accident Hazard Pipeline (MAPD) Emergency Response Plan. Guidance on Testing
- UKOPA/GPG/011 Major Accident Hazard Pipeline (MAPD) Emergency Response Plan. Emergency Plan Template
- UKOPA/GPG/012 Major Accident Hazard Pipeline (MAPD) Emergency Response Plan: Testing and Exercising Proforma
- UKOPA/GPG/013 Requirements for the Siting and Installation of Wind Turbines Installations in the Vicinity of Buried Pipelines
- UKOPA/GPG/014 Requirements for the Siting and Installation of Solar Photovoltaic Installations in the Vicinity of Buried Pipelines
- UKOPA/GPG/015 Managing Pipeline Infringements
- UKOPA/GPG/016 Pipeline Hazard Distances
- UKOPA/GPG/017 Line Walking Surveys
- UKOPA/GPG/018 Remaining Life Assessment
- UKOPA/GPG/019 Seismic screening assessment of UK onshore pipelines and associated installations
- UKOPA/GPG/020 Managing pipelines subject to ground movement
- UKOPA/GPG/021 In Line Inspection (ILI)
- UKOPA/GPG/026 Verification of features identified by In Line Inspection
- UKOPA/GPG/027 AC Corrosion Guidelines
- UKOPA/GPG/029 Local Authority Planners information regarding On Shore Pipelines and Associated Installations
- UKOPA/GPG/030 Management of Pipework Vibration
- UKOPA/GPG/031 DC Interference Guidelines
- UKOPA/GPG/032 Seismic Assessment of UK Onshore Pipelines and Associated Installations
- UKOPA/GPG/035 A Guide to Pipeline Process Safety Studies and Methodologies.

APPENDIX 3 : RISK ASSESSMENT TECHNIQUES

A3.1 INTRODUCTION

A3.1.1 This Appendix provides guidance on the techniques and criteria used for the assessment of risk in connection with the evaluation of pipeline safety. Further detail is given in IGEM/TD/2.

The guidance outlines how to assess both the frequency of pipeline failure during service and the harm done to the surrounding population as a result of any failure. Consideration is given to both individual and societal risk together with other factors such as cost benefit analysis and the need, in the UK, to satisfy the principle of ALARP.

A3.1.2 A range of methodologies have been developed to assess the frequency and consequences of gas pipeline failure. Largely, these are company-based and, consequently, their level of sophistication reflects the needs of the company and the information available to the company. Similarly, various methods have been developed to present risk information and these are reflected in the range of acceptance criteria developed.

A3.1.3 The guidance aims to ensure that, whichever methodology and criteria are adopted, the outcome of any assessment will achieve a consistent level of safety. However, the validity of any procedure and methodology adopted needs to be capable of being demonstrated to the relevant statutory body for which a quantified risk assessment (QRA) normally will be required.

A3.1.4 Some assessments are carried out in order to assist management of safety and the discharging of general legal duties. However, most assessments are carried out to satisfy specific requirements of health and safety Legislation and there may be a need for the results to be reviewed by the relevant statutory body. In the latter case, a QRA normally will be required. For this reason, risk criteria data extracted from current HSE publications are incorporated into this appendix for guidance.

A3.2 ASSESSMENT FRAMEWORK

A full risk assessment involves estimation of the frequency and consequences of a range of hazard scenarios and of the individual and societal risk associated with them. Although several different methodologies may be available for each stage of the assessment, each assessment has the following basic steps:

- collect data and define cases to be assessed
- identify all credible failures
- evaluation failure frequencies
- evaluate consequences of failure
- evaluate individual and societal risk
- assess the acceptability/tolerability of the risks
- implement any new mitigation measures required as a result of the assessment
- record and review results.

While these steps are listed in order, there may be significant overlap in their execution. Each of them is described in detail below.

A3.2.1 **Collect data and define case to be assessed**

A3.2.1.1 The first stage of any assessment involves collection of all of the necessary data. Consider the pipeline, the surrounding infrastructure and, in some cases, the local meteorology.

A3.2.1.2 Include in the pipeline data, details of:

- geometry
- operating conditions
- gas properties
- pipeline system behaviour
- time to achieve shutdown
- material properties
- control measures
- any mitigation measures against third party interference, for example slabbing, depth of cover, marker tape, etc.

Also, consider the damage and maintenance history of the pipeline for in-service assessments or, if possible, the histories of similar pipelines for new design.

A3.2.1.3 Include in the infrastructure data, details of:

- location
- occupancy
- pattern of use of all occupied buildings and surroundings within the hazard range of the worst credible failure (see A3.2.2). Data may be needed for consideration of escape from buildings and shelter provided by them. In the UK, sensitive locations (see Appendix 1) need to be identified since these may be subject to more onerous assumptions or criteria.

A3.2.1.4 Collect details of any major road, rail or other traffic flows for the assessment of crossings and in other circumstances where traffic is a necessary consideration.

A3.2.1.5 When needed, include in the meteorological data details of wind strength, direction and atmospheric stability.

A3.2.1.6 Define the extent of the infrastructure and length of pipe to be assessed using the above data.

A3.2.2 **Determine credible failures**

A3.2.2.1 Consider all possible causes and potential modes of failure throughout the life of the pipeline, including but not limited to:

- external damage
- internal and external corrosion
- seam weld defects
- circumferential butt/girth weld defects
- SCC
- fatigue
- ground movement
- material problems
- extreme natural causes – earthquake, flood and lightning
- valve or fitting defect
- operational error

- design error
- construction defect
- combinations of the above.

A3.2.3 **Evaluate failure frequencies**

A3.2.3.1 Address each of these causes in terms of their likelihood of occurrence. Include in the assessment any cause of failure considered credible. Assess the various failure rates after which the contribution to risk will become apparent. Frequencies of occurrence may be obtained from company-specific databases, from published data sources such as UKOPA, EGIG, NTSB or CONCAWE or from models based on damage data and failure behaviour. Whichever source is chosen, take care to ensure that the data used is relevant to the pipeline being assessed and does not lead to an under-estimation of the failure frequency.

Aim to obtain cautious best estimates of the frequency (the greater the uncertainty, the greater the caution which will be required). It may be necessary to adapt the data to allow for higher likelihoods of certain types of failure in some situations. Allowance may be made for mitigation measures (see A3.2.7).

A3.2.3.2 Consider all modes of failure including:

- full bore rupture
- major leaks
- minor leaks
- pin hole leaks.

A3.2.4 **Evaluate consequences of failure**

Consider the nature of the gas release. For example, will the release lead to a vertical plume, a free jet (at what angle) or an impacted jet, and will the gas ignite? The aim is to define an event tree with an overall frequency of occurrence for each failure mode and type of gas release.

A3.2.5 **Estimate individual and societal risk**

This is the most complex stage of the procedure. Consider each credible failure mode and type of gas release identified and the sum estimated risk in the appropriate manner to give overall figures. Take account of the distributed nature of the hazard. For any particular location, this means assessing the effects of failure at a number of positions along the length of pipeline within which failures could affect the infrastructure being considered (interaction length) (see Figure 17). Sum the risk at each position to give an overall distribution. A typical procedure (see Figure 18) is described by the following list of actions:

1. Choose failure mode and type of release
2. Estimate rate of gas release
3. Estimate thermal radiation distribution resulting from gas released and ignited
4. Choose a failure position within the length of pipeline being considered
5. Estimate the effects of radiation on buildings and people and sum risk
6. Repeat steps 4-5 for all failure positions considered.

In the UK, the criteria adopted have to satisfy ALARP and its application will need to take account of:

- simple aversion
- company values
- societal concerns.

A common method of presenting societal risk is by means of an F-N diagram. A schematic example is given in Figure 19. This is a graph of the frequency F (usually per year) of events causing N or more fatalities. Criteria are often set by dividing the domain of the graph into two or more regions. These divisions take the form of a line separating an unacceptable area (high risk) from the area where risks may be tolerated and/or a line defining an envelope within which the risks are sufficiently low as to be considered "negligible" or at least "acceptable". The societal risks calculated for the proposed pipeline are superimposed upon the risk criteria diagram to demonstrate compliance, or to identify the events for which the frequency is to be reduced.

It is essential when using such diagrams that both the criteria and the assessment data are derived using the same methodology and procedure and conform to the same case length.

Figure 19 provides a sample of an actual FN criterion based upon extensive application of previous editions of this Standard, to pipeline systems, for a case length of 1.6 km. The enclosed area defines the envelope within which the risks are sufficiently low as to be considered "negligible" or at least "acceptable". ALARP consideration would, normally, be given to risks which are close to the envelope or outside the envelope.

Where no risk criteria have been defined, compare the predicted risks with risks for pipelines which conform to the design requirements of this Standard and are considered to be of acceptable design. However, the methodology and procedure used to assess risk for the pipeline being assessed has to be the same as the methodology and procedure used to assess the pipelines to which it is being compared.

A3.2.6 **Cost benefit analysis (CBA)**

When the individual risk is assessed to be in the tolerable region and/or the societal risk is outside the acceptable region, carry out a Cost Benefit Analysis (CBA) to evaluate whether the risk is ALARP (see example in A3.2.10). CBA needs to consider the range of mitigation measures available, their costs, and any savings in costs made by the operator as a result of introducing the mitigation measures and a cost for death or injuries.

A3.2.7 **Implementing new mitigation measures**

Implement any risk mitigation measures which are identified as being necessary, as a result of an assessment of proposed changes to pipeline design or operating conditions, before or when the changes to design or operating conditions are made.

Implement any risk mitigation measures identified as being necessary as a result of assessment of changes to the surrounding infrastructure within a reasonable time scale.

In some cases, the risk mitigation measures may have been agreed with, or introduced at the request of, the statutory body.

A3.2.8 **Record and review results**

Produce a report detailing each risk assessment to include all relevant details of the pipeline and surroundings. Retain it for the life of each pipeline. Incorporate a clear plan of all buildings and other relevant infrastructure showing locations of these in relation to the pipeline.
Incorporate reference to all data sources and software used in the assessment and record all failure causes, modes and types of release assessed together with any assumptions made. Results of the assessment need to be stated clearly together with any conclusions and recommendations.

Reaffirm the results of any assessment at regular intervals. Normally, this is carried out as part of the affirmation of MOP (see clause 12.4.2).

A3.2.9 Risk assessment of sleeving

Perform a risk assessment of any sleeve to identify and account for each mechanism which could cause failure of the carrier pipe within the sleeve and identify the consequences of failure.

Failure mechanisms to identify include:

- construction defects
- corrosion
- external interference
- ground movement.

For each mechanism, relevant mitigating factors such as surveillance, CP, maintenance, and condition monitoring should be taken into account, when evaluating the probability of failure.

A3.2.10 Sample individual risk calculation

All persons within the hazard range of a pipeline will be subjected to some level of individual risk.

Suppose that a particular pipeline is predicted to rupture at a frequency of f per km per year and there is a probability of p_i that the gas released will ignite. If a person at a distance y from a rupture in the pipeline has a probability of p_{cy} of becoming a casualty, and this probability can be assumed to be correct for a length of the pipeline dx, their individual risk per year from rupture in this particular length of pipe will be:

$\delta x \ f \ p_i \ p_{cx}$

The overall individual risk, from this failure mode, for someone at this distance from the pipe, is obtained by summing the results of this equation over the length of pipe in which failures will interact with the person (interaction length). The summation takes account of the variation in casualty probability from a maximum value when the failure is at the closest point to the person to zero when the failure is at the interaction limit. It may also need to take account of any changes in failure frequency along the pipeline.

Individual Risk = $\delta x p_i \ [f \ p_{cx})_1 + (f \ p_{cx})_2 + \ldots\ldots\ldots (f \ p_{cx})_I]$

The overall individual risk for all failure modes and types of release will be a summation of the risk resulting from each. By repeating the calculation for a range of distances from the pipeline, it becomes possible to construct a risk transect for the pipeline (see Figure 20).

A3.2.11 Sample cost per life saved calculation

The usual aim of a cost per life saved calculation is to provide information to assist in a judgement on whether possible measures to reduce risk should be taken, or whether the cost of such measures would be grossly disproportionate to the reduction in risk achieved.

Suppose that rupture of a particular section of pipeline is predicted to result in N fatalities at a frequency of f_i per year. A new control measure costing C is proposed and is expected to reduce the frequency of this number of casualties to f_w per year. If the remaining lifetime of the proposed measure is expected to be L years, the inferred cost per life saved will be:

$C\ (LN\ (f_i - f_w))^{-1}$

Note: C could be a one-off cost for the installation of a protective measure such as slabbing or it could be a summation of the cost over the remaining life of the pipeline of an operational measure such as increased surveillance.

Example

Rupture of this particular section of pipeline is predicted to result in 20 fatalities at a frequency of 3 x 10^{-6} per year and 250 m of the pipeline is slabbed at a cost of £200 per metre resulting in a reduction of the frequency to 1 x 10^{-7}. If the remaining life of the pipeline is 40 years and the slabs are expected to remain in place for this time, the inferred cost per life save is:

$10^7(200 \times 250)/[40 \times 20(30 - 1)] = £21.55M$

Because of the distributed nature of the hazard associated with pipelines, it is usual for a pipeline risk assessment to result in a range of casualties at a range of frequencies. Therefore, in general, it is necessary to sum the effect of the control measure over the whole range to obtain an overall figure. In this case, the inferred cost per life saved is:

$C\ (\sum(LN\ (f_i - f_w)_N))^{-1}$.

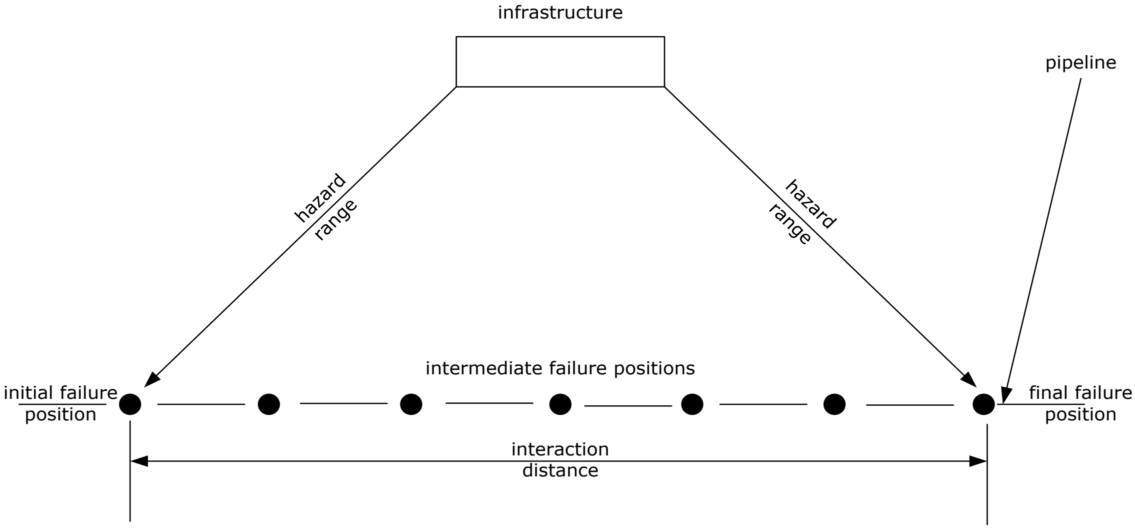


FIGURE 17 – INTERACTION LENGTH

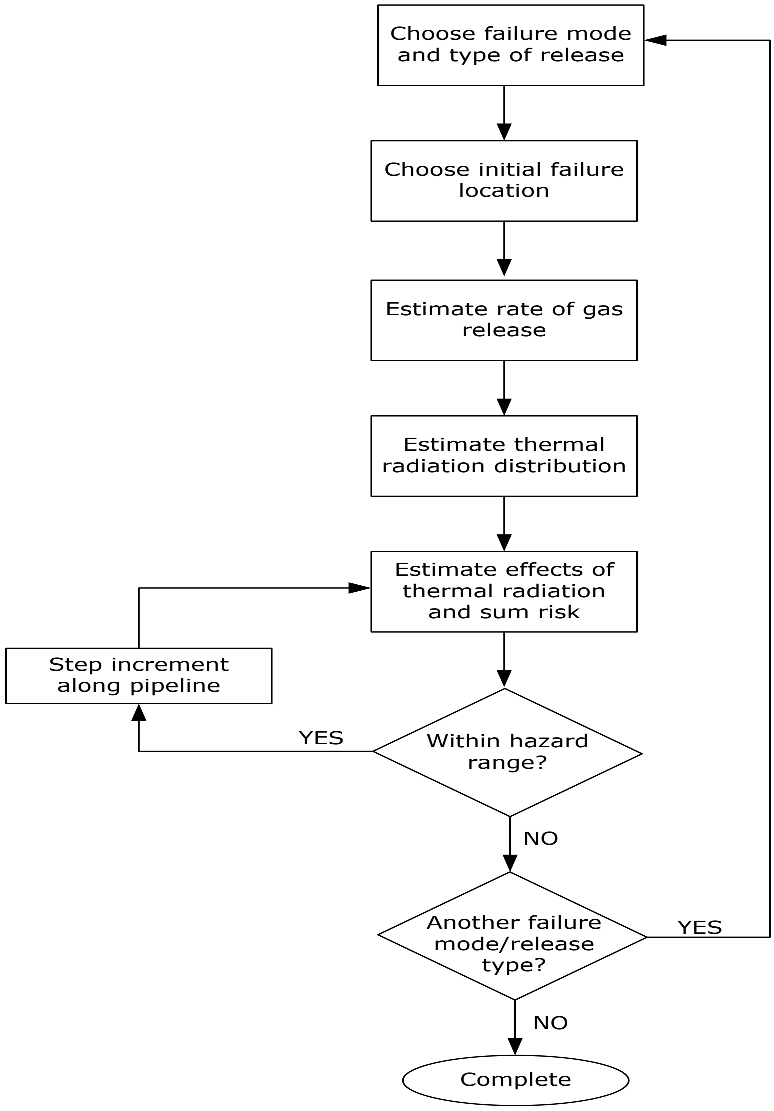


FIGURE 18 – PROCEDURE FOR ESTIMATION OF INDIVIDUAL AND SOCIETAL RISK

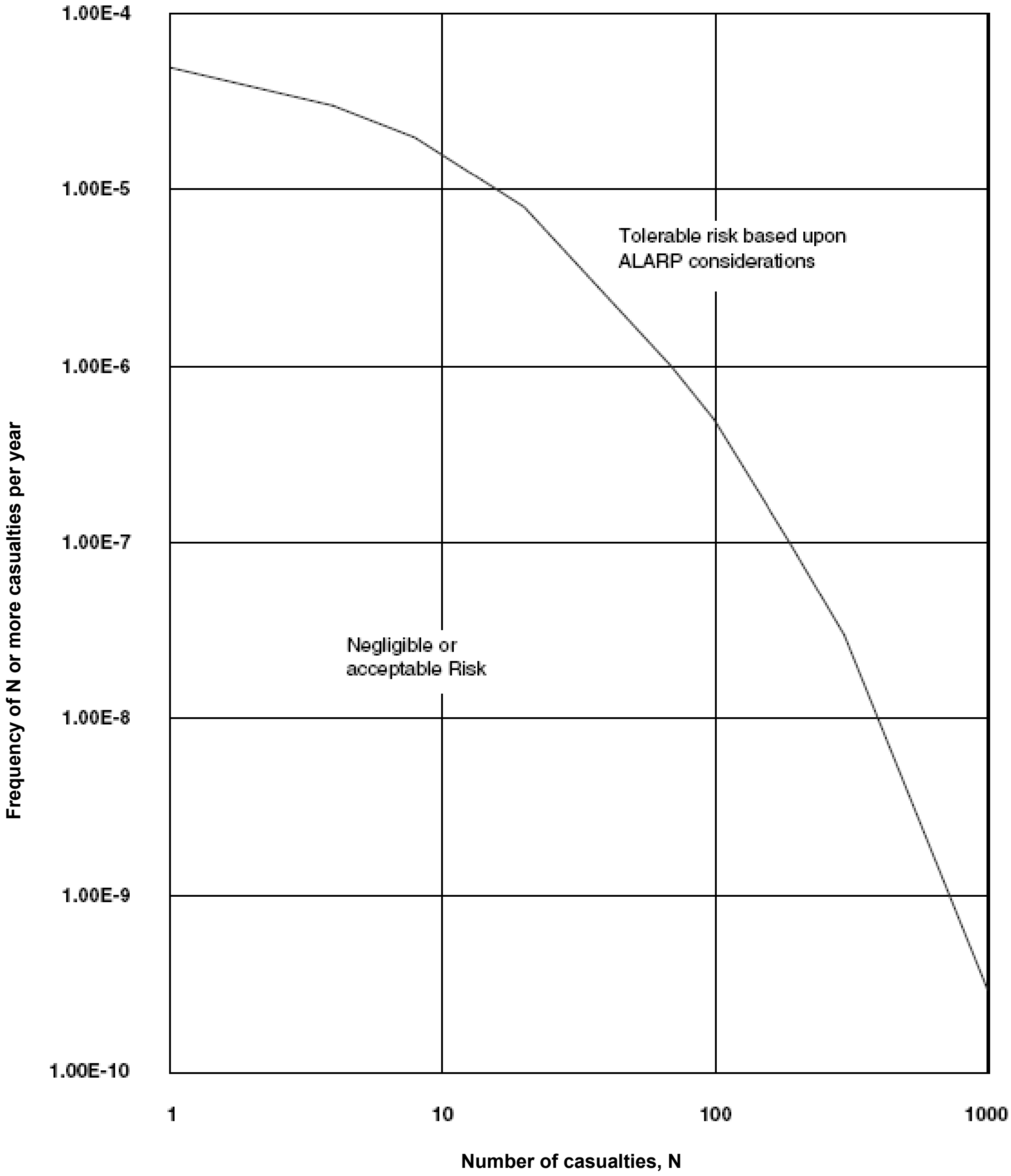


FIGURE 19 - SAMPLE FN CRITERION (BASED ON EXTENSIVE APPLICATION OF PREVIOUS EDITIONS OF IGEM/TD/1)

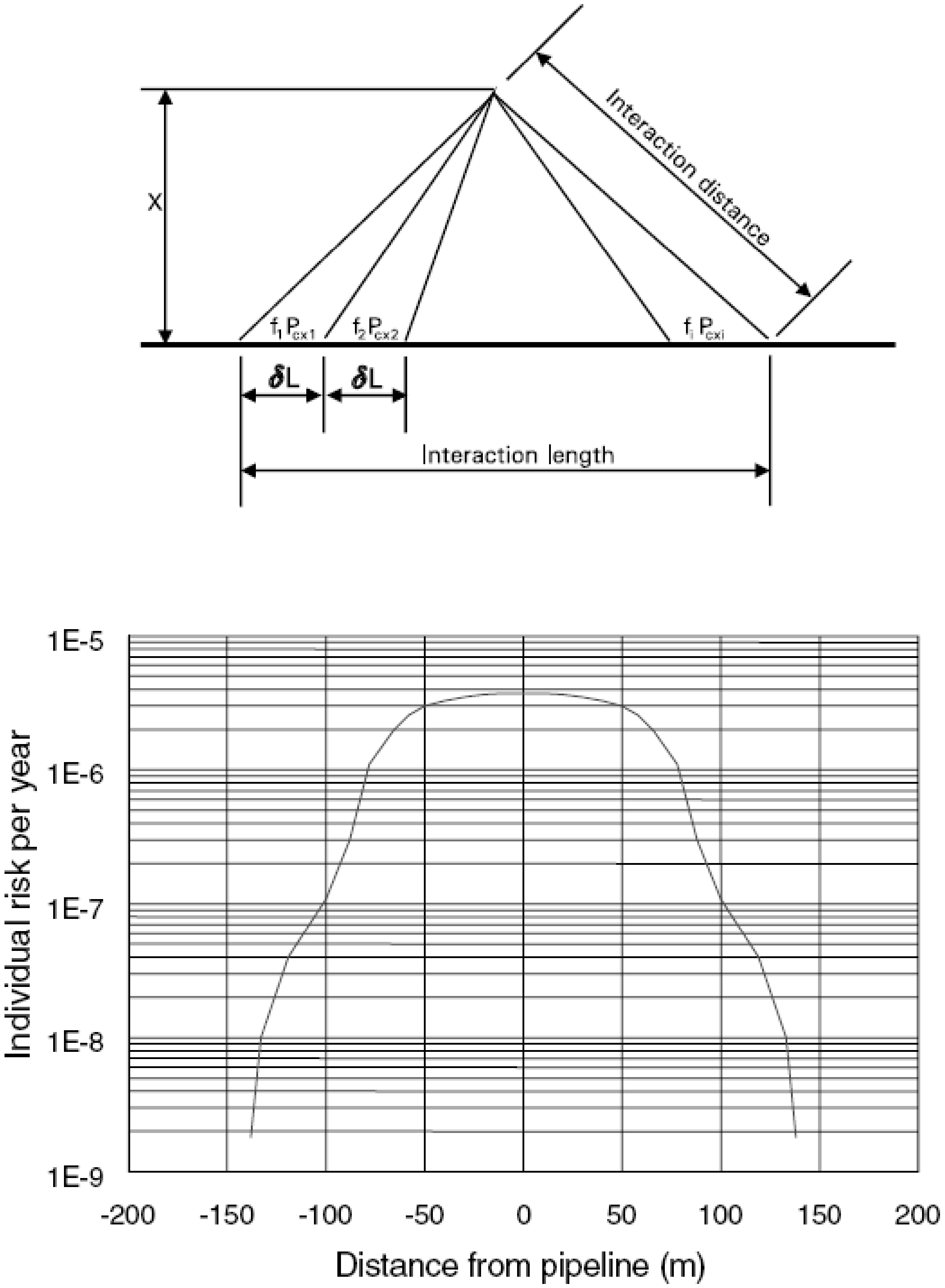


FIGURE 20 - INDIVIDUAL RISK TRANSECT

APPENDIX 4 : STRUCTURAL RELIABILITY ASSESSMENTS (SRAs)

A4.1 GENERAL

This Appendix explains how to assess the possibility and frequency of pipeline failure during service using a Structural Reliability Analysis (SRA) approach consistent with BS EN ISO 16708. The consequences, for example for the surrounding population, as a result of failure, needs to be assessed in terms of individual risk, societal risk and cost benefit analysis. In the UK, this involves satisfying the principle of ALARP. Guidance on risk analysis is provided in Appendix 3.

The SRA approach in this appendix is applicable where it is the intention to operate a pipeline at a design factor exceeding 0.72, but not exceeding 0.80. This design factor is, subsequently, referred to as the "Higher Design Factor".

A4.2 STRUCTURAL RELIABILITY STUDIES

A4.2.1 Study process

A4.2.1.1 The assessment will need to demonstrate that the increase in failure probability of the pipeline as a result of operating at the Higher Design Factor, compared with 0.72, is acceptable. Include the following elements:

- identification of all credible failure mechanism, based on consideration of all the loads the pipeline is likely to see and the ability of the pipeline to resist those loads
- assessment of the proportionate increase in failure probability when operating at the Higher Design Factor rather than 0.72, for each failure mechanism
- assessment of whether the absolute value of failure probability from a particular failure mechanism at the Higher Design Factor is a significant contributor to the overall pipeline failure probability. This applies for each failure mechanism for which the proportionate increase in failure probability is significant.

A4.2.1.2 Significant proportional increases in failure probability, identified for a specific mechanism, are acceptable only if the relevant mechanisms do not contribute significantly to the overall failure probability at the Higher Design Factor. Hence, the overall failure probability, compared with that for a 0.72 design factor, would be significant.

A4.2.1.3 Interpret a "significant" increase in failure probability with due consideration being given to the absolute value of failure probability and the risk associated with any such failure.

A4.2.2 Failure mechanisms

A4.2.2.1 Consider any credible failure mechanism for a particular pipeline. Include the following loads and modifications to the resistance of the pipeline or justify exclusion:

- loads
  - internal pressure
  - axial loads, for example, thermal or due to soil interactions
  - geometric stress concentrations at seam welds
  - stress concentrations at fittings
- resistance
  - distribution of steel properties, diameter, wall thickness
  - defects in the pipe due to:
  - external impact

- corrosion
- construction defects
- fatigue
- stress corrosion cracking.

A4.2.2.2 Consider identifying any other loads or resistance affecting failure mechanisms, which may be relevant to the specific pipeline under consideration.

A4.2.3 **Failure models**

Validate the failure models used in the assessments described in A4.2.2 against experience in that part of their range for which evidence is available.

In addition, ensure the predictions of models are in keeping with best understanding of the physical processes involved in display stability, i.e., give answers which do not change disproportionately to a small change in input parameters over the entire range of interest. Ensure that changes in the input data within the actual error bounds do not result in significant changes to the predictions made by models.

A4.2.4 **Data for Structural Reliability Analysis**

A4.2.4.1 Use one of the following two forms of input data for SRA:

- absolute values (either specified worst cases or actual worst cases where sufficient data is available to establish the actual value with high confidence) or
- distributions of measured values.

A4.2.4.2 Where distributions of measured values are used, ensure the assessment performed allows for any uncertainty in the modelling of those distributions.

A4.3 **WALL THICKNESS, MATERIALS STRENGTH AND GRADES OF LINEPIPE**

Structural reliability-based methods require as inputs either:

- minimum values of wall thickness and material strength and grades of linepipe or
- probability density functions describing the actual variation in wall thickness and material strength and grades based on measured data, for example from mill certificates.

Note: The use of probability density functions will lead to increased accuracy in the prediction of failure probabilities. However, the benefits achieved through an increase in accuracy may be swamped by the effect of the probability density functions describing variation in possible damage to the pipeline, since the defect distribution is likely to have far wider confidence limits than those for wall thickness and strength will be limited.

A4.4 **FATIGUE**

A4.4.1 **General**

A4.4.1.1 Calculate the probability of failure due to fatigue by a fracture mechanics analysis using the general method of BS 7910. Take particular care to ensure that input data for this calculation is fully justified and the assumptions documented.

A4.4.1.2 Consider fatigue for fittings and other areas with non-standard stresses as well as for the basic pipeline geometry.

A4.4.2 Initial defect size

Assume for the fatigue analysis performed, either:

- initial defect sizes based on defect length/depth combinations which would just have survived the hydrostatic test, taking into account appropriate material properties and manufacturing processes, or
- a distribution of initial defect sizes based on actual size measurements.

A4.4.3 Stress cycles

A4.4.3.1 Base the analysis of the cyclic loading on either:

- conservative assessments of the stress range which the pipeline would experience in a worst-case day, or
- actual measured variations in pipeline stress, converted to equivalent stress ranges using an established cycle-counting routine, for example the rainflow method or the reservoir method.

A4.4.3.2 Apply the assessed cyclic loading for every day of the pipeline's service from commissioning.

A4.4.3.3 For uprating, establish the effect on the future cyclic loading of the pipeline and this modified loading applied for the design life of the pipeline following uprating.

A4.5 FIELD BENDING

Include in the assessments described in A4.2 consideration of any stress concentration effects at field bends.

A4.6 TESTING OF PIPELINES

When assessing the acceptability of operating at Higher Design Factor, using structural reliability-based techniques (see A4.2), consider the hydrostatic test level and its relationship to MOP.

Note: *The primary function of the hydrostatic test is to reveal construction defects that could lead to failure of the pipeline during the lifetime of the pipeline. Without the hydrostatic test, such failures could occur during the first gaseous pressure raising (gross construction defects) or at some time in the future due to pressure cycling and associated fatigue crack growth.*

The assurance given by the linepipe specification and effective quality assurance procedures regarding the material grade and wall thickness is sufficient to ensure that there are no defects which would affect the integrity of the pipeline.

The SRA (as described in A4.2) will have taken account of the effect of the hydrostatic test on the probability of failure due to damage associated with in-service processes such as corrosion and external impact. In situations where the probability of failure is dominated by these types of damage, the optimum mitigation method is to carry out high resolution internal inspection.

A4.7 OVERPRESSURE

In the assessments described in A4.2, assume that the pressure in the pipeline may rise to the overpressure limit defined in Sub-Section 12.4 for up to 20 hours in any year.

A4.8 DEPTH OF COVER

In the assessment of external impact failure probability given in A4.2, take account of either the minimum depth of cover (which for new-build pipelines may be equal to or greater than the 1.1 m identified in clause 7.16) or the distribution of actual depths of cover along the pipeline, and the predicted effect of this on the probability of impact damage.

APPENDIX 5 : PRESSURE TESTING PROCEDURES

A5.1 TESTING PROCEDURE – GENERAL

A5.1.1 Ensure all test equipment is designed for an operating pressure of not less than the specified test pressure.

A5.1.2 Hydrostatically strength test and pneumatically leak test installations, before putting into service.

Note: Sections of the installation may require hydrostatic testing at different pressure levels, according to their design pressures.

A5.1.3 If any components or sub-assemblies are to be omitted from a hydrostatic test, test them separately to an equivalent standard.

Note: When the components or sub-assemblies are subsequently installed to the main installation, it is not necessary to repeat the hydrostatic test for the whole installation provided that:

(a) All welded tie-ins are subjected to full NDT inspection, to a standard at least equivalent to that applied to the main installation.

(b) All tie-in connections are carefully inspected for leaks during the pneumatic leak test (installation tests only).

A5.1.4 Backfill below-ground welded pipework and fittings prior to hydrostatic testing to minimise the risk of subsequent post-test damage.

Expose all screwed, bolted or other connections prone to leakage, such as valve spindles and the like, for inspection during the test procedure.

A5.1.5 Blow through small fabrications and check to ensure freedom from blockage and that all foreign matter has been removed.

A5.1.6 Remove any instrumentation or other equipment, which may be damaged during the test procedure and plug the pipework as necessary.

A5.1.7 Measure the volume of water, injected during pressurisation, either by direct measurement or inference from the count of the strokes of a calibrated pump.

A5.2 TESTING PROCEDURE – PIPELINES DESIGNED TO OPERATE AT A DESIGN FACTOR EXCEEDING 0.3

A5.2.1 Raise the pressure in the test section at a controlled rate.

A5.2.2 Record the rise in pressure measured by the dead weight tester and the volume of water injected.

Use a calibrated tank to make spot checks of the volume injected during pressurisation.

A5.2.3 Commence a pressure and temperature record, by chart or digital recorder, and continue for the duration of the test.

A5.2.4 During preliminary pressurisation, adjust the rate of pressure increase to give a maximum pressure rise of 1 bar/minute.

A5.2.5 Carry out a graphical air inclusion plot of pressure against volume (P/V plot) from static head pressure to determine the residual air content of the test section. To ensure accuracy, make the plot to 50% of the design pressure.

A5.2.6 Determine the volume of air by extrapolation of the linear portion of the graph A5.2.6 Raise the pressure in the test section to such a level as to give a corresponding design factor of 0.65.

A5.2.7 Investigate the cause of any significant pressure losses. In the absence of any significant pressure loss, commence a separate graphical P/V plot. This P/V plot represents a stress/strain graph of the test section steel.

A5.2.8 At the commencement of the second P/V plot, determine the volume of water required to raise the pressure by 1 bar. During subsequent pressurisation, check this value frequently to observe any deviation.

A5.2.9 Continue pressurisation until the lesser of the following is reached (this pressure is known as the Limiting Pressure):

- the required maximum test pressure in the test section, as stated in the procedure certificate or,
- the pressure at which twice the volume of water determined at the start of the P/V plot is required to give 1 bar increase in pressure. This effect is, usually, referred to as "double stroking" or "half sloping".

A5.2.10 If, for any reason during pressurisation, the safety of the test is in doubt, suspend the test pending an investigation.

Where half slope occurs before the required maximum test pressure, stop the test for investigation, to include a detailed check of the test procedure and a calibration check of measuring equipment, followed by a check on the pipe mechanical properties.

A5.2.11 When the limiting pressure is reached, stop the pressurising pump and isolate the test section, record the temperature of the test section and cease the P/V plot.

A5.2.12 At the completion of the P/V plot, compare the actual curve with the theoretical elastic line on the P/V plot. If the slopes differ by more than 10%, investigate to determine the cause.

A5.2.13 The test section pipework will continue to yield. Plot the resulting drop in pressure together with the temperature at 10 minute intervals over a 2 hour period, known as the "decay period", on the same x-y axis.

A5.2.14 At the end of the 2 hour decay period, make an assessment as to whether the test section is leak free and if the test procedure may continue.

A5.2.15 If a pressure drop is still observed in subsequent 10 minute intervals, continue the decay period record to help establish the condition of the pipeline.

A5.2.16 If a leak is suspected, reduce the pressure to not more than the design pressure of the test section prior to encroaching within the safety distance, for the purpose of visual examination.

A5.2.17 Continue the test for 24 hours from attaining the limiting pressure. If, for any reason, the test pressure has to be reduced other than for bleed-off of excess pressure, extend the duration of the test by an equivalent period.

A5.2.18 If the test is to continue, re-start the pressurising pump and repressurise the test section to the limiting pressure. Measure and record the quantity of water required to restore the limiting pressure.

A5.2.19 During the subsequent 22 hours, continue to record the pressure and temperature at half hourly intervals.

If the pressure drops 1 bar below the limiting pressure, restart the pressurising pump and restore the limiting test pressure.

Measure and record the quantity of water required on each occasion to restore the pressure to the limiting test pressure and identify on the graphical plot. However, during the last 6 hours of this 22-hour period, no further re-pressurisation will be permitted.

A5.2.20 If, due to changes in temperature, the pressure rises and exceeds the limiting pressure by 0.4 bar, bleed off the excess pressure and remove, measure and record the quantity of water removed from the test section.

A5.2.21 During the last 3 hours of the test period, make graphical plots of pressure and temperature, at maximum half-hourly intervals, on the same x-y axis.

A5.2.22 Decide, from the plot over the last 3 hours, if the test is satisfactory, and make pressure corrections due to variations in temperature (see A5.7).

A5.2.23 The test may be considered satisfactory if the pressure loss over the last 3 hours of the test period is not greater than 0.2 bar in total.

A5.2.24 Calculate and record the pressure at the maximum and minimum elevations of the test section from the limiting test pressure.

A5.2.25 Calculate the design factor at the minimum elevation based on the limiting pressure.

A5.3 TESTING PROCEDURE – PIPELINES DESIGNED TO OPERATE AT A DESIGN FACTOR NOT EXCEEDING 0.3

A5.3.1 Raise the pressure in the test section at a controlled rate.

A5.3.2 Record the rise in pressure measured by the dead weight tester and the volume of water injected.

Use a calibrated tank to make spot checks of the volume injected during pressurisation.

A5.3.3 Commence a pressure and temperature record, by chart or digital recorder, and continue for the duration of the test.

A5.3.4 During preliminary pressurisation, adjust the rate of pressure increase to give a maximum pressure rise of 1 bar/minute.

A5.3.5 Carry out a graphical air inclusion plot of pressure against volume (P/V plot), from static head pressure, to determine the residual air content of the test section. Make the plot to 50% of the design pressure.

Determine the volume of air by extrapolation of the linear portion of the graph.

A5.3.6 Where the P/V plot has not become linear at 50% of the design pressure, it may be continued up to a maximum value of 35 bar or 100% of the design pressure, whichever is the lesser.

A5.3.7 On completion of the air inclusion plot, commence a separate P/V plot and continue until the test pressure is reached. Stop the pressurising pump and take a preliminary reading from the dead weight tester.

A5.3.8 If the test pressure cannot be attained, or if half slope on the P/V plot is reached (see A5.2.9), terminate the test and record as a test failure.

A5.3.9 At the completion of the P/V plot, compare the actual curve with the theoretical elastic line on the P/V plot. If the slopes differ by more than 10%, carry out an investigation to determine the cause.

A5.3.10 On achieving the test pressure, allow an adequate period for the pressure to stabilise. The duration of the stabilisation period will vary according to physical and ambient factors.

A5.3.11 At the end of the stabilisation period, restore the test pressure where necessary, and isolate the pressurising pump. Record the volume of water injected or expelled to restore the test pressure.

A5.3.12 Commence the test period at the restoration of the test pressure and continue for 4 hours.

A5.3.13 During the 4-hour test period, make graphical plots of pressure and temperature, at maximum half-hourly intervals, on the same x-y axis.

A5.3.14 If, during the 4-hour test period, the pressure rises and exceeds the test pressure by 0.4 bar, bleed off the excess pressure and expel, measure and record the quantity of water.

A5.3.15 If, due to temperature variations, the pressure falls 1 bar below the test pressure during the first 3 hours of the test period, restore the test pressure. However, do not allow re-pressurisation during the last hour of the 4 hour test period.

Measure and record the quantity of water required on each occasion to restore the pressure to the limiting test pressure and identify on the graphical plot.

A5.3.16 Decide, from the test period pressure and temperature graphs, if the test is acceptable. Make pressure corrections due to variations in temperature (see clause A5.7).

A5.3.17 The test result is acceptable if there are no significant pressure changes, other than those due to variations in temperature.

A5.3.18 In the event of an unacceptable pressure loss, reduce the pressure to a value not greater than the design pressure, before any visual examination is carried out.

A5.3.19 Calculate the design factor at the maximum elevation.

A5.4 TESTING PROCEDURE - INSTALLATIONS

A5.4.1 Testing of small fabrications

A5.4.1.1 This procedure is intended for small fabrications which readily may be inspected visually and whose volume makes longer term test durations impractical due to the impact of ambient temperature variations.

A5.4.1.2 A plot of pressure against volume (P/V plot) is not required for this test.

A5.4.1.3 Raise the test section pressure in a controlled manner to the test pressure and stop the pump.

A5.4.1.4 Allow the pressure in the test section to stabilise.
The stabilisation period will vary considerably with site conditions, but it is not to be less than 30 minutes.

A5.4.1.5 Once stabilisation has occurred, restore the test pressure if necessary, isolate the pressurising pump, and record the temperature and pressure.

A5.4.1.6 Maintain the test pressure for the test period (not less than 30 minutes).

A5.4.1.7 Investigate any loss in pressure, other than due to variations in temperature, and extend the test period accordingly.

Make pressure corrections due to variations in temperature (see A5.7).

A5.4.1.8 The test result is acceptable if there are no significant pressure changes, other than those due to variations in temperature.

A5.4.1.9 Reduce the test pressure to the design pressure, before any close visual examination takes place.

A5.4.1.10 On completion of testing, release the test pressure in a safe controlled manner.

A5.4.1.11 Produce a test certificate which, together with appropriate drawings detailing the test physical limits and the instrument calibration certificates, will provide the documentation for the test.

A5.4.2 **Testing of installations other than small fabrications**

A5.4.2.1 A plot of pressure against volume (P/V plot) is required for this test.

A5.4.2.2 Record the P/V plot from the rise in pressure measured by the dead weight tester and inject the volume of water.

Use a calibrated tank to make spot checks of the volume injected during pressurisation.

A5.4.2.3 Continuously record ambient temperature and water temperature throughout the test.

A5.4.2.4 Raise the pressure in the test section at a controlled rate.

A5.4.2.5 Commence a pressure and temperature record, by chart or digital recorder, and continue for the duration of the test.

A5.4.2.6 During preliminary pressurisation, adjust the rate of pressure increase to give a maximum pressure rise of 1 bar/minute.

A5.4.2.7 Carry out a graphical air inclusion P/V plot from static head pressure, to determine the residual air content of the test section.

To ensure accuracy, make the plot to 50% of the design pressure before the estimation of residual air volume is made.

Determine the volume of air by extrapolation of the linear portion of the graph (see clause 8.5.1).

A5.4.2.8 Where the P/V plot has not become linear at 50% of the design pressure, it may be continued up to a maximum value of 35 bar or 100% of the design pressure, whichever is lesser.

A5.4.2.9 On completion of the air inclusion P/V plot, commence a separate P/V plot and continue until the test pressure is reached.

A5.4.2.10 Compare the actual curve of the P/V plot with the theoretical elastic line.

Any reduction in the slope of the P/V plot could indicate a leak or yield of a component, so the pressurising pump should be stopped and the reason investigated.

A5.4.2.11 When the test pressure is reached, stop and isolate the pressurising pump and cease the P/V plot.

A5.4.2.12 Allow an adequate period for the pressure to stabilise, i.e., after equalisation of the pipe and water temperature.

A5.4.2.13 At the end of the stabilisation period, restore the test pressure, where necessary, and isolate the pressurising pump.

Record the volume of water injected or expelled to restore the test pressure.

A5.4.2.14 Commence the test period at the restoration of the test pressure and continue for a period of not less than 2 hours.

A5.4.2.15 Take regular readings, maximum 15 minutes interval, of pressure and temperature during the test period and graphically plot against time on the same x-y axis.

A5.4.2.16 At no time during the test period allow the pressure to rise by more than 5% above the test pressure.

Bleed off excess pressure and measure and record the quantity of water released for reference when the assessment of the pressure/time plot is made.

A5.4.2.17 If, during the test period, the pressure falls by more than 10%, due to temperature effects, restore the pressure to the test pressure and maintain the test pressure for a minimum period of 30 minutes.

A5.4.2.18 Where necessary, make pressure corrections due to variations in temperature (see A5.7).

A5.4.2.19 The test result is acceptable if there are no significant pressure changes, other than those due to variations in temperature.

A5.4.2.20 On completion of testing, release the test pressure in a safe controlled manner.

A5.4.2.21 Produce a test certificate which, together with appropriate drawings detailing the test physical limits and the instrument calibration certificates, will provide the documentation for the test.

A5.4.3 **Pneumatic leak test**

A5.4.3.1 As a test medium use clean dry air or nitrogen.

A5.4.3.2 Apply the test to the assembled installation and include all equipment and associated small bore pipework which may have been removed for the hydrostatic pressure test.

For installations that include a meter, refer to IGEM/GM/8.

A5.4.3.3 Ensure that all valves are in the open position.

A5.4.3.4 Gradually increase the test pressure to 7 bar.

A5.4.3.5 Carry out soap solution tests on all connections made after the hydrostatic test to ensure there are no leakages.

A5.4.3.6 Permit only limited tightening of fittings or the making good of minor leakages while the system is under pressure. Carry out any major remedial work only after the test pressure has been completely released.

After any leakages have been made good, restore the test pressure and recheck the system for leakage.

A5.4.3.7 On completion, issue a certificate stating that the installation has been leak tested in accordance with this procedure.

A5.4.3.8 This test may be combined with the nitrogen purge prior to commissioning.

A5.5 TESTING PROCEDURE – SMALL BORE PIPEWORK

A5.5.1 Small-bore pipework, for the purpose of this procedure, is an above-ground pipework system of up to and including 25 mm diameter. This will, generally, be restricted to impulse or instrumentation pipework.

The purpose of the test is to prove strength as well as leak tightness.

A5.5.2 Test small-bore pipework, wherever possible, in the final installed configuration, to maximise the testing of as many complete joints as possible.

A5.5.3 Wherever practical, subject small-bore pipework to hydrostatic testing.

A5.5.4 Where, because of application or configuration, the use of hydrostatic testing of small-bore pipework is impractical, then carry out pneumatic testing.

A5.5.5 Place a person in full charge of all testing and to be on site during all testing operations.

A5.5.6 Connect the pipework to be tested to the test medium using suitable control valves, relief valves and a calibrated standard test gauge, so arranged that the maximum test pressure cannot be exceeded.
See Figure 21 and its notes for a typical procedure and test rig arrangement.

A5.5.7 Make all pressure measurements by means of a standard test gauge (see Sub-Section 8.4).

A5.5.8 Immediately prior to use, calibrate the standard test gauge against a dead weight tester and certify for accuracy. Retain the calibration certificate with the final test documentation.

Make the original manufacturer's test certificate available at the time of the calibration check, in order that any pertinent information can be transferred to the calibration certificate.

A5.5.9 Use a test medium of dry oil-free air or nitrogen.

A5.5.10 Securely anchor all hoses using a method to reduce the risk of injury to personnel in the event of failure.

A5.5.11 Carry out an initial proving test, using a soapy water solution at a pressure not exceeding 2 bar to check the integrity of all joints.

A5.5.12 Following the successful completion of the proving test, increase the test pressure in stages of not more than 10% of the final test pressure to allow pressure conditions to stabilise.

A5.5.13 After reaching the final test pressure, isolate the test pipework from the pressure source and allow the pressure to stabilise.

A5.5.14 Once the pressure has stabilised, monitor for a period of 10 minutes, during which time there should be no pressure loss.

A5.5.15 After the 10 minute test period, gradually reduce the test pressure to the design pressure and carry out a further soap solution leak test. There should be no leakage.

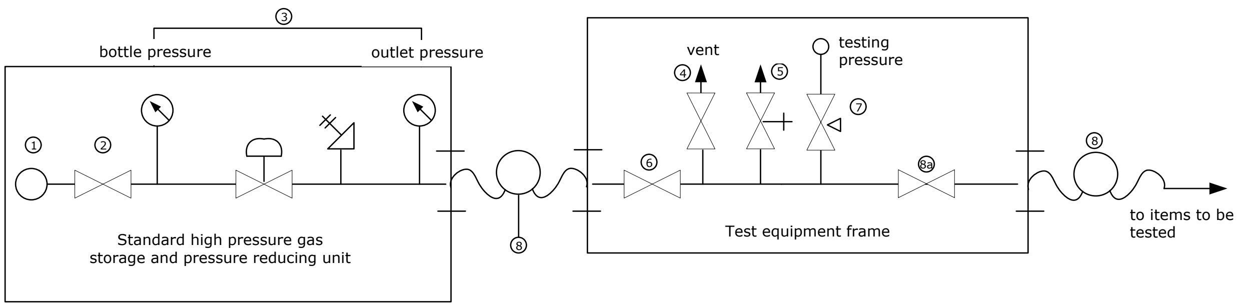
A5.5.16 Release the test pressure in a controlled manner, by the use of a suitable pressure let down valve, vented to a safe location.

A5.5.17 If pressure loss or leakage is detected, deem the test a failure and repeat the test procedure once remedial work has been completed.

A5.5.18 Where a partial test failure occurs, do not permit personnel to approach the test section until the pressure has been reduced to not more than 2 bar or to a safe level.

A5.5.19 Where practical, carry out a further proving test once the pipework has been reinstalled in its final position. This may be tested with gas during initial pressurisation.

A5.5.20 Complete a test certificate which, together with the relevant drawings and test gauge calibration certificate, comprise the permanent test record.



1. *Assemble and test the high-pressure storage cylinder and regulator unit in accordance with the manufacturer's instructions.*

2. *Carry out a visual inspection for damage of all parts of the test rig.*

3. *Calibrate the test gauge (Item 7), using a dead weight test and fit the gauge to the test rig.*

4. *Close the shut off valve at the outlet to the test frame (Item 6a).*

5. *Lower the setting of the test frame relief valve (Item 4) until it is proved to be working. Then, the setting is to be raised in small stages until the test pressure plus 10% is reached.*

6. *Open the shut off valve (Item 6a) at the outlet to the test frame, to pressurise the pipework system.*

7. *Close the shut off valve (Item 6) at the inlet to the test frame when the test pressure is reached, in order to isolate the system under test.*

8. *Upon completion of the test, the pressure is to be relieved using the vent (Item 5).*

FIGURE 21 - PNEUMATIC TESTING OF SMALL BORE PIPEWORK. TYPICAL TEST RIG ARRANGEMENT

A5.6 DERIVATION OF TABLES 15 to 30

For unrestrained pipework i.e., free to move:

$$dP = \frac{10(A - 3B)}{\frac{Dm}{4E.tn}.(5 - 4\upsilon) + \frac{1}{C}}$$

For restrained pipework i.e., buried or anchored:

$$dP = \frac{10(A - 2B)}{\frac{Dm}{E.tn}.(1 - \upsilon^2) + \frac{1}{C}}$$

dP	=	change in internal pressure of water from T°C to (T+1)°C, (bar).
A	=	coefficient of volumetric expansion of water at T°C. $\frac{-64.268 + 17.0105T - 0.20369T^2 + 0.0016048T^3}{10^6}$
B	=	coefficient of expansion of linear expansion of carbon steel taken at T°C (0.000011).
Dm	=	pipe mean diameter (mm), i.e., in the centre of pipe wall.
tn	=	nominal pipe wall thickness, (mm).
E	=	Young's modulus N mm^2 (21 x 10^4 N mm^2 for carbon steel).
C	=	bulk modulus of water N mm^2. This is variable in the tables with temperature between 2,184 N mm^2 at 0°C to 1,962 N mm^2 at 30°C and a constant pressure of 70 bar.
υ	=	Poisson's ratio taken as 0.3 for steel.

See A5.7 for typical graphical representation of the temperature/pressure relationship.

A5.7 USE OF TABLES

Example 1 – Pipelines

Assume a test section for a pipeline as follows:

Length 5000 m, outside diameter 457.20 mm, wall thickness 9.52 mm.

The whole of the test section is buried, i.e., restrained, with the exception of the test points at either end which are exposed, i.e., unrestrained. The exposed sections are 100 m and 50 m long respectively.

The pipe/water temperature for the exposed sections falls from 20°C at the start of the test period to 16°C at the end of the test.

The pipe/water temperature for the buried section remains unchanged.

% pipe exposed (unstrained) $= \frac{(100 + 50)100}{5000}$

$$= 3.0\%$$

From appropriate table:

°C	DECREASE IN PRESSURE (bar)
20 19	2.55
19 18	2.38
18 17	2.20
17 16	2.02

So, the total reduction in pressure for a fall from 20°C to 16°C will be the sum of the above pressures:

2.55 + 2.38 + 2.20 + 2.02 = 9.15 bar decrease.

If the temperature had risen from 16°C to 20°C, there would be an increase in pressure of 9.15 bar.

Hence the reduction in pressure of the unrestrained test section would be 3% of 9.15 bar, i.e., 0.275 bar.

Example 2 – Installations

Assume an installation with a mix of pipe sizes as follows. The percentages shown are the percentage pipework of the total installation, by volume.

DIAMETER (mm)	WALL THICKNESS (mm)	TYPE
323.8	9.52	above ground, unrestrained 40%
219.1	8.18	above ground, unrestrained 20%
168.3	7.11	above ground, unrestrained 10%
323.8	9.52	buried, restrained 30%

Temperature measurement showed that the unrestrained above ground pipework rose in temperature from 15°C to 18°C and the restrained below ground pipework rose in temperature from 16°C to 16.5°C.

Using appropriate table, as demonstrated in Example 1:

DIAMETER (mm)	PRESSURE CHANGE (bar)	%	TYPE
323.8	6.72	40	2.688 bar
219.1	7.11	20	1.420 bar
168.3	7.28	10	0.728 bar
323.8	1.22	30	0.365 bar
		Total	5.201 bar

Thus, the total pressure increase for the installation would be 5.201 bar.

Wall thickness: 5.54 mm		
Temp range °C	R bar	U bar
0 to 1	-1.46	-1.64
1 to 2	-1.15	-1.34
2 to 3	-0.85	-1.04
3 to 4	-0.56	-0.75
4 to 5	-0.27	-0.46
5 to 6	0.02	-0.17
6 to 7	0.30	-0.11
7 to 8	0.58	0.38
8 to 9	0.86	0.66
9 to 10	1.13	0.93
10 to 11	1.39	1.19
11 to 12	1.66	1.45
12 to 13	1.92	1.71
13 to 14	2.17	1.97
14 to 15	2.43	2.22
15 to 16	2.68	2.47
16 to 17	2.93	2.71
17 to 18	3.17	2.96
18 to 19	3.41	3.20
19 to 20	3.65	3.43
20 to 21	3.89	3.67
21 to 22	4.13	3.90
22 to 23	4.36	4.14
23 to 24	4.59	4.37
24 to 25	4.83	4.60
25 to 26	5.05	4.82
26 to 27	5.28	5.05
27 to 28	5.51	5.27
28 to 29	5.74	5.50
29 to 30	5.96	5.72

TABLE 15 - TEMPERATURE/PRESSURE CORRECTIONS OD (outside diameter) = 60.3 mm

Wall thickness: 5.49 mm		
Temp range °C	R bar	U bar
0 to 1	-1.40	-1.57
1 to 2	-1.11	-1.28
2 to 3	-0.82	-1.00
3 to 4	-0.53	-0.71
4 to 5	-0.26	-0.44
5 to 6	0.02	-0.17
6 to 7	0.29	-0.10
7 to 8	0.56	0.37
8 to 9	0.82	0.63
9 to 10	1.08	0.88
10 to 11	1.33	1.14
11 to 12	1.58	1.39
12 to 13	1.83	1.63
13 to 14	2.08	1.88
14 to 15	2.32	2.12
15 to 16	2.56	2.35
16 to 17	2.80	2.59
17 to 18	3.03	2.82
18 to 19	3.26	3.05
19 to 20	3.49	3.27
20 to 21	3.71	3.50
21 to 22	3.94	3.72
22 to 23	4.16	3.94
23 to 24	4.38	4.16
24 to 25	4.60	4.37
25 to 26	5.82	4.59
26 to 27	5.04	4.80
27 to 28	5.25	5.02
28 to 29	5.47	5.23
29 to 30	5.68	5.44

TABLE 16 - TEMPERATURE/PRESSURE CORRECTIONS OD = 88.9 mm

Temp range °C			Wall thickness 4.78 mm		6.01 mm		11.91 mm	
			R bar	U bar	R bar	U bar	R bar	U bar
0	to	1	-1.32	-1.48	-1.37	-1.54	-1.48	-1.66
1	to	2	-1.04	-1.21	-1.08	-1.25	-1.17	-1.35
2	to	3	-0.77	-0.94	-0.80	-0.97	-0.86	-1.05
3	to	4	-0.50	-0.67	-0.52	-0.70	-0.56	-0.76
4	to	5	-0.24	-0.41	-0.25	-0.43	-0.27	-0.46
5	to	6	0.02	-0.16	0.02	-0.16	0.02	-0.17
6	to	7	0.27	-0.10	0.28	-0.10	0.31	-0.11
7	to	8	0.52	0.34	0.54	0.36	0.59	0.39
8	to	9	0.77	0.59	0.80	0.61	0.87	0.66
9	to	10	1.01	0.83	1.05	0.86	1.14	0.94
10	to	11	1.25	1.07	1.30	1.11	1.41	1.21
11	to	12	1.49	1.30	1.55	1.35	1.68	1.47
12	to	13	1.72	1.53	1.79	1.59	1.94	1.73
13	to	14	1.95	1.76	2.03	1.83	2.20	1.99
14	to	15	2.18	1.98	2.27	2.06	2.46	2.24
15	to	16	2.40	2.20	2.50	2.30	2.71	2.50
16	to	17	2.62	2.42	2.73	2.52	2.96	2.74
17	to	18	2.84	2.64	2.96	2.75	2.21	2.99
18	to	19	3.06	2.85	3.18	3.97	3.45	3.23
19	to	20	3.27	3.06	3.41	3.19	3.70	3.48
20	to	21	3.48	3.27	3.63	3.41	3.94	3.71
21	to	22	3.69	3.48	3.85	3.63	4.18	3.95
22	to	23	3.90	3.68	4.06	3.84	4.41	4.19
23	to	24	4.11	3.89	4.28	4.05	4.65	4.42
24	to	25	4.31	4.09	4.49	4.26	4.88	4.65
25	to	26	4.51	4.29	4.70	4.47	5.12	4.88
26	to	27	4.71	4.49	4.91	4.68	5.35	5.11
27	to	28	4.91	4.68	5.12	4.89	5.58	5.34
28	to	29	5.11	4.88	5.33	5.10	5.81	5.57
29	to	30	5.31	5.08	5.54	5.30	6.04	5.80

TABLE 17 - TEMPERATURE/PRESSURE CORRECTIONS OD = 114.3 mm

Temp range °C			Wall thickness 5.56 mm		7.11 mm		11.91 mm	
			R bar	U bar	R bar	U bar	R bar	U bar
0	to	1	-1.26	-1.41	-1.32	-1.48	-1.42	-1.60
1	to	2	-1.00	-1.15	-1.04	-1.21	-1.12	-1.30
2	to	3	-0.74	-0.89	-0.77	-0.94	-0.83	-1.01
3	to	4	-0.48	-0.64	-0.50	-0.67	-0.54	-0.73
4	to	5	-0.23	-0.39	-0.24	-0.41	-0.26	-0.45
5	to	6	0.02	-0.15	0.02	-0.16	0.02	-0.17
6	to	7	0.26	-0.09	0.27	-0.10	0.29	-0.10
7	to	8	0.50	0.33	0.52	0.35	0.57	0.37
8	to	9	0.73	0.56	0.77	0.59	0.83	0.64
9	to	10	0.97	0.79	1.02	0.83	1.10	0.90
10	to	11	1.20	1.02	1.26	1.07	1.36	1.16
11	to	12	1.42	1.24	1.49	1.30	1.61	1.41
12	to	13	1.64	1.46	1.73	1.53	1.87	1.66
13	to	14	1.86	1.67	1.96	1.76	2.11	1.91
14	to	15	2.08	1.89	2.18	1.99	2.36	2.15
15	to	16	2.29	2.10	2.41	2.21	2.60	2.40
16	to	17	2.50	2.30	2.63	2.43	2.84	2.63
17	to	18	2.71	2.51	2.85	2.64	3.08	2.87
18	to	19	2.91	2.71	3.06	2.86	3.32	3.10
19	to	20	3.11	3.91	3.28	3.07	3.55	3.33
20	to	21	3.31	3.11	3.49	3.28	3.78	3.56
21	to	22	3.51	3.30	3.70	3.49	4.01	3.79
22	to	23	3.71	3.50	3.91	3.69	4.24	4.01
23	to	24	3.90	3.69	4.11	3.89	4.46	4.24
24	to	25	4.10	3.88	4.32	4.10	4.69	4.46
25	to	26	4.29	4.07	4.52	4.30	4.91	4.68
26	to	27	4.48	4.25	4.72	4.50	5.13	4.90
27	to	28	4.67	4.44	4.92	4.69	5.35	5.11
28	to	29	4.86	4.63	5.12	4.89	5.57	5.33
29	to	30	5.04	4.81	5.32	5.09	5.79	5.55

TABLE 18 - TEMPERATURE/PRESSURE CORRECTIONS OD = 168.3 mm

Temp range °C	Wall thickness 6.35 mm R bar	6.35 mm U bar	8.18 mm R bar	8.18 mm U bar	12.70 mm R bar	12.70 mm U bar
0 to 1	-1.22	-1.37	-1.29	-1.45	-1.39	-1.56
1 to 2	-0.97	-1.11	-1.02	-1.18	-1.10	-1.27
2 to 3	-0.71	-0.87	-0.75	-0.92	-0.81	-0.99
3 to 4	-0.47	-0.62	-0.49	-0.66	-0.53	-0.71
4 to 5	-0.22	-0.38	-0.24	-0.40	-0.25	-0.43
5 to 6	0.02	-0.14	0.02	-0.15	0.02	-0.16
6 to 7	0.25	-0.09	0.27	-0.09	0.29	-0.10
7 to 8	0.48	0.32	0.51	0.34	0.55	0.36
8 to 9	0.71	0.54	0.75	0.58	0.81	0.62
9 to 10	0.94	0.77	0.99	0.81	1.07	0.88
10 to 11	1.16	0.98	1.23	1.04	1.32	1.13
11 to 12	1.38	1.20	1.46	1.27	1.57	1.37
12 to 13	1.59	1.41	1.69	1.50	1.82	1.62
13 to 14	1.80	1.62	1.91	1.72	2.06	1.86
14 to 15	2.01	1.83	2.13	1.94	2.30	2.10
15 to 16	2.22	2.03	2.35	2.15	2.54	2.33
16 to 17	2.42	2.23	2.57	2.37	2.77	2.56
17 to 18	2.62	2.43	2.78	2.58	3.00	2.79
18 to 19	2.82	2.62	2.99	2.79	3.23	3.02
19 to 20	3.02	2.82	3.20	2.99	3.46	3.24
20 to 21	3.21	3.01	3.41	3.19	3.68	3.46
21 to 22	3.40	3.19	3.61	3.40	3.90	3.68
22 to 23	3.59	3.38	3.81	3.60	4.12	3.90
23 to 24	3.78	3.57	4.01	3.79	4.34	4.12
24 to 25	3.97	3.75	4.21	3.99	4.56	4.33
25 to 26	4.15	3.93	4.41	4.19	4.77	4.55
26 to 27	4.33	4.11	4.61	4.38	4.99	4.76
27 to 28	4.52	4.29	4.80	4.57	5.20	4.97
28 to 29	4.70	4.47	4.99	4.76	5.41	5.18
29 to 30	4.88	4.65	5.19	4.95	5.63	5.39

TABLE 19 - TEMPERATURE/PRESSURE CORRECTIONS OD = 219.1 mm

Temp range °C	Wall thickness 6.35 mm R bar	6.35 mm U Bar	8.74 mm R bar	8.74 mm U bar	12.70 mm R bar	12.70 mm U bar
0 to 1	-1.15	-1.29	-1.25	-1.40	-1.34	-1.51
1 to 2	-0.91	-1.05	-0.99	-1.14	-1.06	-1.23
2 to 3	-0.67	-0.82	-0.73	-0.89	-0.78	-0.95
3 to 4	-0.44	-0.58	-0.48	-0.64	-0.51	-0.68
4 to 5	-0.21	-0.36	-0.23	-0.39	-0.24	-0.42
5 to 6	0.02	-0.14	0.02	-0.15	0.02	-0.16
6 to 7	0.24	-0.08	0.26	-0.09	0.28	-0.10
7 to 8	0.46	0.30	0.50	0.33	0.53	0.35
8 to 9	0.67	0.51	0.73	0.56	0.79	0.60
9 to 10	0.88	0.72	0.96	0.78	1.03	0.85
10 to 11	1.09	0.93	1.19	1.01	1.28	1.09
11 to 12	1.30	1.13	1.41	1.23	1.52	1.33
12 to 13	1.50	1.33	1.63	1.45	1.76	1.56
13 to 14	1.70	1.52	1.85	1.66	1.99	1.79
14 to 15	1.90	1.72	2.06	1.87	2.22	2.02
15 to 16	2.09	1.91	2.27	2.08	2.45	2.25
16 to 17	2.28	2.09	2.48	2.29	2.68	2.46
17 to 18	2.47	2.28	2.69	2.49	2.90	2.69
18 to 19	2.65	2.46	2.89	2.	3.12	2.91
19 to 20	2.84	2.64	3.09	2.89	3.34	3.13
20 to 21	3.02	2.82	3.29	3.0	3.55	3.34
21 to 22	3.20	3.00	3.49	3.28	3.77	3.55
22 to 23	3.38	3.17	3.68	3.47	3.98	3.76
23 to 24	3.55	3.35	3.87	3.66	4.19	3.97
24 to 25	3.73	3.52	4.07	3.85	4.40	4.17
25 to 26	3.90	3.69	4.26	4.04	4.60	4.38
26 to 27	4.07	3.86	4.45	4.22	4.81	4.58
27 to 28	4.24	4.02	4.63	4.41	5.02	4.78
28 to 29	4.41	4.19	4.82	4.59	5.22	4.98
29 to 30	4.58	4.36	5.01	4.77	5.42	5.18

TABLE 20 - TEMPERATURE/PRESSURE CORRECTIONS OD = 273.0 mm

Temp range °C	Wall thickness 6.35 mm		7.14 mm		7.92 mm		9.52 mm		12.70 mm	
	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar
0 to 1	-1.10	-1.22	-1.14	-1.27	-1.17	-1.31	-1.23	-1.37	-1.30	-1.46
1 to 2	-0.87	-1.00	-0.90	-1.03	-0.93	-1.07	-0.97	-1.12	-1.03	-1.19
2 to 3	-0.64	-0.77	-0.66	-0.80	-0.68	-0.83	-0.72	-0.87	-0.76	-0.92
3 to 4	-0.42	-0.55	-0.43	-0.58	-0.45	-0.59	-0.47	-0.62	-0.50	-0.66
4 to 5	-0.20	-0.34	-0.21	-0.35	-0.21	-0.36	-0.22	-0.38	-0.24	-0.41
5 to 6	0.02	-0.13	0.02	-0.13	0.02	-0.14	0.02	-0.14	0.02	-0.15
6 to 7	0.23	-0.08	0.23	-0.08	0.24	-0.09	0.25	-0.09	0.27	-0.10
7 to 8	0.43	0.28	0.45	0.29	0.46	0.30	0.49	0.32	0.52	0.34
8 to 9	0.64	0.49	0.66	0.50	0.68	0.52	0.72	0.55	0.76	0.58
9 to 10	0.84	0.68	0.87	0.71	0.90	0.73	0.94	0.77	1.00	0.82
10 to 11	1.04	0.88	1.08	0.91	1.11	0.94	1.16	0.99	1.24	1.05
11 to 12	1.23	1.07	1.28	1.11	1.32	1.14	1.38	1.20	1.47	1.28
12 to 13	1.42	1.26	1.48	1.31	1.52	1.35	1.60	1.42	1.70	1.51
13 to 14	1.61	1.44	1.67	1.50	1.72	1.55	1.81	1.63	1.93	1.74
14 to 15	1.80	1.62	1.87	1.69	1.92	1.74	2.02	1.83	2.15	1.96
15 to 16	1.98	1.80	2.06	1.88	2.12	1.94	2.23	2.04	2.37	2.18
16 to 17	2.16	1.98	2.24	2.06	2.31	2.13	2.43	2.24	2.59	2.39
17 to 18	2.34	2.16	2.43	2.24	2.50	2.31	2.63	2.44	2.81	2.60
18 to 19	2.52	2.33	2.61	2.42	2.69	2.50	2.83	2.63	3.02	2.81
19 to 20	2.69	2.50	2.79	2.60	2.88	2.68	3.03	2.83	3.23	3.02
20 to 21	2.86	2.67	2.97	2.78	3.07	2.87	3.22	3.02	3.44	3.23
21 to 22	3.03	2.84	3.15	2.95	3.25	3.05	3.41	3.21	3.65	3.43
22 to 23	3.20	3.00	3.32	3.12	3.43	3.22	3.60	3.39	3.85	3.63
23 to 24	3.36	3.16	3.50	3.29	3.61	3.40	3.79	3.58	4.05	3.83
24 to 25	3.53	3.32	3.67	3.46	3.78	3.57	3.98	3.76	4.26	4.03
25 to 26	3.69	3.48	3.84	3.63	3.96	3.75	4.17	3.95	4.45	4.23
26 to 27	3.85	3.64	4.00	3.79	4.13	3.92	4.35	4.13	4.65	4.43
27 to 28	4.01	3.80	4.17	3.96	4.31	4.09	4.53	4.31	4.85	4.62
28 to 29	4.17	3.96	4.34	4.12	4.48	4.26	4.72	4.49	5.05	4.81
29 to 30	4.33	4.11	4.50	4.28	4.65	4.43	4.90	4.67	5.24	5.01

TABLE 21 - TEMPERATURE/PRESSURE CORRECTIONS OD = 323.8 mm

Wall thickness: 7.92 mm		
Temp range °C	R bar	U bar
0 to 1	-1.14	-1.57
1 to 2	-0.90	-1.28
2 to 3	-0.67	-1.00
3 to 4	-0.43	-0.71
4 to 5	-0.21	-0.44
5 to 6	0.02	-0.17
6 to 7	0.24	-0.10
7 to 8	0.45	0.37
8 to 9	0.66	0.63
9 to 10	0.87	0.88
10 to 11	1.08	1.14
11 to 12	1.28	1.39
12 to 13	1.48	1.63
13 to 14	1.68	1.88
14 to 15	1.87	2.12
15 to 16	2.06	2.35
16 to 17	2.25	2.59
17 to 18	2.44	2.82
18 to 19	2.62	3.05
19 to 20	2.80	3.27
20 to 21	2.98	3.50
21 to 22	3.16	3.72
22 to 23	3.33	3.94
23 to 24	3.51	4.16
24 to 25	3.68	4.37
25 to 26	3.85	4.59
26 to 27	4.02	4.80
27 to 28	4.19	5.02
28 to 29	4.25	5.23
29 to 30	4.52	5.44

TABLE 22 - TEMPERATURE/PRESSURE CORRECTIONS OD = 355.6 mm

Temp range °C	Wall thickness							
	7.92 mm		8.74 mm		10.31 mm		14.27 mm	
	R bar	U Bar	R bar	U bar	R bar	U bar	U bar	
0 to 1	-1.10	-1.22	-1.13	-1.26	-1.18	-1.32	-1.28	-1.43
1 to 2	-0.87	-0.99	-0.89	-1.03	-0.93	-1.08	-1.01	-1.16
2 to 3	-0.64	-0.77	-0.66	-0.80	-0.69	-0.84	-0.75	-0.90
3 to 4	-0.42	-0.55	-0.43	-0.57	-0.45	-0.60	-0.49	-0.65
4 to 5	-0.20	-0.34	-0.21	-0.35	-0.22	-0.37	-0.23	-0.40
5 to 6	0.02	-0.13	0.02	-0.13	0.02	-0.14	0.02	-0.15
6 to 7	0.23	-0.08	0.23	-0.08	0.24	-0.09	0.26	-0.09
7 to 8	0.43	0.28	0.45	0.29	0.47	0.31	0.51	0.33
8 to 9	0.64	0.48	0.66	0.50	0.69	0.52	0.74	0.57
9 to 10	0.84	0.68	0.86	0.70	0.91	0.74	0.98	0.80
10 to 11	1.03	0.88	1.07	0.90	1.12	0.95	1.21	1.03
11 to 12	1.23	1.07	1.27	1.10	1.33	1.16	1.44	1.25
12 to 13	1.42	1.25	1.47	1.30	1.54	1.36	1.66	1.48
13 to 14	1.61	1.44	1.66	1.49	1.74	1.56	1.89	1.70
14 to 15	1.79	1.62	1.85	1.67	1.94	1.76	2.10	1.91
15 to 16	1.98	1.80	2.04	1.86	2.14	1.96	2.32	2.12
16 to 17	2.16	1.98	2.23	2.04	2.34	2.15	2.53	2.33
17 to 18	2.33	2.15	2.41	2.22	2.53	2.34	2.74	2.54
18 to 19	2.51	2.32	2.59	2.40	2.72	2.53	2.95	2.75
19 to 20	2.68	2.49	2.77	2.58	2.91	2.71	3.16	2.95
20 to 21	2.85	2.66	2.95	2.75	3.10	2.90	3.36	3.15
21 to 22	3.02	2.83	3.12	2.92	3.28	3.08	3.56	3.35
22 to 23	3.19	2.99	3.30	3.10	3.46	3.26	3.76	3.55
23 to 24	3.36	3.16	3.47	3.26	3.65	3.44	3.96	3.74
24 to 25	3.52	3.32	3.64	3.43	3.82	3.61	4.15	3.94
25 to 26	3.68	3.48	3.81	3.60	4.00	3.79	4.35	4.13
26 to 27	3.84	3.63	3.97	3.76	4.18	3.96	4.54	4.32
27 to 28	4.00	3.79	4.14	3.92	4.35	4.13	4.74	4.51
28 to 29	4.16	3.95	4.30	4.08	4.53	4.30	4.93	4.70
29 to 30	4.32	4.10	4.47	4.25	4.70	4.47	5.12	4.88

TABLE 23 - TEMPERATURE/PRESSURE CORRECTIONS OD = 406.4 mm

Temp range °C	Wall thickness 7.92 mm R bar	7.92 mm U Bar	9.52 mm R bar	9.52 mm U bar	10.31 mm R bar	10.31 mm U bar
0 to 1	-1.05	-1.17	-1.12	-1.25	-1.14	-1.28
1 to 2	-0.83	-1.96	-0.88	-1.02	-0.90	-1.04
2 to 3	-0.62	-0.74	-0.65	-0.79	-0.67	-0.81
3 to 4	-0.40	-0.53	-0.43	-0.57	-0.44	-0.58
4 to 5	-0.19	-0.33	-0.20	-0.35	-0.21	-0.35
5 to 6	0.01	-0.12	0.02	-0.13	0.02	-0.13
6 to 7	0.22	-0.08	0.23	-0.08	0.24	-0.08
7 to 8	0.42	0.27	0.44	0.29	0.45	0.30
8 to 9	0.61	0.46	0.65	0.49	0.67	0.51
9 to 10	0.80	0.65	0.86	0.70	0.88	0.71
10 to 11	0.99	0.84	1.06	0.89	1.08	0.92
11 to 12	1.18	1.02	1.26	1.09	1.29	1.12
12 to 13	1.36	1.20	1.45	1.28	1.49	1.31
13 to 14	1.54	1.38	1.64	1.47	1.68	1.51
14 to 15	1.72	1.55	1.83	1.66	1.88	1.70
15 to 16	1.90	1.73	2.02	1.84	2.07	1.89
16 to 17	2.07	1.90	2.20	2.02	2.26	2.07
17 to 18	2.24	2.06	2.39	2.20	2.45	2.26
18 to 19	2.41	2.23	2.57	2.38	2.63	2.44
19 to 20	2.57	2.39	2.74	2.55	2.81	2.62
20 to 21	2.74	2.55	2.92	2.72	2.99	2.80
21 to 22	2.90	2.71	3.09	2.89	3.17	2.97
22 to 23	3.06	2.87	3.26	3.06	3.35	3.14
23 to 24	3.22	3.02	3.43	3.23	3.52	3.31
24 to 25	3.38	3.18	3.60	3.39	3.69	3.48
25 to 26	3.53	3.33	3.77	3.56	3.86	3.65
26 to 27	3.68	3.48	3.93	3.72	4.03	3.82
27 to 28	3.84	3.63	4.10	3.88	4.20	3.98
28 to 29	3.99	3.78	4.26	4.04	4.37	4.15
29 to 30	4.14	3.93	4.42	4.20	4.54	4.31

Temp range °C	Wall thickness 11.91 mm R bar	11.91 mm U Bar	15.88 mm R bar	15.88 mm U bar
0 to 1	-1.19	-1.33	-1.27	-1.43
1 to 2	-0.94	-1.08	-1.01	-1.16
2 to 3	-0.70	-0.84	-0.74	-0.90
3 to 4	-0.45	-0.60	-0.49	-0.65
4 to 5	-0.22	-0.37	-0.23	-0.40
5 to 6	0.02	-0.14	0.02	-0.15
6 to 7	0.25	-0.09	0.26	-0.09
7 to 8	0.47	0.31	0.51	0.33
8 to 9	0.69	0.53	0.74	0.57
9 to 10	0.91	0.74	0.98	0.80
10 to 11	1.13	0.96	1.21	1.03
11 to 12	1.34	1.17	1.44	1.25
12 to 13	1.55	1.37	1.66	1.47
13 to 14	1.75	1.57	1.88	1.69
14 to 15	1.96	1.77	2.10	1.91
15 to 16	2.16	1.97	2.31	2.12
16 to 17	2.35	2.17	2.53	2.33
17 to 18	2.55	2.36	2.74	2.54
18 to 19	2.74	2.55	2.94	2.74
19 to 20	2.93	2.73	3.15	2.94
20 to 21	3.12	2.92	3.35	3.14
21 to 22	3.31	3.10	3.55	3.34
22 to 23	3.49	3.28	3.75	3.54
23 to 24	3.67	3.46	3.95	3.73
24 to 25	3.85	3.64	4.14	3.93
25 to 26	4.03	3.82	4.34	4.12
26 to 27	4.21	3.99	4.53	4.31
27 to 28	4.39	4.17	4.72	4.50
28 to 29	4.56	4.34	4.91	4.68
29 to 30	4.74	4.51	5.10	4.87

TABLE 24 - TEMPERATURE/PRESSURE CORRECTIONS OD = 457.2 mm

Temp range °C	Wall thickness 9.52 mm R bar	Wall thickness 9.52 mm U Bar	Wall thickness 17.48 mm R bar	Wall thickness 17.48 mm U bar
0 to 1	-1.08	-1.21	-1.27	-1.42
1 to 2	-0.85	-0.98	-1.00	-1.16
2 to 3	-0.63	-0.76	-0.74	-0.90
3 to 4	-0.41	-0.5	-0.48	-0.65
4 to 5	-0.20	-0.33	-0.23	-0.40
5 to 6	0.01	-0.13	0.02	-0.15
6 to 7	0.22	-0.08	0.26	-0.09
7 to 8	0.43	0.28	0.50	0.33
8 to 9	0.63	0.48	0.74	0.57
9 to 10	0.83	0.67	0.98	0.80
10 to 11	1.02	0.86	1.21	1.02
11 to 12	1.21	1.05	1.43	1.25
12 to 13	1.40	1.24	1.66	1.47
13 to 14	1.59	1.42	1.88	1.69
14 to 15	1.77	1.60	2.09	1.90
15 to 16	1.95	1.78	2.31	2.11
16 to 17	2.13	1.95	2.52	2.32
17 to 18	2.30	2.12	2.73	2.53
18 to 19	2.48	2.29	2.94	2.74
19 to 20	2.65	2.46	3.14	2.94
20 to 21	2.82	2.63	3.35	3.14
21 to 22	2.98	2.79	3.55	3.33
22 to 23	3.15	2.95	3.74	3.53
23 to 24	3.31	3.11	3.94	3.72
24 to 25	3.47	3.27	4.14	3.92
25 to 26	3.63	3.43	4.33	4.11
26 to 27	3.79	3.58	4.52	4.30
27 to 28	3.95	3.74	4.71	4.49
28 to 29	4.11	3.89	4.90	4.69
29 to 30	4.26	4.04	5.09	4.86

TABLE 25 - TEMPERATURE/PRESSURE CORRECTIONS OD = 508.0 mm

Temp range °C	Wall thickness 9.52 mm		11.91 mm		12.70 mm		14.27 mm		15.88 mm		17.48 mm		25.40 mm	
	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar
0 to 1	-1.02	-1.13	-1.10	-1.22	-1.12	-1.25	-1.16	-1.29	-1.19	-1.33	-1.22	-1.36	-1.32	-1.48
1 to2	-0.80	-0.92	-0.87	-1.00	-0.88	-1.02	-0.91	-1.05	-0.94	-1.08	-0.96	-1.11	-1.04	-1.20
2 to3	-0.59	-0.71	-0.64	-0.77	-0.65	-0.79	-0.68	-0.82	-0.70	-0.84	-0.71	-0.86	-0.77	-0.94
3 to4	-0.39	-0.51	-0.42	-0.55	-0.43	-0.57	-0.44	-0.59	-0.45	-0.60	-0.47	-0.62	-0.50	-0.67
4 to 5	-0.18	-0.31	-0.20	-0.34	-0.20	-0.35	-0.21	-0.36	-0.22	-0.37	-0.22	-0.38	-0.24	-0.41
5 to 6	0.01	-0.12	0.02	-0.13	0.02	-0.13	0.02	-0.14	0.02	-0.14	0.02	-0.14	0.02	-0.16
6 to 7	0.21	-0.07	0.23	-0.08	0.23	-0.08	0.24	-0.08	0.25	-0.09	0.25	-0.09	0.27	-0.10
7 to 8	0.40	0.26	0.43	0.28	0.44	0.29	0.46	0.30	0.47	0.31	0.48	0.32	0.52	0.34
8 to 9	0.59	0.45	0.64	0.48	0.65	0.49	0.67	0.51	0.69	0.53	0.71	0.54	0.77	0.59
9 to 10	0.77	0.63	0.84	0.68	0.86	0.70	0.89	0.72	0.91	0.74	0.94	0.76	1.01	0.83
10 to 11	0.96	0.81	1.04	0.88	1.06	0.89	1.09	0.93	1.13	0.96	1.16	0.98	1.25	1.07
11 to 12	1.14	0.98	1.23	1.07	1.26	1.09	1.30	1.13	1.34	1.17	1.37	1.20	1.49	1.30
12 to 13	1.31	1.16	1.42	1.26	1.45	1.28	1.50	1.33	1.55	1.37	1.59	1.41	1.72	1.53
13 to 14	1.49	1.33	1.61	1.44	1.64	1.47	1.70	1.53	1.75	1.57	1.80	1.62	1.95	1.76
14 to 15	1.66	1.49	1.80	1.62	1.83	1.66	1.90	1.72	1.96	1.77	2.01	1.82	2.18	1.98
15 to 16	1.83	1.66	1.98	1.80	2.02	1.84	2.09	1.91	2.16	1.97	2.21	2.02	2.40	2.20
16 to 17	1.99	1.82	2.16	1.98	2.20	2.02	2.28	2.10	2.35	2.17	2.41	2.22	2.62	2.42
17 to 18	2.16	1.98	2.34	2.15	2.39	2.20	2.47	2.28	2.55	2.36	2.62	2.42	2.84	2.64
18 to 19	2.32	2.14	2.51	2.33	2.57	2.38	2.66	2.47	2.74	2.55	2.81	2.61	3.06	2.85
19 to 20	2.48	2.30	2.69	2.50	2.74	2.55	2.84	2.65	2.93	2.73	3.01	2.81	3.27	3.06
20 to 21	2.63	2.45	2.86	2.67	2.92	2.72	3.03	3.83	3.12	2.92	3.20	3.00	3.48	3.27
21 to 22	2.79	2.60	3.03	2.83	3.09	2.89	3.21	3.00	3.31	3.10	3.39	3.19	3.69	3.48
22 to 23	2.94	2.75	3.19	3.00	3.26	3.06	3.38	3.18	3.49	3.28	3.58	3.37	3.90	3.68
23 to 24	3.09	2.90	3.36	3.16	3.43	3.23	3.56	3.35	3.67	3.46	3.77	3.56	4.10	3.88
24 to 25	3.24	3.05	3.52	3.32	3.60	3.39	3.73	3.53	3.85	3.64	3.96	3.74	4.31	4.08
25 to 26	3.39	3.20	3.69	3.48	3.77	3.56	3.91	3.70	4.03	3.82	4.14	3.92	4.51	4.28
26 to 27	3.54	3.34	3.85	3.64	3.93	3.72	4.08	3.86	4.21	3.99	4.32	4.10	4.71	4.48
27 to 28	3.69	3.48	4.01	3.79	4.10	3.88	4.25	4.03	4.39	4.17	4.50	4.28	4.91	4.68
28 to 29	3.83	3.63	4.17	3.85	4.26	4.04	4.42	4.20	4.56	4.34	4.69	4.46	5.11	4.88
29 to 30	3.98	3.77	4.32	4.11	4.42	4.20	5.59	4.36	4.74	4.51	4.87	4.64	5.31	5.07

TABLE 26 - TEMPERATURE/PRESSURE CORRECTIONS OD = 609.6 mm

Temp range °C	Wall thickness 11.91 mm R bar	11.91 mm U Bar	15.88 mm R bar	15.88 mm U bar	19.05 mm R bar	19.05 mm U bar	22.22 mm U bar	
0 to 1	-1.02	-1.13	-1.12	-1.25	-1.18	-1.32	-1.22	-1.37
1 to 2	-0.80	-0.92	-0.88	-1.02	-0.93	-1.07	-0.97	-1.12
2 to 3	-0.59	-0.71	-0.65	-0.79	-0.69	-0.83	-0.72	-0.87
3 to 4	-0.39	-0.51	-0.43	-0.57	-0.45	-0.60	-0.47	-0.62
4 to 5	-0.18	-0.31	-0.20	-0.35	-0.21	-0.37	-0.22	-0.38
5 to 6	0.01	-0.12	0.02	-0.13	0.02	-0.14	0.02	-0.14
6 to 7	0.21	-0.07	0.23	-0.08	0.24	-0.09	0.25	-0.09
7 to 8	0.40	0.26	0.44	0.29	0.47	0.31	0.49	0.32
8 to 9	0.59	0.45	0.65	0.49	0.69	0.52	0.71	0.54
9 to 10	0.78	0.63	0.86	0.70	0.90	0.74	0.94	0.77
10 to 11	0.96	0.81	1.06	0.89	1.12	0.95	1.16	0.99
11 to 12	1.14	0.98	1.26	1.09	1.32	1.15	1.38	1.20
12 to 13	1.31	1.16	1.45	1.28	1.53	1.36	1.59	1.41
13 to 14	1.49	1.33	1.64	1.47	1.73	1.56	1.81	1.62
14 to 15	1.66	1.50	1.83	1.66	1.94	1.75	2.02	1.83
15 to 16	1.83	1.66	2.02	1.84	2.13	1.95	2.22	2.03
16 to 17	1.99	1.82	2.20	2.02	2.33	2.14	2.43	2.23
17 to 18	2.16	1.98	2.39	2.20	2.52	2.33	2.63	2.43
18 to 19	2.32	2.14	2.57	2.38	2.71	2.52	2.82	2.63
19 to 20	2.48	2.30	2.74	2.55	2.90	2.70	3.02	2.82
20 to 21	2.63	2.45	2.92	2.72	3.08	2.88	3.22	3.01
21 to 22	2.79	2.60	3.09	2.89	3.27	3.07	3.41	3.20
22 to 23	2.94	2.75	3.26	3.06	3.45	3.24	3.60	3.39
23 to 24	3.09	2.90	3.43	3.23	3.63	3.42	3.79	3.57
24 to 25	3.25	3.05	3.60	3.39	3.81	3.60	3.97	3.76
25 to 26	3.39	3.20	3.77	3.56	3.99	3.77	4.16	3.94
26 to 27	3.54	3.34	3.93	3.72	4.16	3.94	4.34	4.12
27 to 28	3.69	3.48	4.10	3.88	4.34	4.11	4.52	4.30
28 to 29	3.83	3.63	4.26	3.04	4.51	4.29	4.71	4.48
29 to 30	3.98	3.77	4.42	4.20	4.68	4.46	4.89	4.66

TABLE 27 - TEMPERATURE/PRESSURE CORRECTIONS OD = 762.0 mm

Temp range °C	Wall thickness 12.70 mm R bar	12.70 mm U Bar	15.88 mm R bar	15.88 mm U bar	19.05 mm R bar	19.05 mm U bar	25.40 mm U bar	
0 to 1	-0.97	-1.08	-1.05	-1.17	-1.12	-1.25	-1.21	-1.35
1 to 2	-0.77	-0.88	-0.83	-0.96	-0.88	-1.02	-0.96	-1.10
2 to 3	-0.57	-0.68	-0.62	-0.74	-0.65	-0.79	-0.71	-0.86
3 to 4	-0.37	-0.49	-0.40	-0.53	-0.43	-0.57	-0.46	-0.61
4 to 5	-0.18	-0.30	-0.19	-0.33	-0.20	-0.35	-0.22	-0.38
5 to 6	0.01	-0.11	0.01	-0.12	0.02	-0.13	0.02	-0.14
6 to 7	0.20	-0.07	0.22	-0.08	0.23	-0.08	0.25	-0.09
7 to 8	0.38	0.25	0.42	0.27	0.44	0.29	0.48	0.31
8 to 9	0.56	0.43	0.61	0.47	0.65	0.49	0.71	0.54
9 to 10	0.74	0.60	0.81	0.65	0.86	0.70	0.93	0.76
10 to 11	0.91	0.77	1.00	0.84	1.06	0.89	1.15	0.97
11 to 12	1.09	0.94	1.18	1.02	1.26	1.09	1.36	1.19
12 to 13	1.25	1.10	1.37	1.20	1.45	1.28	1.57	1.40
13 to 14	1.42	1.27	1.55	1.38	1.64	1.47	1.78	1.60
14 to 15	1.58	1.43	1.72	1.56	1.83	1.66	1.99	1.81
15 to 16	1.74	1.58	1.90	1.73	2.02	1.84	2.19	2.01
16 to 17	1.90	1.74	2.07	1.90	2.20	2.02	2.40	2.20
17 to 18	2.06	1.89	2.24	2.07	2.39	2.20	2.59	2.40
18 to 19	2.21	2.04	2.41	2.23	2.57	2.38	2.79	2.59
19 to 20	2.36	2.29	2.58	2.39	2.74	2.55	2.98	2.78
20 to 21	2.51	2.34	2.74	2.55	2.92	2.72	3.17	2.97
21 to 22	2.66	2.48	2.90	2.71	3.09	2.89	3.36	3.16
22 to 23	2.81	2.62	3.06	2.87	3.26	3.06	3.55	3.34
23 to 24	2.95	2.76	3.22	3.03	3.43	3.23	3.74	3.53
24 to 25	3.09	2.90	3.38	3.18	3.60	3.39	3.92	3.71
25 to 26	3.23	3.04	3.53	3.33	3.77	3.56	4.10	3.89
26 to 27	3.37	3.18	3.69	3.48	3.93	3.72	4.29	4.07
27 to 28	3.51	3.31	3.84	3.63	4.10	3.88	4.47	4.24
28 to 29	3.65	3.45	3.99	3.78	4.26	4.04	4.65	4.42
29 to 30	3.98	3.58	4.14	3.93	4.42	4.20	4.82	4.59

TABLE 28 - TEMPERATURE/PRESSURE CORRECTIONS OD = 914.4 mm

Temp range °C	Wall thickness							
	14.27 mm		17.48 mm		19.05 mm		28.71 mm	
	R bar	U Bar	R bar	U bar	R bar	U bar	U Bar	
0 to 1	-0.96	-1.06	-1.03	-1.15	-1.06	-1.19	-1.20	-1.34
1 to 2	-0.76	-0.87	-0.82	-0.94	-0.84	-0.97	-0.95	-1.09
2 to 3	-0.56	-0.67	-0.60	-0.73	-0.62	-0.75	-0.70	-0.85
3 to 4	-0.36	-0.48	-0.39	-0.52	-0.41	-0.54	-0.46	-0.61
4 to 5	-0.17	-0.29	-0.19	-0.32	-0.19	-0.33	-0.22	-0.37
5 to 6	0.01	-0.11	0.01	-0.12	0.01	-0.12	0.02	-0.14
6 to 7	0.20	-0.07	0.21	-0.07	0.22	-0.08	0.25	-0.09
7 to 8	0.38	0.25	0.41	0.27	0.42	0.28	0.48	0.31
8 to 9	0.55	0.42	0.60	0.46	0.62	0.47	0.70	0.53
9 to 10	0.73	0.59	0.79	0.64	0.81	0.66	0.92	0.75
10 to 11	0.90	0.76	0.97	0.82	1.00	0.85	1.14	0.96
11 to 12	1.07	0.92	1.16	1.00	1.19	1.03	1.35	1.18
12 to 13	1.23	1.09	1.34	1.18	1.38	1.22	1.56	1.38
13 to 14	1.40	1.25	1.51	1.35	1.56	1.40	1.77	1.59
14 to 15	1.56	1.40	1.69	1.52	1.74	1.57	1.97	1.79
15 to 16	1.72	1.56	1.86	1.69	1.94	1.75	2.18	1.99
16 to 17	1.87	1.71	2.03	1.86	2.09	1.92	2.38	2.19
17 to 18	2.02	1.86	2.20	2.02	2.27	2.09	2.57	2.38
18 to 19	2.18	2.01	2.36	2.18	2.44	2.25	2.77	2.57
19 to 20	2.32	2.15	2.52	2.34	2.60	2.42	2.96	2.76
20 to 21	2.47	2.30	2.68	2.50	2.77	2.58	3.15	2.95
21 to 22	2.62	2.44	2.84	2.65	2.93	2.74	3.34	3.13
22 to 23	2.76	2.58	3.00	2.81	3.09	2.90	3.52	3.31
23 to 24	2.90	2.72	3.15	2.96	3.25	3.06	3.71	3.50
24 to 25	3.04	2.86	3.31	3.11	3.41	3.21	3.89	3.67
25 to 26	3.18	2.99	3.46	3.26	3.57	3.37	4.07	3.85
26 to 27	3.32	3.13	3.61	3.40	3.73	3.52	4.25	4.03
27 to 28	3.46	3.26	3.76	3.55	3.88	3.57	4.43	4.21
28 to 29	3.59	3.39	3.91	3.70	4.03	3.82	4.61	4.38
29 to 30	3.73	3.52	4.05	3.84	4.19	3.97	4.78	4.55

TABLE 29 - TEMPERATURE/PRESSURE CORRECTIONS 0D = 1066.8 mm

	Wall thickness							
	15.88 mm		17.48 mm		25.4 mm		38.1 mm	
Temp range °C	R bar	U bar	R bar	U bar	R bar	U bar	R bar	U bar
0 to 1	-0.97	-1.09	-1.01	-1.14	-1.14	-1.28	-1.25	-1.43
1 to 2	-0.77	-0.89	-0.80	-0.93	-0.90	-1.05	-0.99	-1.17
2 to 3	-0.57	-0.70	-0.59	-0.72	-0.66	-0.82	-0.73	-0.91
3 to 4	-0.37	-0.50	-0.38	-0.52	-0.43	-0.59	-0.48	-0.66
4 to 5	-0.18	-0.31	-0.18	-0.32	-0.21	-0.37	-0.23	-0.41
5 to 6	0.01	-0.13	0.01	-0.13	0.02	-0.15	0.02	-0.16
6 to 7	0.20	0.06	0.21	0.06	0.23	0.07	0.26	0.08
7 to 8	0.38	0.24	0.40	0.25	0.45	0.28	0.50	0.31
8 to 9	0.56	0.41	0.58	0.43	0.66	0.49	0.73	0.55
9 to 10	0.74	0.59	0.77	0.61	0.87	0.69	0.96	0.78
10 to 11	0.91	0.76	0.95	0.79	1.07	0.89	1.19	1.00
11 to 12	1.09	0.93	1.13	0.96	1.27	1.09	1.41	1.22
12 to 13	1.25	1.09	1.30	1.13	1.47	1.29	1.63	1.44
13 to 14	1.42	1.25	1.47	1.30	1.67	1.48	1.85	1.66
14 to 15	1.58	1.41	1.64	1.47	1.86	1.67	2.06	1.87
15 to 16	1.74	1.57	1.81	1.63	2.05	1.85	2.27	2.08
16 to 17	1.90	1.72	1.97	1.79	2.24	2.04	2.48	2.29
17 to 18	2.06	1.88	2.13	1.95	2.42	2.22	2.68	2.49
18 to 19	2.21	2.03	2.29	2.11	2.60	2.40	2.89	2.69
19 to 20	2.36	2.17	2.45	2.26	2.78	2.57	3.09	2.89
20 to 21	2.51	2.32	2.60	2.41	2.96	2.75	3.28	3.09
21 to 22	2.66	2.46	2.76	2.56	3.13	2.92	3.48	3.29
22 to 23	2.80	2.61	2.91	2.71	3.30	3.09	3.67	3.48
23 to 24	2.94	2.75	3.06	2.86	3.48	3.26	3.86	3.67
24 to 25	3.09	2.89	3.21	3.00	3.65	3.43	4.05	3.86
25 to 26	3.23	3.02	3.35	3.14	3.81	3.59	4.24	4.05
26 to 27	3.37	3.16	3.50	3.29	3.98	3.75	4.43	4.23
27 to 28	3.50	3.29	3.64	3.43	4.15	3.92	4.62	4.42
28 to 29	3.64	3.43	3.78	3.57	4.31	4.08	4.80	4.60
29 to 30	3.78	3.56	3.93	3.71	4.47	4.24	4.98	4.78

TABLE 30 - TEMPERATURE/PRESSURE CORRECTIONS OD = 1219.2 mm

A5.8 ACCEPTANCE CRITERIA

For the temperature range of 6°C to 30°C, the pressure will rise with rise in temperature (see Figure 22).

For the temperature range of 0°C to 6°C the opposite reaction will occur, i.e., a rise in temperature will produce a fall in pressure and vice-versa (see Figure 22).

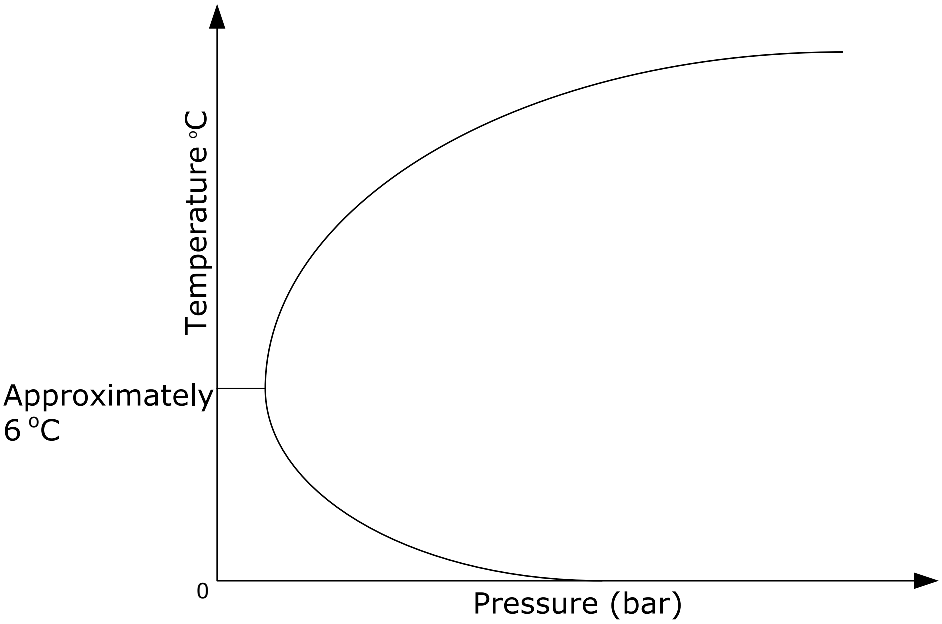


FIGURE 22 - TYPICAL TEMPERATURE/PRESSURE CORRELATION FOR PURE WATER IN STEEL PIPE

APPENDIX 6 : TESTING - WATER FILLING AND EMPTYING PROCEDURES

A6.1 GENERAL

Prior to the commencement of filling, check to ensure that:

- the proposed test section is free from debris or other extraneous matter. Where necessary, this may be accomplished by preparatory pigging
- adequate vent and drain points exist and steps have been taken to ensure that all pipework, including bridles and the like, can be fully vented, filled with test water and emptied on completion
- all valves are in the open position.

  Note: Annuli of ball valves are capable of being pressurized where necessary, by means of temporary connections from the annulus vent to the test section pipework or by closing the valve by approximately 50%. In all cases, the manufacturers' instructions for testing need to be observed.

- all below-ground pipework has been backfilled, so far as is practical
- all below-ground connections prone to leakage such as flanged joints, drains, valve spindles and the like, have been left fully exposed for inspection during the test
- small bore pipework has been disconnected and suitable plugs or blind flanges installed, whenever it is not practical to include such pipework within the main hydrostatic test
- a good system of communication exists between the filling and venting stations to provide adequate control of filling and venting operations
- the pumping system used for filling is such as to reduce entrained air to a minimum and includes a break tank
- wherever practical, the filling point connection is connected to the lowest point in the test section
- the filling pump is capable of overcoming hydrostatic head due to changes in elevation and of maintaining a continuous and even flow of water
- due regard has been paid to freezing conditions and the need to protect vulnerable pipework.

  Postpone filling and testing operations during periods when the air temperature is 2°C and falling, unless adequate precautions have been taken. Consider the use of insulation materials and antifreeze solutions.

  Small-bore instrument pipework, including that monitoring the testing operations, is particularly vulnerable.

  It may be necessary to empty sections deemed to be vulnerable.

- a safe, controlled means of releasing the test pressure is available, to take account of thermal expansion during the test and on completion of the test
- provision has been made for the removal of all test water on completion of testing
- where pigs are used for filling or emptying, consideration is given to the use of pig locators/tracking devices.

A6.2 FILLING

A6.2.1 Wherever practical, carry out filling of the pipeline test sections by pigging, to minimize the volume of air remaining in the test section.

A6.2.2 Use two hi-seal pigs separated by a slug of water of adequate length to ensure entrained air behind the second pig is reduced to a minimum.

A6.2.3 Check pig rubbers for adverse wear and change where necessary, prior to the commencement of any filling operations.

A6.2.4 Consider the use of face or back pressure on the lead filling pig to prevent breakaway from the line fill.

It is recommended that this face pressure is not less than 2 bar and the pig speed is, generally, between 2 km h^{-1} and 9 km h^{-1}.

A6.2.5 Maintain a pig register for the purpose of logging pigs in and out of the test sections and recording their condition immediately after each use.

A6.2.6 Where, as in installation tests, it is impractical to use pigs for filling, consider the gradient or slope of the pipework and the possible use of multiple fill points.

A6.2.7 On completion of filling operations, allow time for the water temperature to stabilize prior to the commencement of pressurization. The time needed is dependent upon the temperature differential between the water source and ground.

A6.2.8 Once stabilisation has occurred, determine the air content of the test section (see clause 8.5.1 and Appendix 5 as appropriate), utilising a P/V plot. If the air content is found to exceed the limits set in clause 8.5.1, take remedial measures which may include refilling or additional venting.

A6.3 EMPTYING

A6.3.1 After satisfactory completion of the hydrostatic test, reduce the test pressure to a safe level, by means of a pressure reduction valve. Consider the rate of reduction and agree in advance. Take into account the condition of the test water, the means of disposal and any potential impact on third parties.

A6.3.2 Do not retain the full test pressure for transfer to another test section.

A6.3.3 For associated installations, remove all water from the test section. Pay particular attention to low points, bypasses and such items as valve bodies, where siphoning or other techniques may be required to remove completely all the water.

A6.3.4 Where pigs were used for filling, emptying may be achieved by the same means, using compressed air as a propellant.

Under this circumstance, do not attempt to empty the test section by allowing the water to drain away under the effects of gravity alone.

A6.3.5 Either transfer discharge water to an adjacent test section or dispose of it to an agreed location.

A6.3.6 Transfer of water to an adjacent test section should not be carried out using flexible hoses. Purpose built steel fabrications utilising mechanical joints must be used to reduce the risk of injury to personnel in the event of failure.

Note: Flexible hoses are more prone to whip in the event of failure, increasing the risk of serious injury.

APPENDIX 7 : IN-LINE PIGGING OPERATIONS

A7.1 **SAFETY**

A7.1.1 Adequate supervision, as well as clearly defined codes of practice, standards and maintenance schedules are necessary, if protection is to be afforded to all personnel, members of the public, property and plant.

A7.1.2 Install all equipment required for the operation in accordance with relevant codes of practice, corresponding to current pipeline construction standards and test before attachment.

A7.1.3 **Hazardous areas**

- Consider the hazardous areas designated around the pig traps and the temporary venting sites
- the requirements for the hazardous areas, during the pigging, may be different from those for normal working conditions on the site. Site any source of ignition as far away as possible and in no case less than 15 m away from any point of possible leakage of gas or flammable liquids. Consider the prevailing wind conditions
- treat temporary lighting as a source of potential ignition.

A7.1.4 **Venting arrangements**

- Consider the implication of venting and gas dispersion to atmosphere. Situate vents in a safe location and, on the day of the operation, determine that conditions are safe for venting large quantities of gas. Additional guidance is provided in IGE/SR/23
- for temporary vent systems, the actual vent flow rate chosen depends upon a number of factors including:
  - location
  - available size for the controlled vent area
  - permissible noise levels
  - time available
  - weather conditions.
- arrange vent stacks to discharge vertically upwards with the top of any vent stack at least 3 m above the ground and any adjacent platform. Ensure the stack exit velocity is sufficient to ensure rapid gas dispersion, with due regard to environmental constraints
- for vents stacks used to vent from pressures above 15 bar, incorporate 2 vent valves. Use the downstream valve to control the vent so that, if it freezes, the upstream valve can be used to close off the vent
- considering thermal radiation, in the event of venting gases igniting, locate the vent stack in a controlled vent area, subject to operational procedures. Provide for emergency shut down by, for example, fitting remotely operable valves in series with the venting control valves.

A7.1.5 **Noise abatement**

A certain amount of noise is inherent in a pigging operation, particularly with the gas venting and the use of mechanical plant. Employ the best practicable means to minimize noise emission to levels acceptable to site personnel and third parties. Such means include:

- siting and screening of plant
- use of acoustically attenuated power tools, compressors and generators
- avoidance of operations outside normal working hours.

A7.1.6 **Electrical equipment**

Install suitable explosion-protected electrical apparatus used on site where gas may be present.

Note: The requirements for the hazardous areas during pigging may be different from those for normal working conditions on site.

A7.2 **PLANNING AND PRELIMINARY WORKS**

A7.2.1 Prepare a detailed programme of operations and agree it with all affected parties. Define individual and functional responsibilities as well as safety procedures.

A7.2.2 In the preparation of the programme, consider the following:

- the mechanism to be used to control the pig speed
- the mechanism to be used to track the pig and measure the speed
- the need to isolate offtakes and/or branches along the length of the pipeline
- consultation with the appropriate gas control organizations
- the pigging sequence needed to complete the on-line inspection
- any special requirements of any of the pigs for example speed range
- the need to specify the valve operating sequence. Prepare a suitable procedure
- the need to establish emergency, safety and operational procedures, to be followed in the event of the failure, sticking or stalling of the pig, a pipeline failure or a gas supply failure
- the impact of the pigging operation on other site work and activities
- the establishment of good communication links
- the need to check the condition of pig trap seals and replace if necessary
- the availability of supplies of nitrogen, to purge the pig traps before the insertion and removal of the pigs
- the implications of venting gas to atmosphere and the need to give notice to the Police, Fire and aviation authorities, nearby inhabitants and other interested parties
- the likely weather conditions and the proximity of any sources of ignition and hazardous areas
- the possibility of liquid being present and the requirement to install tankage, drip trays and pipework at the reception site
- the regulations applying to the safe handling, storage and disposal of flammable liquids
- the methods to be used and the requirements for the disposal of any deposits or liquids recovered, including safe removal of the tankage. Take account of the possibility of extracting pyrophoric material

- the need to brief all staff on their involvement immediately prior to the commencement of the operation and to undertake a final check of all equipment and the position of all valves
- the need for welfare facilities on site for the duration of the pigging operation.

Do not consider the above list to be exhaustive. They can be adapted to prevailing circumstances. Some of the items are covered in greater detail in the rest of this Appendix.

A7.2.3 **Pigging procedure**

Treat all pigging operations as non-routine operations. Prepare a detailed written procedure detailing the valve operating sequence and all the steps required to complete the pigging operation and having regard to and indicating clearly, preparations and actions necessary to ensure:

- that the line is free of any liquid or, if liquid is thought to be present, it should include items for the collection and disposal of any liquid
- that gas flow will be maintained throughout the operation
- that it is understood what actions are to be taken in the event of an unscheduled circumstance, such as the pig sticking.

A7.2.4 **Speed control**

Make arrangements for controlling the speed of the pig. This can be achieved by:

- controlling the gas flow in the pipeline network
- throttling the gas flow at the launch or receive site via a plug valve that can easily be replaced if damaged. Do not use a ball valve for throttling
- using a pig with an on-board speed control mechanism.

A7.2.5 **Offtakes**

A7.2.5.1 Wherever possible, isolate offtakes which have a diameter greater than 50% of the mainline diameter and which do not or may not, have guide bars fitted to the offtake tee, during the pig’s passage to prevent the pig jamming in the throat of the tee.

A7.2.5.2 For offtakes with more than one inlet connection on the piggable pipeline, close all but one inlet to avoid a duplicate gas path that would cause the pig to stop.

A7.2.5.3 Monitor offtake filters during the pigging operation in case they are blocked by debris disturbed by the pig.

A7.2.6 **Pig tracking**

Use specialist pig tracking instrumentation to record and monitor the pig’s progress. If this is not possible, establish listening posts along the length of the pipeline, to provide information on the pig’s progress. It may be necessary to excavate to expose the pipeline at some locations to provide an adequate coverage of listening posts.

A7.2.7 **Pig characteristics**

A7.2.7.1 Consider additional factors relating to the pig performance, for example acceptable velocity, range and differential pressures, during the pigging operation.

A7.2.7.2 Determine the limits which can be tolerated in the event of an unscheduled occurrence, such as a pig sticking.

A7.2.8 **Non pigging site activities**

A7.2.8.1 Fence the site to prevent unauthorised access and to give protection from other activities taking place in the vicinity. Where necessary, suspend these activities during critical periods of the pigging operation.

A7.2.8.2 When tanks to receive liquid are to be installed ensure they are:

- of a standard suitable for the storage of a volatile liquid
- tested hydrostatically to 0.7 bar after fabrication and revalidated annually
- a sufficient capacity to contain all the liquid which may be present in the pipeline
- provided with facilities for sealing the tanks, with provision left for breathing to atmosphere through a flame trap, which is to be open during the pigging operation
- fitted with large diameter vents, without flame traps and of suitable height to be used during the operation, to prevent build-up of pressure in the tank. Do not fit valves to these large diameter vents
- constructed and supported such that interconnecting pipework will withstand full pipeline pressure and be complete with a liquid flow control valve and a form of slam-shut device to prevent the tank being over-pressurised
- fitted with a suitable pressure gauge
- installed in a safe place, at least 15 m from the pig receive trap and any source of ignition and be on good hard standing, accessible to road transport. The provision of bunds may be necessary if the tanks are not fitted with integral bunds
- arranged such that all flanged joints are electrically bonded and the pipework connected to earth with a resistance not exceeding 20 ohms.

A typical pipework layout incorporating appropriate safety devices is shown in Figure 23.

A7.3 **PIGGING SEQUENCE**

Before an on-line inspection tool can be used, prove that its passage will not be impeded in any way. A typical sequence of operations for proving the pipeline requires steps 1 to 5 as detailed below, although there may be variations in the detail in particular circumstances.

For repeat inspections, discretion may be used to modify or omit some of these steps. In exceptional circumstances, where large accumulations of debris are suspected, specialist advice will be needed concerning preferred cleaning procedures, before any pigs are passed through the pipeline.

A7.3.1 **Pigging sequence : Step 1 : Check for severe bore reductions**

A7.3.1.1 The first pig which is passed through the pipeline needs to be capable of passing severe bore reductions, of typically 25%. The pig is used to prove that the gauging or geometry pig will pass through the pipeline.

A7.3.1.2 Pigs need to have a small diameter body fitted with conical cups, having “blow over” characteristics appropriate to flow demands at the time of pigging, or be equipped with a bypass arrangement which will come into effect if the pig becomes stuck. The pigs need to be constructed of such materials and be to a design that does not result in damage during the passage through the pipeline.

A7.3.2 **Pigging sequence : Step 2 : Record changes in pipeline cross section (detect dents)**

Pass a geometric pig, which can measure and/or record the location of gross changes in the cross-sectional dimensions of the pipeline, from the launcher to the receiver. This is to prove that the pipeline bore will accommodate the pigs intended to be passed through the pipeline. Use the interpretation of this record to help determine whether to proceed with the sequence or to stop and investigate anomalies. The record may also be used to assess the degree of cleaning required.

A7.3.3 **Pigging sequence : Step 3 : Check for bends less than 3D**

Subject to the bend-passing ability of the inspection pig and/or cleaning pigs to be used, it may be necessary to use a suitable gauge pig, to confirm the absence of bends of equivalent radius of less than 3 times the diameter of the pipe.

A7.3.4 **Pigging sequence : Step 4 : Clean the pipeline (this may involve several pig runs)**

Remove pipeline debris from the pipeline using a "cleaning pig". Magnets may be fitted to the cleaning pig in order to remove ferrous material. Repeat the operation until the pipeline is judged to be clean.

A7.3.5 **Pigging sequence : Step 5 : Profile the pipeline to ensure the inspection pig can pass through**

Pass a "profile pig", which has been designed to check that the configuration of the pipeline is compatible with the inspection pig, through the pipeline. Depending on the type of cleaning pig, it may be necessary to pass the profile pig through the pipeline prior to the use of the cleaning pig.

A7.3.6 **Pigging sequence : Step 6 : The on-line inspection**

Do not allow the time interval between the completion of the pigging operations steps 1 to 5 and the on-line inspection pigging operation to be excessive. Ensure it is appropriate to local circumstances and as short as possible, to reduce the possibility of changes occurring as a result of ground movement or interference.

A7.4 **RUNNING THE PIG**

A7.4.1 Prior to commencing a pig run, confirm that:

- all preparatory work has been completed at all sites
- all valves are in the correct open or closed positions
- tankage, if installed, has been purged with nitrogen. In the event of delay between purging and arrival of liquids, allow the nitrogen purge to continue to prevent diffusion of atmospheric air into the tanks
- all personnel are at their appointed posts
- communications are established and secure
- notifications required by third parties have been complied with
- the effect of actual weather conditions and the proximity of any sources of ignition and hazardous areas to the operational areas have been considered
- a final consent is obtained to proceed from the gas control centre.

A7.4.2 **Launch**

A7.4.2.1 Carry out a final check as to size and serviceability of the pig, prior to loading into the pig trap.

A7.4.2.2 Connect electrically the launching equipment and pig to the pig trap before opening the pig trap door to dissipate any build-up of static charge.

A7.4.2.3 During pressurization of the pig trap, take care to equalize pressure across the pig and the downstream pig trap isolation valve, to avoid damage to the pig trap valve in the event of the pig moving forward and to prevent the pig moving backwards into the pig trap oversize when the pig trap valve is opened.

A7.4.3 **Pig running**

Monitor the progress of the pig using the tracking equipment or by reports from the listening posts. Control the pressures upstream and downstream, to achieve a consistent pig speed. Maintain an appropriate downstream pressure to avoid velocity excursions and to avoid sustained excessive velocities.

A7.4.4 **Reception**

A7.4.4.1 Connect electrically the receiving equipment to the pig trap before opening the pig trap door to dissipate any build up of static charge.

A7.4.4.2 As the pig approaches the receive trap, carefully monitor its progress.

A7.4.4.3 If the receive tee has guide bars, stop the pig at the tee and then receive it in a controlled and safe manner.

A7.4.4.4 If the receive tee does not have guide bars, control the pig velocity to ensure that the pig can be received in a safe manner.

A7.4.4.5 Where liquid is present or suspected, route the venting gas to the reception tanks at a stage early enough to ensure that liquid is not carried forward into the offtake or next section of the pipeline or discharged to atmosphere. A suitably positioned listening post can be used to indicate the pig approach.

A7.4.4.6 Fill reception tanks successively, leaving sufficient ullage in each tank to ensure no overflow, for example 90% full. Vent the pig trap, ensuring that no pressure is trapped between the pig and the pig trap isolation valve, purged to nitrogen and remove the pig. Where liquid is present, take care to avoid spillage.

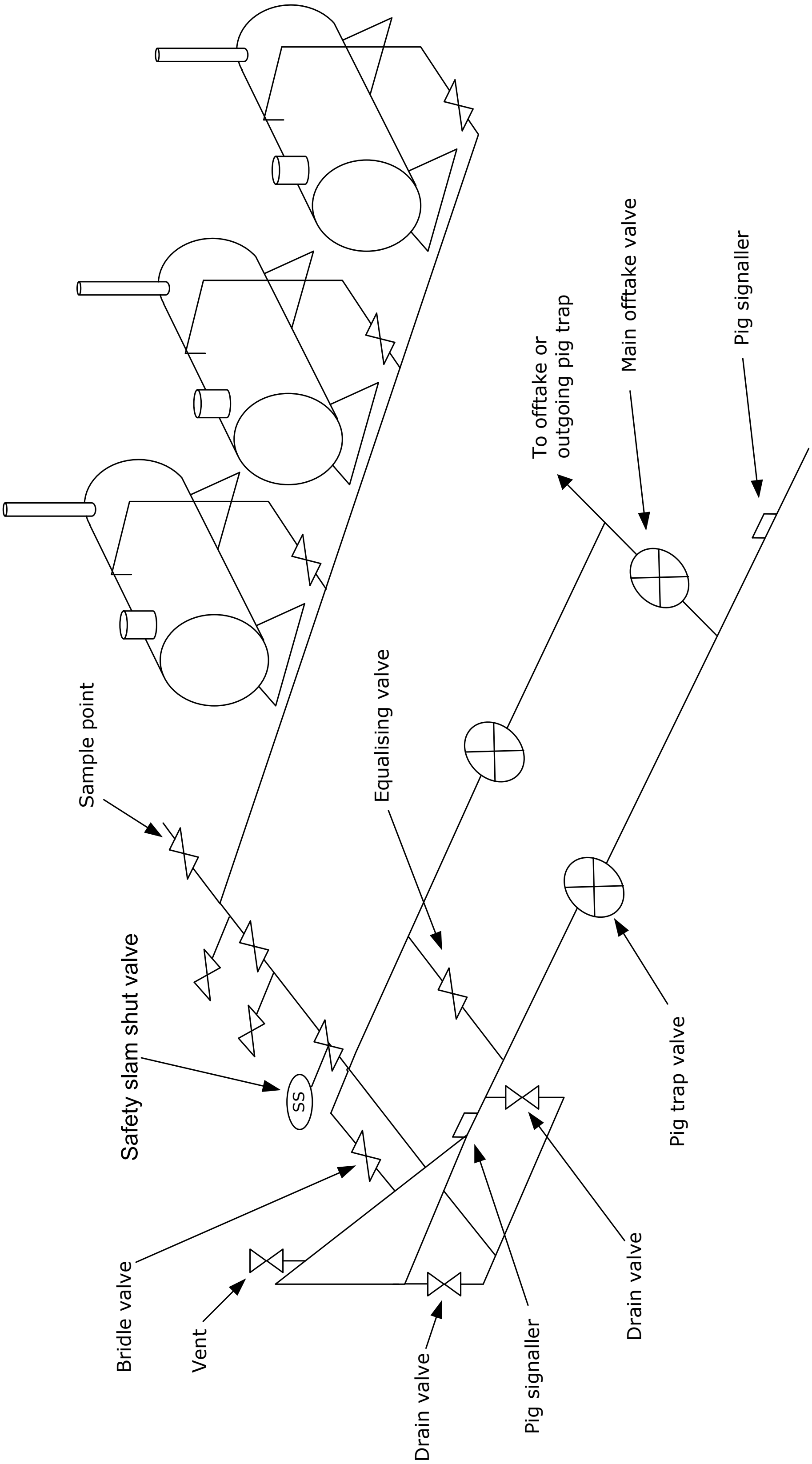
A7.4.5 **Completion**

Immediately on completion, take the following actions in accordance with the written procedure:

- notify the gas control centre
- readjust the system pressures and restore valves to the required operational position
- if liquid has been present, regrease all valves
- if offtakes exist on the system, check all fillers
- maintain the pig trap doors, for example clean sealing faces and regrease and replace seals as necessary
- purge all temporary connections to nitrogen before removing and blanking off
- blank off all tank vents except one, which is fitted with a flame trap. Do not fit a valve with the flame trap
- determine the mass of deposits and/or liquids and take samples for analysis
- remove the deposits and/or liquids from the site as soon as possible and dispose of in accordance with appropriate regulations.

A7.5 RECORDS

Prepare a report of the inspection operation, incorporating all the results and experiences. Retain this report as part of the pipeline records.



Note 1: *Some difference in layout may occur if the pig trap is not "universal" as shown.*

Note 2: *Two drain valves are fitted on the pig trap to cater for the possibility of one aperture being sealed off by pig cups*

FIGURE 23 - TYPICAL ARRANGEMENT OF PIPEWORK AT A PIG RECEPTION

APPENDIX 8 : WATER COURSE CROSSING SURVEY TECHNIQUES

A8.1 SELECTION OF SURVEY TECHNIQUES

A8.1.1 Table 31 provides a guide to methods of inspecting water course crossings according to the water depth.

A8.1.1.1 Minor, very shallow water course crossings may be surveyed by wading. Take special care in fast flowing waterways or where water temperatures are low.

A8.1.1.2 Hydrographic surveys can provide sufficient data to quantify any change in status, for example position, exposure, burial and cathodic protection levels of the pipeline. However, they may not be able to highlight damage, unless of significant proportions. Shallow water imposes limitations on the performance of acoustic equipment and operations may be restricted at times of high water current.

A8.1.1.3 Remote operated vehicle operations vary depending on the vehicle size but, in the simplest form, can operate in similar conditions to a hydrographic survey. The larger and more complex the remote operated vehicle, the larger the required support vessel and crew. Work will be restricted by high water current, lack of visibility and by access limitations due to the support vessels draught.

The advantage of remote operated vehicle surveys is that both acoustic and visual data can be obtained, but they can take longer to complete than hydrographic surveys.

A8.1.1.4 In shallow water, diving operations, using graduated poles, is the basic method of determining the location of a pipeline. In deeper water, where the pipeline is exposed, the versatility of a diver is unequalled, because of their ability to feel and see the pipeline.

Carry out all diving operations in accordance with appropriate diving regulations. Due to the specialist nature of this type of work, obtain the advice of personnel experienced in diving before operations are undertaken.

A8.1.1.5 The monitoring of the external condition of a pipeline crossing, by internal inspection equipment, is not limited by the nature of the water course, only by the ability of the pipeline to be pigged (see clause 12.10.3). Give careful consideration to duplicate or twin crossing, where the standby line may not be piggable.

WATER DEPTH (m)	WADING	HYDROGRAPHIC	REMOTE OPERATED VEHICLE	DIVER	INTERNAL INSPECTION
< 1	Possible	Not practical	Not practical	Not practical	Applicable
1 to 5	Not applicable	Possible[1]	Not practical	Applicable	Applicable
5 to 15	Not applicable	Applicable	Possible[2]	Applicable	Applicable
15 to 50	Not applicable	Applicable	Applicable	Applicable[3]	Applicable
> 50	Not applicable	Applicable	Applicable	Applicable[4]	Applicable

Notes:
1 – Resolution of records deteriorates as water depth decreases
2 – Operations can be limited by the size of the remote operated vehicle and the draft of the support vessel
3 – Remotely operated vehicle inspection is safer than diver inspection, especially at the greater depths (when saturation diving may be required)
4 – Saturation diving only

TABLE 31 - UNDERWATER SURVEY METHODS

A8.2 UNDERWATER PIPELINE INSPECTION TECHNIQUES

A8.2.1 Inspection of major water course or estuary crossings can be undertaken by one or more methods, depending on the amount of information required and the local conditions.

The following is a brief description of the options currently available.

A8.2.1.1 *Hydrographic survey*

A hydrographic or acoustic survey involves the gathering of data, from the transmission and reception of acoustic signals. The survey is undertaken from a shallow draft vessel, suitably equipped for the operation, with position control maintained by an appropriate navigation system.

The type of survey equipment used can be categorised as follows:

(a) Echo sounder – this equipment continuously records the depth of water beneath the survey vessel. The data is used to produce a plot of seabed topography and may also indicate trenches, spoil heaps or areas of pipeline exposure. By comparing with previous survey data, major changes in seabed material can be monitored.

(b) Sub-bottom profiler – this system operates in a similar manner to an echo sounder, but at lower frequencies. At these lower frequencies, the beam penetrates the seabed and some energy is reflected at density change interfaces. Concrete coated pipelines are excellent reflectors and produce a characteristic pattern on the records, which enables the depth of burial to be determined.

(c) Side scan sonar – this equipment emits a pulse of acoustic energy across the seabed with the reflected signals being recorded. The strength of the reflected signal is a characteristic of the seabed material and topography and is used to produce a representational high-resolution plot from which the position and lengths of exposed pipeline can be ascertained. In addition, should the pipeline be suspended above the seabed, then the height of free span can be calculated from the records.

(d) Trailing wire cathodic protection system – although not an acoustic device, this system is usually operated in conjunction with the above. Depending on the length of crossing, the amount of shipping and the water current, an insulated wire, connected to the pipeline ashore, can be trailed over the crossing. By reference to a half cell suspended from the vessel, gross deficiencies in the cathodic protection levels can be highlighted.

A8.2.1.2 *Remote operated vehicle survey*

Where there is sufficient water depth and suitable environmental conditions, a remote operated vehicle can be used to visually and acoustically inspect the pipeline and the adjacent ground. A remote operated vehicle is a tethered submersible which is operated from a surface vessel and varies in size according to its required tasks.

A remote operated vehicle equipped only with a video camera can be used, but, for detailed inspection, it would carry a suite of cameras, together with pipe tracking sensors described in A8.2.1.1, using the remote operated vehicle as a stable work platform.

A8.2.1.3 *Diver inspection*

Divers, using surface demand air or mixed gas saturation diving techniques, can inspect all exposed areas of a pipeline and, where necessary, depending on environmental conditions, record, on video, the state of the pipeline for further viewing. NDT inspection can also be undertaken on any damaged sections of pipeline.

If the pipeline is buried, a graduated probe magnetometer can be used to determine the approximate depth of burial or to confirm that the pipeline is at least buried to the minimum depth required. CP levels can be obtained using a half cell and meter or, for bare steel, bathycorrometer.

A8.2.1.4 *Internal inspection*

Refer to clause 12.10.3.3 for details of the application of internal inspection equipment and for external condition monitoring of water course crossings. Inspection vehicles are available for the detection of metal loss, loss of weight coating and sizing free spans.

A8.3 SURVEY PROCEDURES

A8.3.1 Prepare a detailed programme of operations and agree it with affected parties. Define individual and functional responsibilities as well as safety procedures.

A8.3.2 Prior to commencing any operations, confirm that:

- equipment is fit for purpose and that all calibration and/or test certificates are current
- the survey works are covered by a permit to work system
- all necessary licenses and approvals from any interested parties/authorities have been obtained. In particular, ensure all agreements with affected landowners are available.

A8.3.3 In order that survey data can be prepared, use a standard reference datum.

Note: The most common reference datums in the UK are published by OSGB (1936).

A8.3.4 During the site works, prepare a report detailing the work carried out during the previous 23 hours, including any significant findings, rate of progress and proposed work for the next period.

A8.4 SURVEY REPORTS

Include in the survey report:

- Background
    - the title of the owner and controlling authority
    - frequency and extent of dredging operations
    - tidal effects
    - extracts from hydrographic survey data
    - location of sand and mud banks, including details of drift
    - anchoring of navigational aids and vessel anchoring points
    - bank erosion
    - harbour and civil works.
- Details and results of the survey
    - workscope
    - methodology and practices used
    - details of equipment and personnel
    - survey results
    - charts and drawings
    - conclusions.

APPENDIX 9 : METHANOL SWABBING

This operation is based on the principle of double slugging, where two slugs of methanol are passed through a pipeline, separated by nitrogen, the methanol being contained between conventional swabbing pigs. It is usual with this method to gas up immediately behind the methanol pig train. To prevent the formation of flammable mixtures, a nitrogen slug will need to precede the first and following pigs.

A9.1 METHANOL RECEPTION ARRANGEMENTS

A9.1.1 Ensure tanks installed to receive methanol are of a suitable standard to store volatile liquids and are hydrostatically tested to 0.7 bar. Re-validate the hydrostatic test annually.

A9.1.2 Ensure the capacity of the installed tankage to receive methanol is sufficient to contain the volume of injected methanol plus any other liquids present in the pipeline.

A9.1.3 Provide facilities for sealing and for allowing breathing to atmosphere via a flame trap and which can be closed during pigging.

A9.1.4 Fit the tanks with large diameter vents which are not fitted with flame traps or valves. Size these vents to suit the purging procedure used during pigging to prevent pressure build up in the tanks.

Ensure the pipework from the pipeline to the tanks and any interconnecting pipework between the tanks is designed, constructed and tested to withstand full pipeline pressure, and is fitted with a liquid flow control valve and slam-shut protection to prevent over-pressurising the tanks.

Electrically bond all flanged joints and connect the pipework/tank system to earth with a resistance less than 20 ohms.

Fit a suitable pressure gauge to each tank.

Locate the tanks on good hard standing, accessible from the access roads, and at least 15 m from the pig receiver and any sources of ignition. Consider providing bunds to contain any spillage.

At the launch and reception sites, purge the methanol reception tanks and pipework with nitrogen. Vent the nitrogen from the pipeline atmosphere and collect the methanol/water mixture in the tanks. Take care to ensure that venting is directed through the tanks, allowing sufficient time to prevent escape of methanol into the atmosphere.

A9.2 LAUNCH AND RECEPTION SITE OPERATIONS

A9.2.1 Before nitrogen injection begins, open the vent at the reception terminal.

With the pig launcher isolation valve open, inject sufficient nitrogen to purge the trap and to give a slug of at least 10% of the length of the pipeline at atmospheric pressure, with a minimum length of 800 m.

A9.2.2 Liquid nitrogen tankers may be the most convenient means of providing the large quantities of nitrogen required for this purpose. Ensure the connections from source of supply are to appropriate engineering standards.

A9.2.3 When separate vaporisers are used, anchor them securely to the ground and site the source of heat at least 15 m away from any flammable material and from operational equipment.

A9.2.4 Confirm the contents of any nitrogen supply before connecting to the manifold. Design the manifold for safe operation at the commissioning pressures.

A9.2.5 Warn personnel of the danger of asphyxiation, due to oxygen deficiency, arising from a high concentration of nitrogen in a confined space. Where necessary, carry out a periodic test to show that there is a safe working atmosphere.

A9.2.6 During methanol injection, keep the number of personnel in the pig trap launch area to a minimum.

A9.2.7 Make available adequate supplies of methanol prior to the start of the operation. Ensure the methanol has been ordered to, and complies with, the following specification:

- specific gravity at 15.5°C not more than 0.798
- acidity not more than 0.003% by weight, calculated as formic acid.

Check methanol delivered to the site and, before use, certify that it complies with the above specifications.

A9.2.8 Using suitable equipment, insert Pig 1 into the trap and propel forward a short distance along the pipeline under nitrogen pressure (see Figure 24).

Inject the first slug of methanol downstream of the pig trap isolating valve, making sure that the isolating valve is closed and the adjacent downstream vent open. On completion, close the vent. Calculate the volume of methanol to be injected:

Volume per slug = 0.7 x d litres/km of pipeline,

d = nominal diameter of pipe (mm).

After the first slug of methanol has been injected, insert Pig 2 into the trap and propel along the pipeline by nitrogen to give a slug of length not less than 800 m when compressed to gassing up pressure.

Insert Pig 3 into the trap and propel it forward a sufficient distance to allow the second slug of methanol to be injected. On completion of the methanol injection, place Pig 4 into the trap and propel it clear of the pig trap valve using nitrogen. At this stage, close the reception terminal valve.

A9.2.8.1 *Gas injection*

A further pig (Pig 5) may be despatched, after a predetermined interval, to minimise the quantity of liquid left in the line and to facilitate the purging of the pig trap and associated pipework prior to receipt of gas.

Before the gas injection operation commences, confirm that the communication network is operational and that all personnel are at their respective locations.

Confirm that the operation can proceed from the appropriate gas transmission control centre.

Note: Gas may be injected into the pipeline via the pig trap control valve(s).

Initially, increase the flow of gas injected to that calculated to propel the pigs at an approximate speed of between 6 to 8 km h^{-1} for optimum performance. Once the pre-determined pressure downstream of the commissioning train is reached, normally between 1 and 2 bar, control the pressure by venting at the reception terminal. Until the approach of the pig train, do not exceed 2 bar.

Gas pressures will vary as the pigs negotiate bends and gradients, but do not adjust the flow of gas or venting rate unless an excessive differential pressure develops across the pigs or their reported arrival at listening posts indicates that the speed is, generally, not in accordance with that programmed.

A9.2.8.2 *Reception terminal operations*

During purging, keep the number of personnel in the terminal pig trap area to a minimum.

(a) Transfer of control

When the reception pressure has increased to a pre-determined maximum value, normally between 1.4 bar and 2 bar, regulate the vent and transfer control to that end of the pipeline.

Check the atmosphere issuing from the terminal vent. When nitrogen begins to arrive, open the discharge valves to the methanol reception tanks (ensure all other vents to the atmosphere are closed). Divert discharged nitrogen to purge each methanol reception tank in turn, prior to the arrival of the methanol.

Carry out atmosphere checks in the vicinity of the methanol reception tanks regularly during nitrogen purging and methanol discharge. Do not allow personnel to be exposed for prolonged periods to an atmosphere where the methanol vapour concentration exceeds 200 ppm.

(b) Progress and arrival of pigs

Take care during the removal of the pigs at the reception terminal, owing to the presence of methanol and its associated potential hazards. Wear suitable protective clothing. Make available breathing apparatus, safety equipment, safe lighting and an adequate supply of water for hosing down for any contingency.

Careful listening and interpretation of pressure variations will indicate the approach of Pig 1 and the first slug of methanol.

Note: The location of pigs can be estimated from the flow of the gas and their progress checked by the arrival time of pigs at the listening posts.

Arrival of the first pig will be indicated by the pig signaller which needs to be re-set immediately to detect the arrival of Pig 2.

When the first pig has been received, shut off the flow of gas at the launch terminal and use the residual pressure in the line, as far as possible, to discharge methanol slugs and bring home the remaining pigs.

On receipt, remove pigs by an approved hydraulic cradle or lower them carefully from the pig trap on to timber battens. Provide suitable tools to remove the pig. Ensure the means of removal is such that sparking does not occur.

(c) Reception tank filling procedure

Fill reception tanks in sequence and carefully check the level gauges to avoid over filling. When the "on-line" tank is full, close the pig receiver discharge valve and do not re-open it until the full tank is shut off and the next empty tank put on line.

Confirm completion of discharge of the first slug by the arrival of Pig 2. Close the pig receiver isolation valve and drain the receiver and vent to atmospheric pressure with the vent(s) left open. Do not allow personnel to be in the direct line of the pig receiver door while the door is being opened to remove Pigs 1 and 2.

Open the pig receiver isolation valve and continue gas injection with the venting of the intermediate slug of nitrogen, via the reception tanks, until Pig 3 and the second slug of methanol arrives. Continue the discharge of the second slug of methanol until the completion of this operation is confirmed by the arrival of Pig 4. Remove the pigs in the manner described in A9.2.8.2 (b). If a fifth pig has been used, continue the purge until that pig arrives in the trap. Remove it in the manner described in A9.2.8.2 (b).

During these operations, take samples of methanol/water as detailed below. On completion of the operation, confirm the satisfactory purge to gas.

A9.2.8.3 *Methanol sampling, testing and interpretation of results*

(a) Make preliminary arrangements together with suitable sampling and testing equipment.

(b) Take samples of liquid from sampling cocks fitted on the connection between the pig trap and the reception tanks. Before taking each sample, purge the sampling tee. Take samples of 0.5 litres and label them at the start, the middle and at the end of each slug. If, for any reason, the samples cannot be tested immediately on site, store them in approved containers, leaving sufficient space in each container for expansion of the liquid. Ensure the person transporting the samples wears appropriate protective clothing.

(c) Test each sample by measuring its specific gravity with a hydrometer accurate to + 0.002. The range should be 0.800 to 1.000.

Samples are frequently contaminated with rust, therefore allow them to stand for a few minutes, then either decant or filter through a coarse paper before measuring the specific gravity. Measure the temperature of the liquid and if it is above or below 15.5°C, correct the observed specific gravity in accordance with Tables 32 and 33.

Ensure tests are made immediately on site wherever possible. If there is any reason to suspect the presence of hydrocarbon condensate in the liquid, send a sample to a laboratory for confirmation.

(d) Determine the volume of liquid to be pigged from each slug by taking measurements from level gauges provided in the reception tanks.

(e) Report the provisional results of the methanol sample test immediately to the appropriate control centre for confirmation of their acceptance.

Base acceptance of the swabbing operation on the total volume of liquid pigged out and the weight percentage of methanol in the last two samples of the second slug, as shown in Table 34.

Report the corrected specific gravities of the last two samples of each slug to confirm the volume of liquid pigged out. Finally, prepare a full set of results in a standard form (see Figure 24). Circulate the completed form to the relevant control centre for record purposes and to any other interested parties.

(f) Remove the methanol/water mixture and samples from site as quickly as possible using a chemical waste disposal contractor or in accordance with appropriate statutes and regulations.

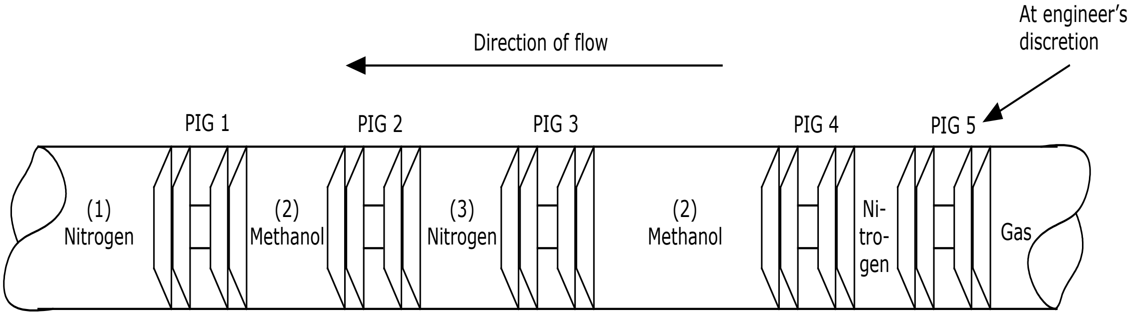


FIGURE 24 - TYPICAL ASSEMBLY OF A COMMISSIONING SLUG

Observed specific gravity	Correction per °C deviation from 15.5°C (per °C)
0.79 to 0.86	0.0009
0.86 to 0.92	0.0007
0.92 to 0.95	0.0005
0.95 to 0.98	0.0004
0.98 to 1	0.0002

The correction is added to the observed specific gravity for determinations above 15.5°C and subtracted when the sample temperature is below 15.5°C.

TABLE 32 - AQUEOUS METHANOL TEMPERATURE CORRECTIONS TO OBTAIN SPECIFIC GRAVITY AT 15.5°C

SG	WF	SG	WF	SG	WF	SG	WF
0.998	0.01	0.961	0.23	0.918	0.51	0.861	0.76
0.997	0.02	0.959	0.27	0.916	0.52	0.859	0.77
0.995	0.03	0.958	0.28	0.914	0.53	0.856	0.78
0.993	0.04	0.956	0.29	0.912	0.54	0.854	0.79
0.991	0.05	0.955	0.3	0.910	0.55	0.851	0.8
0.990	0.06	0.953	0.31	0.907	0.56	0.849	0.81
0.988	0.07	0.951	0.32	0.905	0.57	0.846	0.82
0.987	0.08	0.950	0.33	0.903	0.58	0.843	0.83
0.985	0.09	0.948	0.34	0.901	0.59	0.841	0.84
0.984	0.1	0.947	0.35	0.899	0.6	0.838	0.85
0.982	0.11	0.945	0.36	0.897	0.61	0.836	0.86
0.981	0.12	0.943	0.37	0.895	0.62	0.833	0.87
0.979	0.13	0.941	0.38	0.892	0.63	0.830	0.88
0.978	0.14	0.940	0.39	0.890	0.64	0.827	0.89
0.977	0.15	0.938	0.4	0.888	0.65	0.825	0.9
0.975	0.16	0.936	0.41	0.885	0.66	0.822	0.91
0.973	0.17	0.934	0.42	0.883	0.67	0.819	0.92
0.972	0.18	0.932	0.43	0.881	0.68	0.817	0.93
0.971	0.19	0.931	0.44	0.878	0.69	0.814	0.94
0.969	0.2	0.929	0.45	0.876	0.7	0.811	0.95
0.968	0.21	0.927	0.46	0.874	0.71	0.808	0.96
0.966	0.22	0.925	0.47	0.871	0.72	0.805	0.97
0.965	0.23	0.923	0.48	0.869	0.73	0.802	0.98
0.963	0.24	0.921	0.49	0.866	0.74	0.800	0.99
0.962	0.25	0.919	0.5	0.864	0.75	0.797	1.0

SG is specific gravity WF is weight fraction methanol

TABLE 33 - SPECIFIC GRAVITY OF AQUEOUS METHANOL AT 15.5°C

Total volume of liquid pigged out as a percentage of the volume of methanol introduced	Minimum weight percentage of methanol in the last two samples
60	70
70	65
80	60
90	50

TABLE 34 - MINIMUM VALUES FOR RELATIONSHIP BETWEEN METHANOL INJECTED AND LIQUID RECOVERED

APPENDIX 10 : AREA TYPE CLASSIFICATION - ADDITIONAL GUIDANCE

The following guidelines are to be used when designing the route of a pipeline and assessing the impact of a new development in the vicinity of a pipeline to assess the population density and distance of buildings from the pipeline as per the area classification definitions detailed in Sub-Section 6.7.

Wherever practical the following areas are to be avoided: built up/urban areas, centres of population or frequent human activity, including major recreational facilities, seasonal caravan camping sites, festival or show grounds.

A10.1 ROUTEING CONSIDERATIONS

A10.1.1 During the routeing process the following safety distance criteria is to be utilised. Table 35 provides specific advice on development type.

A10.1.2 Public or Community Facilities:

Schools and places of worship (churches, mosques, temples etc) are to be treated as “sensitive” developments

A10.1.3 Transport installations:

Airports, river and seaports and Ministry of Defence (MoD) facilities, are to be treated as for Public or Community Facilities as per Table 35.

Development Type	Criteria		
	Small	**Medium**	**Large**
Public or Community Facilities			
Café, Camp sites, Cemetery, Community Hall, Hostel Meeting Rooms, Local Government Offices, Conference Centre, Public House, Inn, Restaurant, Hotel, Allotments, Park, Gallery, Museum, Sporting Facilities, Cinema, Club, Library, Surgery, Clinic, Court, Police Station, Racetrack, Car Boot Sales, Funfairs, Coach/Bus/Railway Stations, Airport, Sea/River port	<100 People – 1 BPD	>100 to <1,000 People – 3 BPD	>1,000 People – 4 BPD
Commercial Retail Areas			
Retail areas, Shops, Department Store, Builder's Merchant, Cash and Carry, Bank, Car Dealer, Garden Centre, Retail Warehouse, Markets	<5,000m^2 – 1 BPD	>5,000m^2 to<50,000m^2 – 3 BPD	>50,000m^2 – 4 BPD
Commercial Industrial			
Factory, Bakery, Brewery, Chemical Works, Depot, Offices, Refinery, Research Facility, Scrap Yard, Docks, Warehouse, Plant Nursery	<100 People – 1 BPD	>100 to <1,000 People – 3 BPD	>1,000 People – 4 BPD
Sensitive Areas			
Hospital, Hospice, Prison, Nursing Home, Retirement Home, Church, Children's Nursery, Day Care, School, College, Theme Park, Large Sports Stadium, Open Air Market, Outdoor festival concert venue	All cases – 4 BPD		

TABLE 35 - DEVELOPMENT TYPES

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