IGEM
Institution of
Gas Engineers & Managers

IGEM/TD/3 Edition 5 with amendment July 2015
Communication 1780

Steel and PE pipelines for gas distribution

Founded 1863
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Steel and PE pipelines for gas distribution

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Communication 491 (1956)
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Communication 1677 (2003) – 4th Edition
Communication 1770 (2014) – 5th Edition

For information on other IGEM Standards please visit our website, www.igem.org.uk

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SECTION 1 : INTRODUCTION

1.1 Recommendations on distribution mainlaying were first published by the Institution of Gas Engineers (IGE) in 1956 as Communication 491.

Recommendations superseding Communication 491 were published progressively in 1966 (Communication 734), 1977 (Communication 967), 1983 (Communication 1203), 1992 (Communication 1514) and 2003 (Communication 1677).

This Standard revises and supersedes IGEM/TD/3 Edition 5 (Communication 1770 which is now obsolete).

1.2 This Standard 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 the Institution.

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

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

1.4 Significant amendments have been made compared to the fourth Edition. These include:

- updating from recommendations to a Standard
- competency requirements
- reviewing and updating of the legislation section
- information for pipelines operating above 20°C
- revised proximity distances for PE pipelines
- additional guidance for concrete slabbing
- updated testing requirements
- pigging requirements
- additional advice when using squeeze-off equipment adjacent to leaking or suspect fusion joints
- minimum distances between fittings and squeeze-off of polyethylene (PE) pipe.

1.5 This Standard makes use of the terms "must", "shall" and "should" when prescribing particular requirements. Notwithstanding Sub-Section 1.8:

- 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.

1.6 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. They are also intended to ensure that security of gas supply is maintained.

1.7 This Standard is applicable to conditions normally encountered in the distribution of gas. Additional design considerations may be necessary where unusual conditions are encountered, for example 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.

1.8 Notwithstanding Sub-Section 1.5, 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 of this Standard. Amendments to this Standard will be issued when necessary and their publication will be announced in the Journal of the Institution and other publications as appropriate.

1.9 The primary responsibility for compliance with legal duties 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:

(a) 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".

(b) 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.

(c) have systems and procedures in place to ensure that the exercise of professional judgement by "responsible engineers" is subject to appropriate monitoring and review.

(d) not require "responsible engineers" to undertake tasks which would necessitate the exercise of professional judgement that is not within their competence. There should be written procedures defining the extent to which "responsible engineers" can exercise their professional judgement. When "responsible engineers" are asked to undertake tasks which deviate from this, they should refer the matter for higher review.

Note: The responsible engineer is a suitably qualified, competent and experienced engineer or a suitably qualified, competent and experienced person acting under his or her supervision, appointed to be responsible for the application of all or part of this Standard.

1.10 Materials and the techniques of construction and operation are constantly being improved and it is intended to keep this Standard under review.

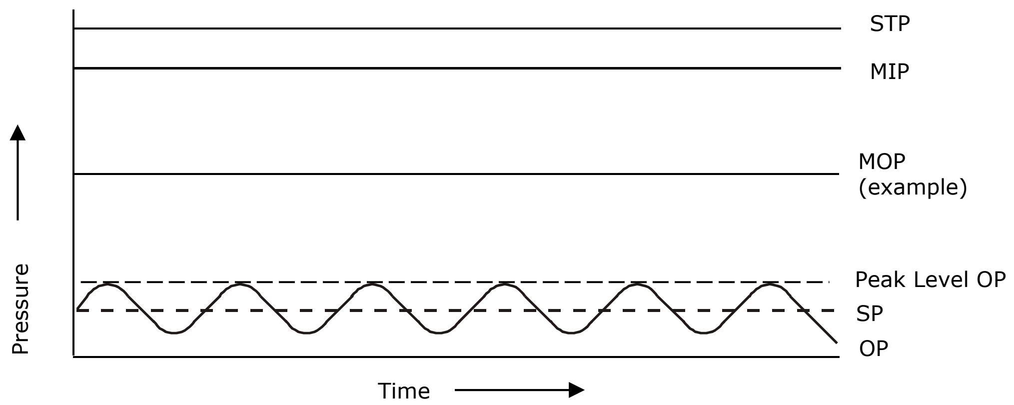
1.11 It is now widely accepted that the majority of accidents in industry generally are in some measure attributable to human as well as technical factors. People who initiated actions that caused or contributed to accidents might have acted in a more appropriate manner to prevent them.

To assist in the control of risk and proper management of these human factors, due cognisance should be taken of HSG48.

1.12 Requests for interpretation of this Standard in relation to matters within their scope, but not precisely covered by the current text, may be addressed to Technical Services, IGEM, IGEM House, High Street, Kegworth, Derbyshire, DE74 2DA, email, 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 imply acceptance of any liability for the consequences and does not relieve the responsible engineer of any of his or her obligations.

1.13 IGEM has adopted the terms and definitions used in European standards for pressure i.e. maximum operating pressure (MOP), operating pressure (OP), maximum incidental pressure (MIP) and strength test pressure (STP). Figure 1 explains these terms. Further guidance can be found in IGEM/TD/13.

1.14 This Standard was published in October 2015. Amendments are shown throughout the document by ➤ ➤.



STP	=	Strength test pressure
MIP	=	Maximum incidental pressure
MOP	=	Maximum operating pressure
OP	=	Operating pressure
SP	=	Set point of the regulator.

Note: This is extracted from IGEM/TD/13 and simplified for the purposes of IGEM/TD/3 Edition 5.

FIGURE 1 - PRESSURE TERMINOLOGY

SECTION 2 : SCOPE

2.1 This Standard covers the design, construction, inspection, testing, operation and maintenance of steel and polyethylene (PE) pipelines for the distribution of dry Natural Gas (NG) (predominantly methane) (with or without odorisation) and Liquefied petroleum gas (LPG). It also covers modification and connection to existing pipeline systems.

Note: Consistent with European Standards, IGEM now defines pipeline type by specific pressure limits, rather than using such terms as "high, intermediate, medium and low pressure". In general, it also strives to avoid using the terms "distribution main" and "service" but, in the UK, these are terms still in common use. In general, this Standard applies to pipelines of MOP not exceeding 16 bar and which are not "services" as defined by IGE/TD/4.

In most cases, this will mean IGE/TD/4 will apply between the "distribution main" as covered by IGE/TD/3 and the emergency control valve (ECV) denoting the end of the gas supply network. IGEM/G/1 provides extensive definitions with respect to the end of a gas supply network.

2.2 For NG, this Standard covers pipelines operating at MOP not exceeding 10 bar for PE and not exceeding 16 bar for steel and at a temperature from 0°C to 20°C inclusive for PE and -25°C to 40°C inclusive for steel. For LPG, this Standard limits MOP to 2 bar in the LPG vapour phase.

Note 1: This Standard does not specifically cover the construction of pipelines of other materials. However, Section 9 (operation and maintenance) does include requirements on the maintenance of iron systems.

Note 2: When any new material, for example ductile PVC, PEX (cross linked polyethylene), reinforced thermoplastic pipe materials, etc. is to be used, a structured methodology is required to establish that its use is acceptable. Engineers may consider alternatives brought about by advances in technology and proven concepts (see Sub-Section 1.8).

Note 3: For PE pipelines operating above 20°C the effect of fatigue impact will need to be accounted for in the design. Guidance is given in this Standard.

2.3 This Standard covers the predominantly underground network of pipes that distribute gas from a pipeline used for gas transmission, central LPG storage facility or gas production plant, service or services supplying domestic, commercial and industrial premises.

Note 1: Steel pipelines for high pressure gas transmission (MOP exceeding 16 bar and not exceeding 100 bar) are covered in IGEM/TD/1 and services are covered in IGE/TD/4. Additional advice for gas supplies to multi-occupancy buildings is given in IGEM/G/5.

Note 2: UKLPG Code of Practice 22 covers LPG service pipework not exceeding 63 mm diameter and installation volume not exceeding 0.02 m^3. IGE/TD/4 covers LPG service pipework where the diameter exceeds 63 mm or where the installation volume exceeds 0.02 m^3. IGEM/TD/3 covers LPG distribution systems supplying service pipework.

Note 3: Pressure regulating installations (PRIs) are covered in IGEM/TD/13.

2.4 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 the recommendations will be 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.

2.5 All pressures quoted are gauge pressures unless otherwise stated.

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".

SECTION 3 : COMPETENCY, QUALITY ASSURANCE AND INTEGRITY OF A PIPELINE

3.1 COMPETENCY

3.1.1 Any person engaged in the design, project management, construction, testing, commissioning, maintenance and auditing activities shall be competent for the role that they are undertaking. The operators, designers and constructors of pipelines, where the post holder's activities can materially affect work activities carried out, shall:

- have a documented process for determining competency that details minimum competency requirements including training, experience, knowledge and qualification for operational and management positions

  Note: Best practice is demonstrated when role specific competency requirements are built up from job descriptions which are broken down into job related tasks against which personnel can be assessed.

- establish and maintain sufficient current, valid, credible and authentic evidence to demonstrate that individuals are competent to do work within the accredited scope (s), by:
  - ensuring that the minimum documented competencies are satisfied and that staff are trained and qualified for the work they carry out
  - a documented assessment of persons performing roles for which competencies have been set, by a suitably competent person
  - a review of individuals' ongoing competencies shall be carried out by a suitably competent person. These competency reviews shall be documented and recorded.

  Note 1: Role specific competencies are best summarised in a matrix detailing the minimum requirements for each role and showing the actual level of competence for each role holder. Such a matrix should be supported with evidence confirming qualifications, training, experience, aptitude and fitness.

  Note 2: Best practice for first line supervisors and technical staff the review will need to be carried out at least once every three years as a minimum. For operatives, the review will need to carried out on an annual basis as a minimum.

- have a training programme in place which is adequate to close any competency gaps
- maintain a robust process to ensure that the renewal of time limited qualifications is completed before the expiry of validity. (It is a requirement that all operatives with such time limited qualifications e.g., CPCS, NRSWA, EUSR etc. shall have evidence of in date qualifications on site).

  Note: Further guidance on competency can be found in IGEM/TD/102.

3.1.2 As appropriate, the training shall cover all aspects of safety and emergency procedures and equipment, as well as technical matters concerning the operation and maintenance of pipelines and associated equipment.

3.1.3 Under the Pipelines Safety Regulations (PSR), most of the duties concerning design, construction, operation and maintenance fall upon the operator of the pipeline. However, the operator is defined in such a way that this may change at different stages in the life of a pipeline. This Standard identifies the requirements but does not specify where the responsibility lies.

3.2 QUALITY ASSURANCE

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.

3.2.2 Arrangements shall be made to ensure that materials and workmanship are in accordance with the construction specification. All material certificates, test certificates, weld records (PE and steel) and coat-and-wrap records should be retained as required as part of the permanent construction record.

3.2.3 Particular emphasis shall be placed on the inspection of materials, jointing, 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. The results of such inspections should be retained as an ongoing and permanent record of the pipeline.

3.3 INTEGRITY OF A PIPELINE

3.3.1 The initial integrity of a pipeline is established through proper design, material selection and sound construction practices. After the pipeline has been commissioned and is in operation, a programme of monitoring and maintenance (appropriate to the material and duty of the pipeline) shall be undertaken to ensure integrity is maintained.

3.3.2 All of the requirements shall be considered and implemented as necessary to ensure that an installed pipeline operates at the levels of safety envisaged. 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 shall be considered.

Note 1: The integrity of a pipeline or pipeline system is dependent upon many inter-relating activities. Figure 2 shows the main links between the major activities. It does not attempt to show all the items necessary to ensure pipeline integrity, nor does it show the complex links within a major activity. However, it does provide a flowchart checklist to ensure that all aspects of pipeline integrity are being addressed.

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

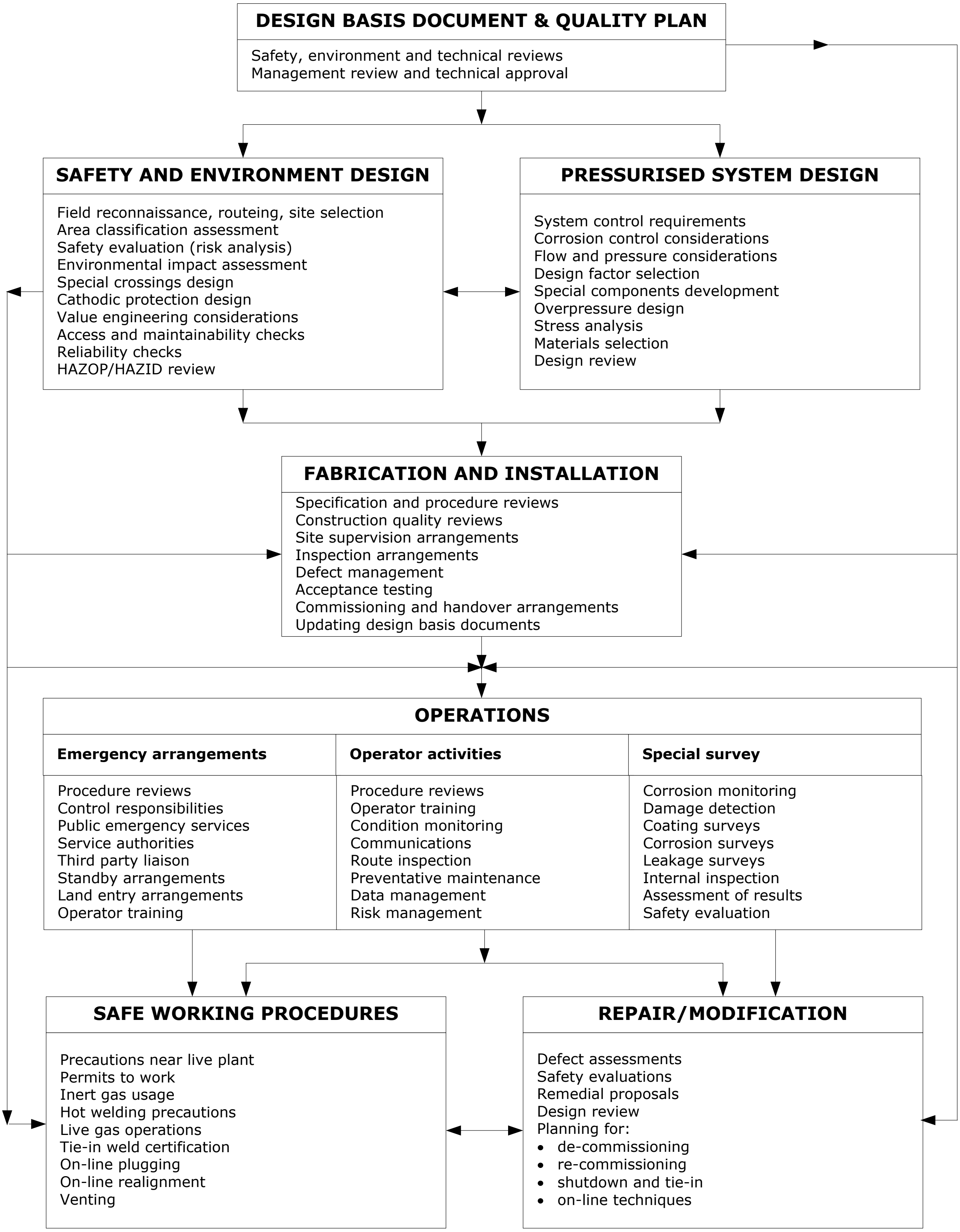


FIGURE 2 - PIPELINE INTEGRITY NETWORK

SECTION 4 : LEGAL CONSIDERATIONS

This Standard is set out against a background of legislation in force in Great Britain (GB) at the time of publication. The devolution of power to the Scottish, Welsh and Northern Ireland Assemblies means that there may be variations to the legislation described below for each of them and consideration of their particular requirements must be made. Similar considerations are likely to apply in other countries and reference to the appropriate national legislation will be necessary. The following legal and regulatory considerations are particularly relevant to the laying of pipelines for gas distribution.

Appendix 2 lists relevant legislation, standards, guidance notes etc. Where British Standards, etc. are quoted, equivalent national or international standards, etc. equally may be appropriate.

4.1 GENERAL

4.1.1 European Community (EC) legislation

In countries within the EC, it shall be ascertained, at the planning stage, whether a pipeline is likely to be subject to EC legislation.

4.1.2 National and local legislation

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

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

4.1.3 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.

4.1.4 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 buildings, the specification for the pipeline, the actual method of construction and the general working environment during construction and operation.

4.1.5 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 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.

4.1.6 **Land rights, easements and servitudes**

4.1.6.1 The rights necessary to lay, operate, inspect, maintain, repair and replace a pipeline and any ancillary equipment, not within a public highway, must be obtained from owners and/or occupiers of land affected by the works.

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.

4.1.6.2 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 or the supply agreement.

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

Excavated and other materials 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.

4.1.6.3 Of special concern are the access rights of the pipeline easement/servitude, 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 adjacent to the pipeline.

Note: Access along the easement/servitude strip only is unlikely to be sufficient.

4.1.6.4 Legal advice should be sought on the content of easement/servitude 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
- safe operation of the pipeline (including cathodic protection (CP))
- restoration of drainage
- development of the land through which the pipeline runs.

4.1.7 **Transmittable diseases**

Outbreaks of infectious or contagious animal diseases and other diseases along, or in the vicinity of, the proposed route of the pipeline may affect the laying of pipe.

Advice shall 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.

4.1.8 **Rivers, canals and foreshores**

4.1.8.1 Where crossings of rivers, canals or foreshores are contemplated, appropriate authorities or owners should be consulted.

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

4.1.8.2 The owners of the river and canal banks, beds and fishing rights shall be considered, as should third parties to whom the owners may have granted rights.

Note 1: It is desirable to consult with such interested parties as to the season of the year at which pipe laying would best be undertaken.

Note 2: It is necessary to obtain consent for the supply and disposal of water for hydrostatic testing, including the times, points and rates at which water may be drawn and discharged.

4.1.9 Railway land

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

4.1.10 Deposits of waste

4.1.10.1 The disposal of all wastes which are poisonous, noxious or polluting and likely, after disposal on land, to give rise to an environmental hazard, must be given special attention and may require authorisation or licensing from an appropriate authority.

4.1.10.2 Disposals of non-toxic waste water may be subject to licensing with special conditions and the advice of any relevant responsible authority should be sought.

4.1.10.3 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 public authority, before such activities can be undertaken.

4.1.11 Control of noise

Consideration must be given to law or 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 LEGAL CONSIDERATIONS IN GREAT BRITAIN

The following Acts and Regulations apply within GB. Legislation is subject to periodic change and it is the responsibility of the employer to ensure they are complying with the current prevailing legislation. Reference should also be made to section 4 of IGEM/TD/1 Edition 5.

4.2.1 Gas Act

The construction of a pipeline is an activity which a gas transporter (GT) is entitled to undertake under the Gas Act as amended.

4.2.2 Pipelines Act, as amended

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

- "Cross-country" pipelines (those of a Pipeline Construction Authority (PCA)) which carry deemed planning permission
- "Local" pipelines (16.093 km or under in length) which require local authority planning permission under the normal planning system.

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

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

4.2.3.2 Certain streets will be subject to special controls such as protected streets, streets with special engineering difficulties or traffic-sensitive streets. The Act lays down general requirements as to the execution of street works, places the duty of reinstatement on the pipeline operator and provides for the principle of charging for highway occupation, traffic regulation and use of alternative routes.

4.2.3.3 The Act also requires pipeline operators to make records of their apparatus in streets, to maintain apparatus, to inform other utilities, etc. of its location and to accept liability for damage or loss caused by it.

4.2.3.4 There are special provisions regarding highway, bridge and transport works. The detailed workings of the Act are implemented by regulations and codes of practice, introduced under the auspices of the Secretary of State.

4.2.4 **Town and Country Planning Act**

The laying underground of pipes or other apparatus by a GT is permitted development under the Town and Country Planning Act (General Permitted Development) Order.

4.2.5 **Health and Safety at Work etc. Act (HASAWA)**

The Act sets out general duties which employers have towards employees and members of the public and which employees have to themselves and to each other. It is also the "umbrella" under which health and safety Regulations are made. These Regulations generally require an assessment of risk for the particular hazard, control measures to be identified and deployed, training to be provided and where appropriate, health surveillance to be carried out.

Note: Further information on these regulations is available from HSE website.

4.2.6 **Traffic Management Act**

Under the Traffic Management Act (TMA), Local and Highway Authorities have introduced permitry schemes, each with their own set of guidance and requirements. These permitry schemes need to be consulted and complied with wherever they are in place prior to carrying out works which the schemes encompass on designated roads within the Local or Highway Authorities area.

4.2.7 **Management of Health and Safety at Work Regulations**

These Regulations 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.

4.2.8 **Pressure Systems Safety Regulations (PSSR)**

4.2.8.1 These Regulations apply to gas pipelines. However, gas pipelines of MOP not exceeding 2 bar (or not exceeding 2.7 bar under fault conditions) are exempted from parts of the Regulations.

The only hazard under consideration is that due to pressure - not from any flammable or toxic characteristics of the relevant fluid.

4.2.8.2 An important aspect of these Regulations is the requirement to have a written scheme of examination before commissioning and to have periodic checks carried out, by a competent person, of the pipeline system and its protective devices.

In particular, the Regulations impose duties on any person who designs, constructs, commissions, repairs or modifies pressurised systems to do so in a manner that prevents danger.

4.2.9 **Pipelines Safety Regulations (PSR)**

4.2.9.1 These Regulations apply to all pipelines, both onshore and offshore, but excluding pipelines that are:

- wholly within premises occupied by a single undertaking
- contained wholly within caravan sites
- contained wholly within land which constitutes a railway asset.

4.2.9.2 Generally, the Regulations place emphasis on pipeline integrity and have specific additional requirements for major accident hazard pipelines (MAHP) of MOP exceeding 7 bar, including the production and regular updating of a Major Accident Prevention Document (MAPD) and the requirement for the local authority to produce and revise emergency plans. The Regulations complement the Gas Safety (Management) Regulations (GS(M)R) and include the:

- definition of a pipeline
- general duties for all pipelines
- need for co-operation between pipeline operators
- arrangements to prevent damage to pipelines
- description of a dangerous fluid
- notification requirements
- preparation and maintenance of a MAPD
- arrangements for emergency plans and procedures
- description of the pipeline safety management system.

Note: Notification of MAHPs enables HSE to set land use planning zones around the pipeline and associated above ground installations (AGIs). HSE provides each local planning authority along the pipeline route with 3 zone distances which are used to generate HSE's land-use planning advice in the vicinity of the pipeline. The requirement for notification applies to all pipelines operating at above 7 bar, including PE.

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

These Regulations place a duty on clients, designers, CDM co-ordinators, principle contractors 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. Certain projects are notifiable to HSE and require the appointment of a CDM co-ordinator and provision of welfare facilities.

4.2.11 **Gas Safety (Management) Regulations (GS(M)R)**

These Regulations impose duties on those conveying gas. They require submission of a safety case to HSE. In certain circumstances, operators may apply for an exemption to submit a safety case. The regulations also cover arrangements for dealing with gas escapes and for loss of supply.

4.2.12 **Control of Substances Hazardous to Health (COSHH)**

These Regulations require assessment of risk from substances that may affect the health of workers or the public. These include issues such as silica dust from cutting concrete and possible exposure to biological agents such as leptospirosis (which can lead to Weil's disease).

4.2.13 **Control of Vibration at Work Regulations**

These Regulations apply to those using vibrating machinery, such as wacker plates, jack-hammers etc. There are limits for vibration exposure and health surveillance may be required for at risk individuals. Utility employees and their contractors are a group of workers at particular risk from ill health related to vibration.

4.2.14 **Confined Spaces Regulations**

A confined space is a place which is substantially enclosed (though not always entirely), and where serious injury can occur from hazardous substances or conditions within the space or nearby (e.g. lack of oxygen). These Regulations may apply to excavations, trenches, valve pits and chambers as well as pressure vessels. The Regulations require avoidance of entry to confined spaces, e.g. by doing the work from the outside. If entry to a confined space is unavoidable, a safe system of work is required to be developed and followed, and adequate emergency arrangements be put in place before the work starts.

4.2.15 **Working at Height Regulations**

These Regulations apply to any work at height, such as working on pig traps, valve platforms, pipe bridges or excavations. Employers are required to ensure all work at height is properly planned and organised, and persons involved in work at height are competent. The risks from working at height are to be assessed, with any risks from fragile surfaces being properly controlled and appropriate work equipment being selected and used. Any equipment for work at height is to be properly inspected and maintained.

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

These Regulations apply to all work equipment (which includes pipelines) requiring equipment to be suitable for the intended use, safe for use and maintained in a safe condition. Equipment is required to be inspected to ensure the equipment remains in a safe condition. In addition, equipment is to be used only by people who have received adequate information, instruction and training, and accompanied by suitable safety measures, e.g. protective devices, markings and warnings.

4.2.17 **Manual Handling Regulations**

These require employers to carry out a risk assessment on all manual handling tasks that pose an injury risk. The employer's duty is to avoid manual handling as far as reasonably practicable if there is a possibility of injury. If this cannot be done then they are required to take steps to reduce the risk of injury as far as reasonably practicable.

4.2.18 **Personal Protective Equipment at Work Regulations**

These Regulations require that personal protective equipment (PPE) is to be supplied and used at work wherever there are risks to health and safety that cannot be adequately controlled in other ways. The Regulations require that PPE is properly assessed before use to ensure it is suitable, maintained and stored properly, employees are provided with instructions on how to use it safely and it is used correctly by employees.

4.2.19 **Lifting Operations and Lifting Equipment Regulations (LOLER)**

These Regulations require employers to ensure lifting equipment is suitable for the intended use, safe for use and maintained in a safe condition. Where required, lifting equipment is to be inspected to ensure the equipment remains in a safe condition. In addition, equipment is to be used only by people who have received adequate information, instruction and training, and accompanied by suitable safety measures, e.g. protective devices, markings and warnings.

4.2.20 **Electricity at Work Regulations**

These Regulations apply to a wide range of electrical work and are concerned with the prevention of danger arising from electric shock, burns, arcing, electrostatic discharges or explosion initiated by electrical energy.

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

These Regulations require the risks from fire and explosions in the workplace to be controlled. Employers are required to identify fire and explosion risks and put measures in place to either eliminate those risks or, where this is not possible, control them. Risks can be controlled by reducing the effects of any incident involving dangerous substances. This will require the provision of arrangements to deal with incidents, emergencies etc. and the provision of information, training and use of dangerous substances for employees. In addition, areas in the workplace where explosive atmospheres may occur have to be identified and classified so that ignition sources can be appropriately located (from unprotected equipment, for example) or suitably protected equipment selected.

4.2.22 **Ionising Radiation Regulations (IRR)**

These apply where radioactive substances and electrical equipment emitting ionising radiation are used (e.g. radiography of welds). The Regulations require employers to keep exposure to ionising radiations as low as are reasonably practicable. Exposures are not to exceed specified dose limits. Restriction of exposure is to be achieved first by means of engineering control and design features. Where this is not reasonably practicable, employers are required to introduce safe systems of work and only rely on the provision of personal protective equipment as a last resort. There are also requirements to notify HSE of certain activities involving use of ionising radiation.

4.2.23 **Control of Noise**

4.2.23.1 These Regulations require assessment of the risks to employees from work related noise. Action has to be taken to reduce the noise exposure that produces those risks. They require provision of hearing protection to employees if noise exposure cannot be reduced enough by using other methods. Legal limits on noise exposure is not to be exceeded and information, instruction and training to employees on noise has to be provided. Health surveillance is required where there is a risk to health from noise.

4.2.23.2 A certain amount of noise is inherent in operation and maintenance activities. The best practicable methods are to be employed to minimise noise emission, to protect site personnel and the public. Any relevant legal provisions requirements are to be applied.

Consideration to be given to the following:

- 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 take into account the impact on the environment.

4.2.23.3 Noise is a major issue both for designers (who need to endeavour to "design out" noisy processes wherever possible) and managers of construction or demolition sites where the potential of nuisance needs to be recognised at the earliest possible stage.

4.2.23.4 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. 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 has regard to any code of practice approved or issued under COPA. It has to 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. Although the Standard has been adopted under COPA, it is not legally binding in itself. However, the content of each relevant part of the standard is taken to represent current good practice.

4.2.23.5 Noise abatement zones are established essentially for the purposes 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.

4.2.23.6 Part III of the Environmental Protection Act (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 it in criminal proceedings before a Magistrates Court in the event of non-compliance without reasonable excuse.

4.2.23.7 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 will serve an abatement notice on the person responsible.

4.2.23.8 The aim of The Noise at Work Regulations is to reduce the risks of occupational hearing damage to as low as reasonably practicable.

There are among others, legal duties to:

- protect the hearing of those at work and of others
- carry out a noise assessment if employees are exposed to noise levels exceeding 85 db(A)
- take measures to reduce noise levels to the lowest level reasonably practicable
- use warning signs to indicate where hearing protection must be worn
- inform workers about risks to hearing.

4.2.23.9 The HSE publication "Reducing Noise at Work – Guidance on the Noise at Work Regulations" is designed to give those with responsibilities for reducing noise exposure guidance and advice on legal duties on the introduction of control measures, the selection of ear protection and how to carry out a noise assessment by a competent person.

4.2.24 **Trees**

4.2.24.1 On roads and highways, trees and their root systems can be adversely affected by pipe laying activities. Such damage should be avoided and guidance is provided in the National Joint Utilities Group (NJUG) agreement NJUG Volume 4 on work in vicinity of trees.

4.2.24.2 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 is required.

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

4.2.25 **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 Safety 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
- 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.

4.2.26 **Rivers, canals and foreshores**

4.2.26.1 Part 1 of the Environment Act established the Environment Agency (EA) in England and Wales and the Scottish Environmental Protection Agency (SEPA) in Scotland, 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 for hydrostatic testing. In England and Wales, the EA also regulates the abstraction of water (which requires an abstraction licence).

4.2.26.2 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 (PPG), in particular PPG6 "Working at Construction and Demolition Sites".

4.2.26.3 British Waterways is a statutory body established by the Transport Act. It owns and manages approximately 2000 miles of canals and river navigations. The

British Waterways' Code of Practice governs works that might affect their waterways and properties.

4.2.26.4 Where works are to be constructed in, under or over the sea, any tidal waters, navigable river, or 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/servitude must be obtained from the owners which are, generally, the Crown Estate Commissioners.

4.2.27 Railway land

Where apparatus is to be laid through land owned or operated by Network Rail or any of its associated companies, the appropriate officers should be consulted at an early stage.

Note: Considerable time delays may be encountered in agreeing construction method statements and rail safety considerations.

4.2.28 Deposits of waste

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

4.2.28.2 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 are expected to achieve, as is reasonable in the circumstances.

Every person who is subject to the duty of care is required to ensure not only that they do not commit an offence but that any other person does not similarly commit 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 is required to 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 is required to 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
- in Scotland, a waste disposal authority.

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

4.2.29 **Pipelaying across country**

Many bodies and authorities have an interest in the operations of pipelaying across country. The following list, which is not exhaustive, identifies some of the key consultees in the UK:

- Planning officers of County and District Councils, Local Unitary Authorities and, in Scotland, Regional Councils
- English Nature, Countryside Agency (England)/Countryside Council for Wales and Scottish Natural Heritage
- Environment Agency (England and Wales)/Scottish Environmental Protection Agency (Scotland)
- DEFRA
- English Heritage and Historic Scotland
- Department for Business, Innovation and Skills
- HSE
- Country Landowners' Association/Scottish Landowners' Federation
- National Farmers' Union/National Farmers' Union of Scotland
- The Coal Authority
- Utilities - electricity, water, telephone, gas companies etc
- National Trust.

4.2.30 **Environmental protection**

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

4.2.30.2 For GTs, the relevant legislation is the Public Gas Transporter Pipeline Works (Environmental Impact Assessment) Regulations. These make an Environmental Impact Assessment (EIA) mandatory for gas pipelines of more than 800 mm in diameter and more than 40 km long.

In addition, Schedule 3 of these Regulations describes pipeline works for which an environmental statement (ES) may be required and includes pipelines which pass through sensitive areas (as defined by the Regulations) or which operate at a pressure in excess of 7 bar. Such pipelines require an environmental determination by the Secretary of State at the DTI as to whether an EIA, or the need for an environmental determination, is essential if delay is to be avoided during later planning stages.

4.2.30.3 For non-GTs, the relevant regulations are the Electricity and Pipeline Works (Assessment of Environmental Effects) Regulations and the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations.

4.2.30.4 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 needs to accompany any request for determination from the relevant planning authority expressing their opinion of the project.

4.2.30.5 An EIA requires consideration for the environment and public participation in the decision-making process of project development. The ES needs to 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 environment study.

SECTION 5 : DESIGN

5.1 DESIGN PROCESS

5.1.1 The design of any system can be a very complex, highly interactive and iterative process which needs to take into account a wide range of fixed and variable factors to produce a fit-for-purpose design at the best-cost solution. The important factors which shall be considered are:

- demand to be satisfied
- gas pressure and quality
- gas velocity
- route of the system
- material type
- safety assessment
- cost of construction
- future maintenance
- availability of maintenance techniques
- growth.

5.1.2 The specific nature of the proposed system will dictate the most appropriate approach to reach a design, varying from a simple pipeline extension within a single pressure tier network to a complete reinforcement scheme affecting more than one pressure tier with boundary control and system upgrading. For network planning, reference should be made to IGE/GL/1 (for MOP not exceeding 7 bar) and IGE/GL/2 (for MOP exceeding 7 bar).

5.1.3 When designing the system, the planning horizon or forecast period should be established. This should be defined in terms of the existing pattern of gas demand, the scale and probability of growth, the cost of installation over time and the period of time over which the design provides an effective solution.

5.1.4 Design records and assumptions should be retained, in an easily retrievable format, in the event clarification is sought in the future about the "fitness-for-purpose".

Note: In particular, this may prove important where systems operated by different organisations have to interact.

5.1.5 An effective planning process shall take into consideration the lead times and technical requirements of any formal design approval mechanisms, for example as detailed in IGE/GL/5.

5.2 DEMAND

Demand on the system varies considerably, reflecting customer requirements, and the following factors shall be considered:

- day of the week
- outside temperature
- time of day
- nature of gas use.

Note: Normally, demand on a summer evening is considerably less than on a winter evening. However, the overall demand in summer compared to winter may not vary appreciably – due to unusual factors such as use of holiday resorts in summer months only. Therefore, it is critical to have a clear understanding of the nature of consumer behaviour throughout the whole year if proposed systems are to satisfy the requirements of the users.

The peak flow likely to be experienced in the system will be influenced by a number of factors as described in the following clauses.

5.2.1 **Consumer type**

5.2.1.1 The number and nature of appliances in use shall be assessed to determine the magnitude of flow for domestic consumers.

Note: The pattern of demand is likely to be similar for consumers with similar lifestyles and appliances. The predominance of central heating boilers with electronic timers has a significant effect on peak flow calculations for any given group of domestic consumers.

5.2.1.2 Normally, industrial and commercial loads should be studied in categories, dependent on the nature of the business.

The use of any pressure-boosting plant downstream of the primary meter shall be taken into consideration, in order to assess the potential impact on the upstream system due to:

- black start (worst case instantaneous demand surge) and
- crash or black stop (worst-case instantaneous cessation of gas usage).

Note 1: These categories reflect the type and pattern of use of appliances. For example, schools, hospitals and shopping centres will all have different demand profiles and generate peaks at different times of day.

Note 2: Due to some of the factors mentioned above, it may be that instantaneous or six-minute peak demands (see IGE/GL/1) do not coincide with the day(s) of peak diurnal demand.

5.2.2 **Diversity**

The peak flow for more than one consumer is always less than the total of each individual consumer’s peak demand. This "diversity of demand" arises because consumer habits and appliance use vary. As the number of consumers in a group increases, the probability of coincident use of appliances decreases. Studies of demand patterns for individuals and groups should be used to evaluate this probability and derive statistical models from which design curves can be produced.

In its simplest terms, diversity factor (D) can be defined as:

$$D = \frac{\text{Maximum potential demand}}{\text{Maximum actual demand}}$$

Note 1: This means that, if one consumer is considered, the maximum potential demand would equal the maximum actual demand and, hence, D would be 1. If 30 consumers were considered, it would be highly unlikely that all would ignite their appliances at exactly the same time, in which case the actual demand would be less than the potential and D would be greater than 1.

Note 2: Detailed guidance on the planning of large systems and the use of diversity is provided in IGE/GL/1 and IGE/GL/2, respectively.

5.2.3 **General factors**

The following factors shall also be considered when assessing peak flows:

- non-temperature sensitive loads

  Note: Where gas demand is not temperature-sensitive, the highest flows in the system may not occur at times of lowest temperature. Therefore, it is important to understand the size and nature of any individual and aggregated loads affecting the network as instantaneous or six-minute peak demands may not always coincide with times of peak demand

- failure of electricity supply

  Note: Where there is a high proportion of appliances dependent on electrical power to operate, peak demand levels higher than that derived from diversity curves can be encountered following restoration of electricity supplies after a failure of the electricity supply system

- peak demand shaving

  Note: When designing a bulk supply system, the peak demand may be reduced by supplementing the supply through a storage facility.

5.3 PRESSURE AND GAS QUALITY

5.3.1 General

5.3.1.1 Wherever possible, to optimise pipe sizing, system design should be based on obtaining the highest available pressure to overcome frictional losses in the proposed network. However, consideration shall, equally, be given to other issues such as routing and proximity.

The two primary pressure factors in the design solution should be the source pressure available and the pressure required at the end of the system (terminal pressure).

5.3.1.2 To avoid deposits in a pipeline and to minimise the possibility of any kind of corrosion (including internal stress corrosion) the following steps shall be considered:

- ensuring the hydrocarbon dew-point, at MOP, is at all times below the temperature of the pipeline (this will also ensure that the calorific value (CV) of the gas is not reduced by condensation of hydrocarbons)
- ensuring gas contains no solids which may interfere with the integrity or operation of pipes and appliances.

Note: GS(M)R and BS 4250 contain requirements for NG and LPG quality respectively.

5.3.2 Source pressure

5.3.2.1 The source pressure at the point of offtake for a new system shall be determined in relation to the expected performance of the upstream system, not only at times of peak seasonal demand but at all other times of the year.

Note: Many system operators will consider operating their networks at lower pressures in the summer months, to reduce leakage. This may conflict with the terminal pressure required when pressure loss along the proposed pipeline is calculated. Consequently, the consultation process with other system operators is a critical factor in the design process.

5.3.2.2 The available source pressure may have to be increased within the current MOP of a system, via existing pressure regulators, reinforcement or uprating of the upstream system. All of these will have a financial and safety implication which shall be built into the design and construction programme of the proposed downstream system.

Note: Where the source pressure exceeds 16 bar, a composite design may incorporate the appropriate parts of IGEM/TD/1 Edition 5 and IGEM/TD/13.

5.3.3 Terminal pressure

5.3.3.1 The terminal pressure must satisfy any statutory requirements and should satisfy any contractual agreements.

Note: The terminal point may be at the very extremity of the system or at the end of a pipe designed to supply consumers directly.

5.3.3.2 Pressure in the network may vary throughout the year other than for demand reasons, for example due to routine plant maintenance and seasonal variation, through pressure control systems. The impact of such variation shall be taken into account.

5.3.4 Pressure drop

5.3.4.1 The pressure drop between the source and the terminal point should be assessed separately for any downstream system. When a system operates with a high pressure differential, consideration shall be given to the additional frictional losses due to turbulent flow. Reference should be made to IGE/GL/1 or IGE/GL/2, as appropriate.

5.3.5 Velocity

5.3.5.1 Normally, it is not necessary to limit gas velocity in a new pipeline. However, where it is suspected that an existing connected pipeline contains dust particles or debris, consideration shall be given to the effect of the additional demand on the movement of that dust.

5.3.5.2 Where dust is a factor, consideration shall be given to installing filtration equipment (which will create a pressure loss and a future maintenance issue) or installing a larger pipe than normally would be necessary to act as a settling tank.

Note: The latter option may incur greater initial capital investment.

Any such options shall be considered and evaluated against the requirement of the scheme and network as a whole.

Note: A high gas velocity in a network is an indication that it is operating reasonably close to its capacity. Filtered systems, PE networks and those systems known through maintenance records not to have dust problems can be designed to operate with a velocity up to 40 m s^{-1}. As a general rule, if the velocity in such a system is limited to 20 m s^{-1}, dust particles are unlikely to cause a problem.

5.3.5.3 If it is considered necessary to modify a specific system so that it operates at a velocity exceeding 20 m s^{-1} on a permanent basis, analysis should be undertaken to predict the overall operating environment of the system. The assumptions and decisions taken shall be recorded for future use.

5.3.5.4 The following velocity equation should be used for a system of MOP not exceeding 75 mbar:

$$\bar{U}_2 = 353 \frac{Q}{d^2}.$$

$\bar{U}$ = average velocity at the point under consideration (ms^{-1})
Q = gas flow rate (m^{3}h^{-1})
d = internal pipe diameter (mm).

The following velocity equation should be used for a system of MOP exceeding 75 mbar:

$$\bar{U}_2 = \frac{353\,QP_b}{d^2\left[P_1{}^2 - \frac{3730\,fLQ^2}{d^5}\right]^{0.5}}.$$

$\bar{U}_2$ = average velocity at the point under consideration (m s^{-1})
Q = gas flow rate (m^3 h^{-1})
P_b = absolute pressure at datum conditions (bar) (atmospheric pressure)
d = internal pipe diameter (mm)
P_1 = absolute upstream pressure (bar)
L = length of pipe over which the velocity is being measured (mm)
f = friction factor.

5.4 PIPELINE SIZING AND FLOW ANALYSIS

5.4.1 General Flow Equation

The General Flow Equation shall be considered as appropriate for use across all pressure ranges (but see clause 5.4.2 for MOP not exceeding 7 bar) and is the basis for most other flow equations.

Note: *Many flow equations have been developed (some for specific design purposes, for example Weymouth, Spitzgass, Unwin) but none, other than the General Flow Equation, will satisfy every design problem.*

$$Q = 7.574 \times 10^{-4}.\left[\frac{T_s}{P_s}\right].\left[\frac{(P_1^2 - P_2^2).d^5}{STZL}\right]^{0.5}.\left[\frac{1}{f}\right]^{0.5}$$

Q = gas flow rate at base conditions (m^3 h^{-1})
T_s = standard temperature (288K)
P_s = pressure at standard conditions (1.013 bar)
f = friction factor
P_1 = upstream absolute pressure (bar)
P_2 = downstream absolute pressure (bar)
d = internal diameter (mm)
S = specific gravity (0.6 for Natural Gas; 1.5 for propane, 2.0 for butane)
Z = average compressibility factor (see Appendix 6)
T = average temperature of flowing gas (K) (normally taken as 278K)
L = pipe length (m).

5.4.2 Smooth Pipe Law

For the design of NG systems of MOP not exceeding 7 bar and LPG systems up to 2 bar, the Smooth Pipe Law should be used. This is the most appropriate for the partially turbulent flow conditions likely to be prevalent.

Note: *There are numerous flow equations in existence although most are variations on, or approximations to, the Smooth Pipe Law.*

In the General Flow Equation (clause 5.4.1):

$$f = \frac{f_{sp}}{e^2}$$

f_{sp} = $(14.7519+3.5657X+0.0362X^2)^{-2}$
= smooth pipe friction factor (dimensionless)
e = efficiency factor = 0.97 except for butt fused PE mains where internal beads are not removed (see Appendix 8)
X = $\log_{10}$ Re – 5
Re = Reynolds No. (In GB, take Re=25043 x Q/d for Natural Gas and typically 83955 x Q/d for LPG)

5.4.3 **General analysis**

5.4.3.1 In general, supply systems will utilise a steady-state analysis process which provides a snapshot of the pressures and flows within a model of the network for a given demand condition. For analysis of storage systems (which are rare at MOP not exceeding 16 bar), transient analysis should be used to model the variation of pressure, flow and linepack requirement based on specified periods of time.

5.4.3.2 If the new pipeline is to be connected to a system already providing linepack storage, any constraint or impact on the proposed downstream system shall be considered (when transient analysis may be required).

Note: Transient analysis is the most accurate method of estimating the level of storage available from a system. Both transient and steady-state analyses use the Smooth Pipe Law.

5.4.3.3 For MOP not exceeding 75 mbar, adjustments for altitude should be made (pressure increases with increasing altitude for NG). The following equation should be used to ensure that the designated MOP is not exceeded:

$$\Delta P = 0.123(1 - s)h$$

ΔP = change in pressure (mbar)
h = change in altitude (m)
s = density of gas relative to air (dimensionless).

Note: The specific gravity of NG, Propane and Butane are 0.6, 1.5 and 2.0 respectively.

5.4.4 **Flow analysis systems**

5.4.4.1 *Disc calculators*

For a single length of pipe or a simple "tree" network, a disc-type calculator provides a rapid and simple means of calculating gas flow, pressure differential, pipe size and length from a given set of conditions. Such devices should be based on one of the internationally-accepted flow expressions to produce an appropriate solution.

Any calculator used should consider the following criteria:

- flow
- pipe length
- pressure differential for lower pressure (mbar)
- pressure differential for higher pressure (bar)
- basic friction factors
- internal diameter of pipe
- roughness of pipe
- specific gravity
- Reynolds No.

For future reference, consideration shall be given to taking an electronic or paper copy of the disc with its results displayed and keeping it within the design file.

5.4.4.2 *Computer modelling*

For a simple network, consideration shall be given to using basic spreadsheets containing the appropriate flow equations. These may be a quick and easy solution.

Note: Computer-based analysis ranges from small hand-held scientific calculators with suitable software for the analysis of straightforward networks with simple graphical output, to sophisticated PC-based packages capable of analysing highly integrated pipework systems (MOP not exceeding 7 bar) with over 60,000 pipes, to transient analysis of systems of MOP not exceeding 85 bar. Many proprietary systems will include an on-line graphical package to assist in the decision making process and to provide a record.

5.5 ROUTING

5.5.1 General

5.5.1.1 In general, the same essential criteria should be used to determine the route for any system, irrespective of its MOP. However, the nature of pipelines where MOP exceeds 7 bar is such that more detailed advanced planning is, generally, required due to their length, MOP, size and mode of construction.

5.5.1.2 The effect a pipeline has on the environment depends largely on its route. This shall be taken into account early in the design phase to avoid the potential complexity and duration of negotiation.

5.5.1.3 Any area requiring special consideration for environmental controls shall be identified and allowance made, thus minimising the possibility of design changes or more expensive remedial measures on completion of the project.

5.5.1.4 Initially, maps of suitable scale should be consulted to determine the possible routes from supply to termination point.

Note: This exercise will provide a sound basis to allow all reasonable solutions to be considered, avoiding a quick and wrong decision based on what was perceived to be the most obvious.

5.5.1.5 An on-site survey of possible routes should be undertaken and note taken of all apparent physical obstacles, natural or otherwise, that may affect the design, lead times and construction.

Note 1: This is to ensure the design is based on as much realistic information as possible.

Note 2: Consultation with local authorities may be necessary to obtain details of the construction of adjacent buildings and structures and any possible future planning applications or proposals.

5.5.1.6 Where appropriate, the practicality of the chosen route should be verified with trial holes at strategic locations, for example road-crossings, approaches to bridges and generally along the line of lay in the highway.

Note: These will not only identify a physical route for the pipeline but also provide important data about the nature of the ground and reinstatement needs.

5.5.1.7 Where the likelihood of a damaging earthquake is considered significant, the static and dynamic effects of ground shaking should be considered on pipework, and the static effects of potential permanent ground movement should be considered on the above ground and buried pipeline sections which may be affected.

Note: Further advice is contained in IGEM/TD/1.

5.5.2 Route planning for cross country pipelines

5.5.2.1 *Construction plans*

Following the detailed examination/environmental assessment of the route, construction maps (normally strip maps) and drawings should be prepared.

5.5.2.2 *Route selection*

The following represents best practice and summarises the key issues for consideration. Where more detailed guidance is required, reference should be made to IGEM/TD/1.

Route selection should be carried out in three levels of detail, each designed to increase the confidence level in timely and efficient delivery of the project.

Level 1 - Route corridor selection

Route corridor selection should be used to identify options for routes and to define possible route corridors.

Level 2 - Reference route selection

Reference route selection should be used to identify and record more detailed information on environmental and other features within the route corridor that will be used to select a preliminary pipeline route and for negotiations with the land-owner/occupier.

Level 3 - Detail design

Detail design should be used to identify and record information to refine the pipeline route.

5.5.2.3 *Land rights, easement and servitude details*

Appropriate plans should be provided during negotiation of easements/servitudess to enable establishment of the boundaries of each ownership and tenancy and an easement/servitude file maintained.

5.5.3 Route planning for urban environments

5.5.3.1 Wherever possible, the route should avoid:

- areas already congested with underground apparatus
- close proximity to unstable structures or where construction could lead to problems
- areas where there has been recent infill causing significant alteration to natural ground levels
- ground areas of running sand, gravel or flood risk (where anti-buoyancy devices may need to be considered)
- heavily traffic-loaded routes where the road has not been constructed to suitable standards
- areas of known or suspected aggressive soil conditions
- ground liable to subsidence or land-slip
- landfill sites.

Note: The landfill may be deleterious to the pipeline, the area could be liable to subsidence and the gases generated within the site might be confused with odorised Natural Gas.

For steel systems, the following should also be avoided:

- close proximity to existing CP systems, particularly ground-bed locations
- high stray direct current, typically near DC traction systems
- long runs parallel to high voltage overhead power cables.

5.5.3.2 Where metallic pipes are to be laid and doubt exists about the suitablity of the existing soil, resistivity tests shall be undertaken to determine its nature.

5.5.3.3 Consideration shall be given to future maintenance to ensure that sufficient clearance is available for any necessary flow-stopping equipment and/or repair techniques. Inconvenience to the public or highway users, risk to third party plant and expensive reinstatement costs should all be minimised.

5.5.3.4 If it proves necessary to cross land not dedicated to public use, details of ownership and tenancy must be established to enable wayleave negotiations to commence.

5.6 SELECTION OF MATERIALS AND COMPONENTS

5.6.1 General

5.6.1.1 Pipe and lining materials and any coating, fittings and other components shall be appropriate to the operating parameters of the system.

Note: Important design factors are:

- *MOP*
- *structural loading*
- *nature of the ground through which the pipeline will be laid*
- *the long-term integrity of pipe and fittings*
- *ease of jointing and construction*
- *proximity to buildings*
- *availability and lead times of fittings*
- *the initial cost and future maintenance costs of alternatives (assuming all meet the minimum safety, technical and statutory requirements).*

5.6.1.2 Each material has its virtues and drawbacks and these should be weighed against the particular duty they are each expected to perform.

5.6.1.3 The pipeline shall be able to withstand additional loads as described below.

Note: Additional loads arise from operation of the pipeline, the construction procedure and its environment.

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.

Note: Changes may occur due to the environment during the service life of the pipeline.

- Operating loads, arising from:
  - internal pressure
  - temperature
  - 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 conditions
  - 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 activities, de-watering, or the action of additional surface loads, typically embankments
  - slope instability
  - frost heave
  - buoyancy
  - live loading from vehicles
  - where the likelihood of a damaging earthquake is considered significant.

5.6.2 Steel pipelines

5.6.2.1 *General*

Steel linepipe and fittings shall have adequate fracture toughness at or below the minimum design temperature and the material properties of the linepipe, fittings, coating and the lining shall be adequate for the conditions that arise both at the minimum and maximum design temperatures. Reference should be made to appropriate Standards for example, BS EN ISO 3183 Annex M for pipelines and BS EN 10253-2 for fittings.

Note: It is normal to demonstrate fracture toughness at 5^{o} below this temperature.

5.6.2.2 *Linepipe*

The majority of a buried system will operate at a reasonably constant temperature which, in the UK, exceeds 5^{o}C. Therefore, the appropriate test temperature should be 0^{o}C.

Note: If operating temperatures lower than this are expected, another test temperature may be appropriate.

The quality of linepipe shall be verified with respect to strength, fracture toughness and weldability, by testing in accordance with the appropriate linepipe specification.

Note: Provided linepipe steels are purchased and designed in accordance with the specifications referred to in this clause, all fatigue design requirements will be satisfied.

Minimum fracture toughness levels ensure that a pipeline can be operated within design limits, without risk of propagating brittle or ductile fractures.

The Specified Minimum Yield Strength (SMYS) and Specified Minimum Tensile Stress (SMTS) of commonly used grades of pipe are given in Table 1 which should be used when selecting pipe. Materials outside these grades should be subject to specific analysis and design.

Steel linepipe is available in a range of strengths:

- SMYS (N mm^{-2}) which is the point beyond which elastic deformation becomes plastic and the properties of the material may be altered permanently and
- SMTS (N mm^{-2}) which is the minimum stress at which the material could fail under a tensile load.

BS EN ISO 3183					
Grade	**SMYS (MPa)**	**SMTS (MPa)**	**Grade**	**SMYS (MPa)**	**SMTS (MPa)**
B	241	414	L245	245	415
X42	290	414	L290	290	415
X46	317	434	-	-	-

Note: Information on other grades of linepipe can be found in IGEM/TD/1.

TABLE 1 - COMMONLY USED STEEL GRADES, SMYS AND SMTS

The minimum wall thickness (t) of linepipe shall not be less than:

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

t = design thickness of pipe wall (mm)
P = design pressure at the relevant design temperature (bar)
D = outside diameter of the pipe (mm)
s = specified minimum yield strength (N mm^{-2})
f = a factor not to exceed 0.3.

In any event, to prevent problems during handling and trenching, the nominal thickness of linepipe shall not be less than indicated in Table 2.

OUTSIDE DIAMETER OF LINEPIPE (mm)		MINIMUM WALL THICKNESS (mm)
EXCEEDING	NOT EXCEEDING	
	168.3	4.8
168.3	457	6.3
457	610	7.9
610	914	9.5
914	1067	11.9
1067	1219	12.5

TABLE 2 - MINIMUM WALL THICKNESS OF STEEL LINEPIPE

5.6.2.3 *Bends and tees*

The following standards for wrought bends and tees should be used as appropriate:

- BS EN 10253-2
- ASME B16.9
- ANSI B16.28
- ASTM A105
- ASTM A234
- ASTM A420
- ASTM A860
- MSS SP-75.

Bends for inclusion within the pipeline should be manufactured with a minimum radius of three times the outside diameter of the pipe and should allow the free passage of pigs.

Bends for inclusion on an associated installation, for example in filter arrays and block valves not subject to pigging, should be to a minimum radius of 1.5 times the outside diameter of the pipe.

When available, forged or extruded tees should be considered as preferable to other types. When forged or extruded tees are not available, fabricated branch connections in accordance with IGEM/TD/13 should be used, welded to Class 1 of BS 2633.

Small branch connections may be made using butt welding fittings such as those specified in BS 1640 Part 3. Where butt-welded fittings are not utilized, fabricated branch connections, in accordance with IGEM/TD/13, should be used, welded to Class 1 of BS 2633.

5.6.2.4 *Insulation joints*

5.6.2.4.1 Any insulating joint shall perform its function effectively under all combinations of pressure and externally-applied stresses, as specified to the manufacturer.

5.6.2.4.2 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.

5.6.2.4.3 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.

5.6.2.4.4 All joints shall be pneumatically or hydrostatically and electrically tested and test certificates should be made available by the manufacturer. Conditions for pressure testing should allow for free expansion of the joint. The Strength Pressure Test shall precede the electrical test and be undertaken in accordance with Section 7 or a recognised industry Standard.

5.6.2.5 *Fittings to match high strength pipe*

Where fittings of sufficient strength to match the linepipe are not available, a lower strength fitting may be used but suitable thickness compensation shall be applied.

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. However, 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 component.

5.6.2.6 *Properties of fittings*

Fittings shall be of appropriate strength for the line test pressure. They should be qualified with respect to strength, Charpy testing and weldability in a similar manner to linepipe.

5.6.2.7 *Coatings*

Reference should be made to appropriate standards, for example BS 5493, for guidance on selection of materials and requirements for their application.

Wherever possible, pipes and fittings should have the required internal and external protection applied at the manufacturer's works.

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. For example, solar heating or exposure to ultraviolet radiation could affect adversely some coating materials.

Note: Ground entry points, where standard coating systems may not be effective, may require special coating arrangements.

5.6.2.8 *Calculation of stresses and fatigue*

Normally, systems designed to 0.3 SMYS will have a wall thickness such that external stresses and fatigue do not represent a problem, provided the linepipe is handled correctly during the construction phase. If it is deemed necessary to carry out specific stress calculations, for example for a pipeline and fittings that are to be used for linepack and, hence, which may be subjected to significant fatigue cycling, details should be taken from IGEM/TD/1.

Note: Further guidance is provided in IGE/TD/12.

5.6.3 **PE pipelines**

PE 80 and PE 100 are very strain-tolerant materials with good resistance to environmental degradation in service, and require minimal maintenance. Typical properties are shown in Table 3.

	DENSITY	MELT FLOW RATE 5 kg WEIGHT	TENSILE STRENGTH AT YIELD		LONG TERM HYDROSTATIC STRENGTH	
			bar	MPa	bar	MPa
PE 100	951 kg m^{-3}	0.25 g/10 mins	250	25	100	10
PE 80	944 kg m^{-3}	0.9 g/10 mins	180	18	80	8

Note 1: PE 100 pipes can operate at significantly higher operating pressures than PE 80 pipes for the same wall thickness.

Note 2: The strength of PE is time and temperature dependent. This characteristic is used to assess the future available strength of the pipe material.

TABLE 3 - TYPICAL PROPERTIES OF PE PIPE

5.6.3.1 PE pipelines should have a design life of at least 50 years, based on continuous operation at MOP and a temperature of 20°C. Normally, PE pipes should not be installed in locations where the temperature of the ground surrounding the pipe exceeds 20°C. Where temperatures exceed 20°C, reference should be made to clause 5.6.3.4.

Note: BS EN ISO 9080 classifies PE pipes by the minimum required strength (MRS). When pressure tests on pipe samples filled with water are carried out over a range of internal pressures, the lifetimes of the samples are found to span a wide range and there is a distribution of the measured lifetimes at a given stress level. Linear regression analysis is used to establish the regression line. If data is plotted on logarithmic scales, it is found that they can be described by a linear relationship between stress and time. This has established that PE pipes will have a lifetime of at least 50 years when subjected to a constant hoop stress of 80 bar for PE 80 and 100 bar for PE 100 at a constant temperature of 20°C.

5.6.3.2 MOP for PE pipe should be determined by the application of safety factors to MRS values in accordance with appropriate standards.

5.6.3.3 The relationship between circumferential hoop stress and internal pressure should be assumed as:

$$\text{Hoop stress (MPa)} = \frac{\text{internal pressure (bar)}}{20} \times (\text{pipe SDR} - 1)$$

$$\text{SDR} = \frac{\text{minimum outside diameter}}{\text{minimum wall thickness}}$$

A suitable factor of safety should then be used to establish an acceptable pressure rating for the pipe, defined as:

$$\text{Factor of Safety} = \frac{\text{MRS}}{\text{Hoop stress in service}}$$

5.6.3.4 Selection of the MOP for PE pipelines should be made on the basis of it not exceeding 10 bar and that the overall service (design) coefficient 'C' shall be greater than or equal to 2.

$$C = \frac{20 \times MRS}{MOP \times (SDR-1) \times D_f}$$

Where:
MRS = Minimum Required Strength (long term hydrostatic strength)

Note: This is established by extrapolation of data from stress-rupture tests on completely water filled pipe samples under various internal pressures in accordance with BS EN ISO 12162.

MOP = Maximum Operating Pressure of the system
D_f = De-rating factor (see Table 4)

Note: This is the coefficient used to take into account the influence of the operating temperature.

TEMPERATURE (˚C)	DE-RATING FACTOR (D_f)
20	1.0
30	1.1
40	1.3

Note: For temperatures between each step linear interpolation can be applied.

TABLE 4 - DE-RATING FACTORS FOR PE PIELINES OPERATED ABOVE 20˚C

OUTSIDE DIAMETER OF PIPE (mm)	PE 80 (formerly MDPE)				PE 100 (formerly HDPE)		
	SDR 11	SDR 17.6	SDR 21	SDR 26	SDR 11	SDR21	SDR26
	MOP (bar) plus (safety factor)						
16	5.5 (2.9)	-	-	-	-	-	-
20	5.5 (2.9)	-	-	-	-	-	-
25	5.5 (2.9)	-	-	-	-	-	-
32	5.5 (2.9)	-	-	-	-	-	-
40	5.5 (2.9)	-	-	-	-	-	-
50	5.5 (2.9)	-	-	-	-	-	-
55	5.5 (2.9)	-	-	-	-	-	-
63	5.5 (2.9)	-	-	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
75	5.5 (2.9)	-	-	-	-	2.0 (5.0)	2.0 (4.0)
90	5.5 (2.9)	3.0 (3.2)	-	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
110	-	3.0 (3.2)	-	-	-	2.0 (5.0)	2.0 (4.0)
125	5.5 (2.9)	3.0 (3.2)	-	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
140	5.5 (2.9)	3.0 (3.2)	-	2.0 (3.2)	-	2.0 (5.0)	2.0 (4.0)
160	-	3.0 (3.2)	-	2.0 (3.2)	-	2.0 (5.0)	2.0 (4.0)
180	4.7 (3.4)	3.0 (3.2)	-	2.0 (3.2)	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
200	4.4 (3.6)	3.0 (3.2)	-	2.0 (3.2)	-	2.0 (5.0)	2.0 (4.0)
213	-	-	-	2.0 (3.2)	-	-	-
225	-	-	-	2.0 (3.2)	-	2.0 (5.0)	2.0 (4.0)
250	4.0 (4.0)	3.0 (3.2)	-	2.0 (3.2)	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
268	-	-	-	2.0 (3.2)	-	-	-
280	3.8 (4.2)	2.9 (3.3)	-	2.0 (3.2)	-	2.0 (5.0)	2.0 (4.0)
315	3.4 (4.7)	2.7 (3.6)	-	2.0 (3.2)	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
355	3.1 (5.2)	2.5 (3.9)	2.0 (4.0)	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
400	2.9 (5.5)	2.3 (4.2)	2.0 (4.0)	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
450	2.7 (5.9)	2.2 (4.4)	2.0 (4.0)	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
469	-	2.1 (4.6)	2.0 (4.0)	-	-	-	-
500	2.5 (6.4)	2.0 (4.8)	2.0 (4.0)	-	7.0 (2.9)	2.0 (5.0)	2.0 (4.0)
560	-	-	-	-	-	2.0 (5.0)	2.0 (4.0)
630	-	-	-	-	-	2.0 (5.0)	2.0 (4.0)

Note 1: The above values will change as developments improve material properties and reference will need to be made to manufacturers for detail of current temperature and pressure limits.

Note 2: Safety factors are shown in brackets.

Note 3: All PE 100 SDR 11 pipes need to be able to operate at a MOP of 7 bar within temperature range 0 – 20°C.

Note 4: SDR 21 and SDR 26 peelable pipes with PE 100 core need to be able to operate at MOP of 2 bar down to -20°C.

TABLE 5 - OPERATING PRESSURE LIMITS FOR GRADES OF PE FOR THE TEMPERATURE RANGE 0 TO 20°C

MOP in GB has been limited to 4 bar for PE 80 (5.5 bar if diameter ≤ 140 mm). Historically, PE 100 has been limited to MOP of 7 bar as a result of the rating system for charges on pipelines operating at a pressure in excess of 7 bar.

Note 1: The operating range of PE 100 may be extended to 10 bar with a resultant safety factor of 2, if the requirements of BS EN 12007 are met.

Note 2: PE 100 is required to be resistant to fast fracture (rapid crack propagation). This eliminates the need for de-rating larger diameter PE 100 pipes.

PE pipe and fittings should be to the following Gas Industry Standards, as appropriate:

- GIS/PL2 Part 2 (Pipe up to 5.5 bar)
- GIS/PL2 Part 4 (Fusion Fittings)
- GIS/PL2 Part 6 (Spigot/Butt Fusion Fittings)
- GIS/PL2 Part 8 (Pipe (up to 7 bar)
- GIS/PL3 (Self Anchoring Mechanical Fittings).

5.6.3.5 MOP selection should verify the critical rapid crack propagation (RCP) criteria (dependent upon pipe size and material) and determined in accordance with BS EN 1555-2 (ISO 13477/13478).

Note: The critical RCP level is the pressure at which a crack can rapidly propagate through a PE pipeline. This is defined at a reference temperature, which in this case is 0°C. Piping systems intended for distribution of gas at temperatures less than 0°C require additional RCP evaluation and the MOP reduced if necessary to maintain the ratio of the critical RCP to MOP greater than or equal to 1.5.

5.6.4 Valves

For MOP not exceeding 7 bar, valves may be of cast iron, ductile iron, PE or steel construction. For MOP exceeding 7 bar, steel bodied valves shall be used.

Note 1: Plastic-bodied valves can be utilized in certain circumstances, subject to consideration of OP and the size of the pipeline.

Note 2: Metal-bodied valves may be connected to the pipeline by welding, flanges or by using electrofusion fittings (where PE pups are provided with the valve). The appropriate method of installation is described in further detail in Section 6.

5.7 GENERAL SAFETY PRECAUTIONS

5.7.1 General

5.7.1.1 Provided the system is designed using the safety assessment guidance given in this section, there should not be a need for specific risk assessment but, if necessary, clauses 5.7.1 to 5.7.6 should be considered.

The risk associated with any proposed route shall be assessed to verify that all reasonably practicable steps have been taken to minimise the risk to people and/or property in the event of pipeline failure and the release of significant quantities of gas. Due consideration shall be given to any future works that may cause interference damage.

Note: The degree of risk to which people and/or property are exposed is a product of the severity of the hazard and the likelihood of it occurring. The specific hazard with distribution systems is either from gas migrating below ground into property (with the potential for asphyxiation, explosion and fire) or from a gas escape being ignited at or near to its source.

Risk assessment is a complex process, which often requires considerable specialist knowledge. It shall only be undertaken by persons competent in application of the techniques involved.

5.7.1.2 Any risk assessment should take into account 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.

Note 1: Guidance on risk assessment techniques and criteria are given in IGEM/TD/1, together with examples. Further information can be found in IGE/SR/24 and IGEM/G/5.

Note 2: The results of a risk assessment may need to be considered by the relevant statutory body.

5.7.2 **Material failure**

System failure may be caused by ongoing degradation leading to a sudden and spontaneous failure or by external influences such as ground movement or interference damage. The likelihood of failure should be considered to be dependent upon:

- pipe properties
- jointing method
- quality of construction of pipe, joints and associated fittings
- maintenance and operational regime
- susceptibility to interference damage
- ground conditions.

Note: Historical performance records for material types can be used to determine current industry best practice.

5.7.3 **Protective measures**

5.7.3.1 *General*

Materials shall be handled and laid with care, in accordance with manufacturer's instructions in order to retain integrity.

At the design stage, consideration shall be given to jointing techniques and the wide range of devices, techniques, materials and methods to reduce the likelihood of failure.

Note: Of paramount importance are the quality controls applied with respect to the way that equipment is used and maintained and the competence of the personnel.

A proper evaluation of hazard reduction measures should be made.

5.7.3.2 *Cathodic protection (CP) and insulation*

For any new steel pipe or component consideration shall be given to be cathodic protection and the design should be in accordance with the relevant standards.

Note: Protection may be applied either by means of impressed current or sacrifical anode. Impressed current is the preferred method, particularly for longer pipe runs but requires care to avoid interference with other buried apparatus. Sacrificial anodes may be used for short lengths of steel pipe or where surrounding apparatus is so dense that the impressed current method is not suitable.

Insulation joints or flanges should be installed to limit any impact from interference currents, to split the system into manageable parts and to control the extent of the proposed CP system. In general, insulation joints should be considered in the following circumstances:

- at the point of connection to an existing system
- at special crossings, for example bridges and waterways
- where stray interference currents may be present
- where systems of dissimilar materials, for example steel and cast iron, join.

5.7.4 **Interference damage**

If necessary, the risk of interference damage should be reduced by one or more of the following:

- increased depth of installation (but not greater than the maximum depth for the material, see clause 6.4.5)
- additional protection, for example;

  - concrete slabs (see Sub-Section 5.9)
  - steel plates or sleeving
  - marker tape
  - plastic tiles
- use of existing pipes for sleeving
- marker posts.

5.7.5 **Prevention of gas entering buildings**

5.7.5.1 Consideration shall be given to the likelihood of gas entering a building, which is directly related to the volume of gas released. In the worst case scenario, for example interference damage causing the removal of a complete section of pipe, the volume released will be a function of the diameter of the pipeline and its OP.

Other factors which should be considered and which could affect the entry of gas into a building are:

- condition of the existing pipeline and likelihood of failure
- location of the pipeline relative to the building
- the relative ease with which escaping gas can vent into the atmosphere which, in turn, will depend upon;
  - depth of pipeline burial and the surrounding soil conditions
  - intervening terrain, for example whether the ground is open or paved
  - whether there is a preferential route into the building, for example via a cellar, or service/duct.

5.7.5.2 Risk assessment should take into consideration historical evidence on existing systems to justify the residual risk.

Note: Records of pipeline failures can be used to develop risk assessment methodologies.

5.7.6 **Operating pressure**

5.7.6.1 The operating pressure of a system is a key component in any risk assessment process. Any proposed increase in operating limits should be subject to a repeat risk assessment.

5.7.6.2 For a change of pressure, consideration shall be given to:

- the hoop stress on the pipe and fittings giving rise to an increase in the likelihood of failure
- the amount of gas released impacting on the consequence of failure.

5.7.6.3 For a system comprised mainly of older metallic pipes, it is normal practice to consider operating at a pressure as low as demand allows throughout the year to reduce the affect of leakage. In doing so, the system operator should take into consideration the consequences of seasonal pressure variations on materials.

5.8 PROXIMITY TO PROPERTIES

5.8.1 **Steel systems of MOP exceeding 7 bar**

The minimum proximity to normally-occupied buildings should be as specified in Table 6 and, in any event, the proximity shall not be less than 3 m.

Table 6 is based upon the design factor, f, which should not exceed 0.3. This means that the maximum stress in the pipe wall will not be more than 0.3 (30%) of SMYS of the material.

5.8.2 **All systems**

5.8.2.1 The minimum building proximity distances specified in Table 6 should be observed. The distances are risk-based and take account of current industry safe practice, operational experience and research.

Note 1: Proximity distances for PE pipelines in Table 6 assume that an appropriate pipeline wall thickness has been selected in accordance with Table 5.

Note 2: Operational experience was taken from analysis of data from one GB Gas Distribution Network. If GB operational experience is not applicable, an assessment will have to be carried out to justify the use of the proximity distances in Table 6 or to propose appropriate modifications.

5.8.2.2 The proximity distances given in Table 6 for pipelines with MOP exceeding 75 mbar may be insufficient for sensitive buildings where occupants may have reduced mobility (such as schools or hospitals) or in urban areas or near places of public assembly (indoors or oudoors) where there is a significant population present. In such cases consideration shall be given to a separate risk assessment, which takes into account the societal risks and any applied risk reduction measures. Risk assessments should follow the general guidance provided in Section 5.7 and take into account the frequency and consequences of possible fires and explosions and their potential impact on the population nearby.

5.8.2.3 Unless justified through a suitable risk assessment, a pipeline of MOP exceeding 7 bar should not, be laid in a central area of a town or city where there is:

- a high population density
- many multi-storey buildings
- dense traffic
- numerous underground services.

Note: See also clause 4.2.9.2 for additional GB legislative requirements for pipelines operating above 7 bar.

PE					
Type of Main	**Diameter of Main (mm)**	**Minimum Building Proximity Distance (m)**			
		≤ 75 mbar	**> 75 mbar ≤ 2 bar**	**> 2 bar ≤ 5.5 bar**	**> 5.5 bar ≤ 7 bar**
PE Non-Inserted	Up to 125	0.25	2	4	6
	126 to 355	1	2	4	6
	356 to 500	1	2	4	8
	501 to 1000	1	5	13	15
PE Inserted	Up to 125	0.25	1	2	3
	126 to 355	0.5	1	2	3
	356 to 500	0.5	1	2	3
	501 to 1000	0.5	1	3	3
STEEL					
Type of Main	**Wall Thickness of Main (mm)**	**Minimum Building Proximity Distance (m)**			
		≤ 75 mbar	**> 75 mbar ≤ 2 bar**	**> 2 bar ≤ 7 bar**	**> 7 bar ≤ 16 bar**
Steel	t ≤ 9.52	0.25	1	3	13
	9.52 < t ≤ 11.91	0.25	1	3	6
	11.91 < t	0.25	1	3	3

Note 1: Use operating pressure limits in Table 5.

Note 2: Table 6 does not preclude closer proximities where additional risk reduction measures are applied and supported by a suitable risk assessment.

Note 3: Where PE pipes are laid inside a continuous metal sleeve (steel or iron), PE Inserted minimum distances apply.

Note 4: For PE pipelines intended to operate at pressures greater than 7 bar, a risk assessment has to be performed to justify appropriate proximity distances.

TABLE 6 - MINIMUM PROXIMITY TO NORMALLY-OCCUPIED BUILDINGS (NATURAL GAS)

5.9 IMPACT PROTECTION

5.9.1 General

In order to reduce the likelihood of pipeline damage, and where considered necessary, a pipeline should be protected by an acceptable method.

Impact protection can be an effective means of mitigating damage at, for example, road crossings, sensitive locations, etc.

Note: For steel systems, additional protection can affect the efficiency of above ground coating surveys, such as Pearson and Close Interval Potential Surveys (CIPS).

5.9.2 Protective measures

5.9.2.1 The form of protection should be selected to suit the circumstances. Examples are provided in Figure 3.

5.9.2.2 The following criteria shall be fully evaluated when designing slabs for the protection of pipelines:

- vertical loading force and type (point i.e. impact or distributed vehicular)
- unsupported span width, which will determine the concrete depth, mix specification and type of steel bar or mesh reinforcement
- slab length, which will determine if expansion joints are required
- whether the concrete slab is to be buried or forms part of the surface open to the weather elements will determine the concrete specification
- distance between the top of the pipeline and the underside of the proposed concrete slab protection. This will determine the type and minimum depth of shock absorbent material to be placed between the top of the pipeline and the underside of the concrete slab.

An individual site specific evaluation shall be carried out to establish exact requirements before an appropriate concrete slab protection can be designed.

5.9.2.3 In Figures 3(a) and 3(b), "h" should, ideally, be not less than 100 mm and the overall width of the protection should be adequate to guard against lateral encroachment from excavating machinery.

The use of any protection measure may alter the distribution and intensity of external loads around the pipe. The design shall consider such effects and demonstrate that they do not result in unacceptable stresses within the pipe. In particular, this is important where construction or other traffic loading may arise.

5.9.2.4 Care shall be taken during design and installation to ensure that the satisfactory operation of any CP system will not be affected.

5.9.2.5 Consideration shall be given to future access to inspect or maintain the pipeline.

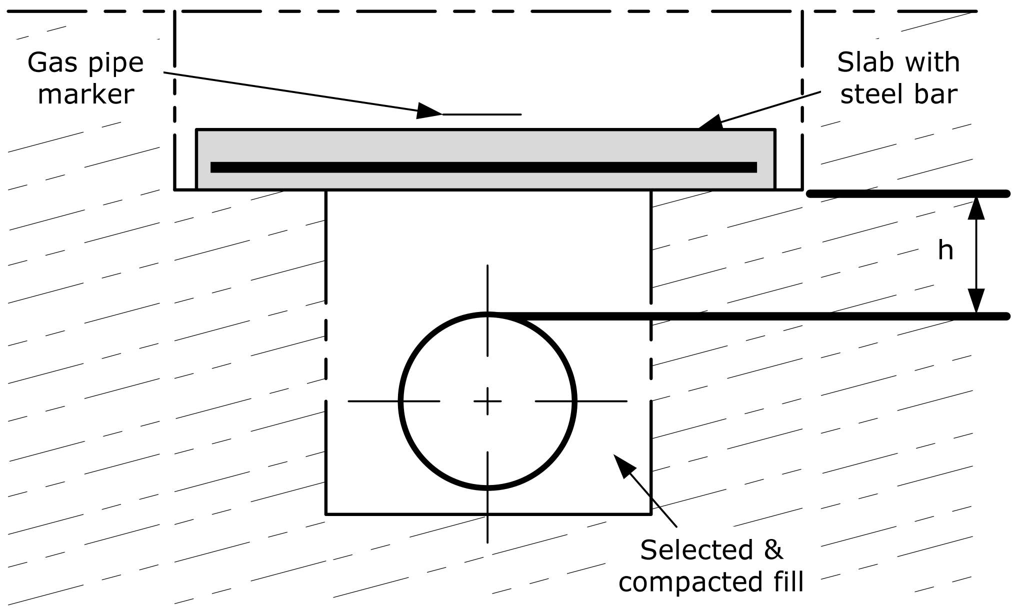


FIGURE 3 (a) - CONCRETE SLAB

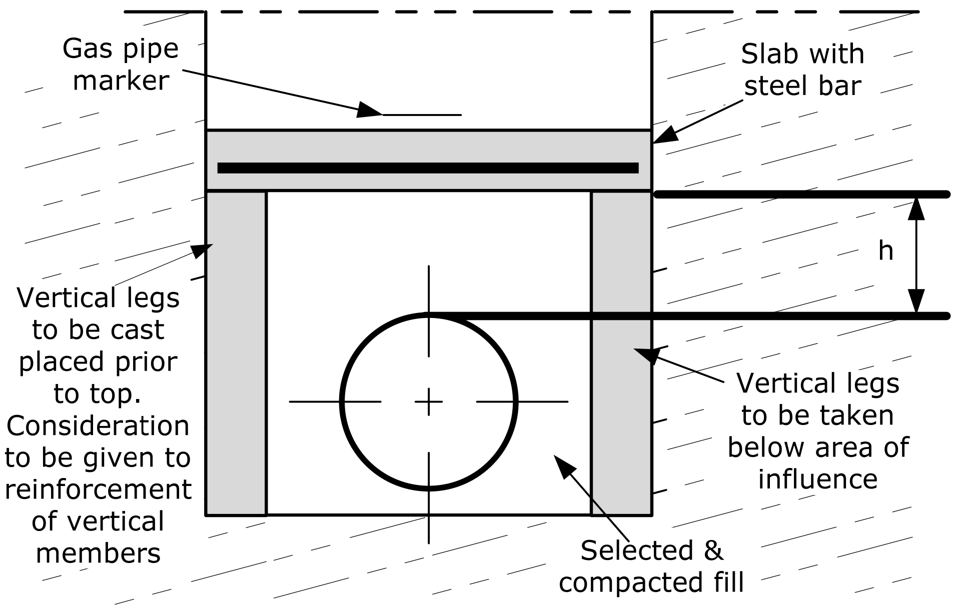


FIGURE 3 (b) - SLAB WITH SUPPORT

For dimension of "h", see clause 5.9.2.3.

FIGURE 3 - COMMONLY USED FORMS OF IMPACT PROTECTION FOR PIPELINES

5.10 WATER CROSSINGS

5.10.1 The design of a pipeline at a water crossing shall not be less onerous than that required for a land pipeline and shall take into consideration the following additional features within the selected pipeline crossing route corridor:

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

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

5.11 SLEEVING

Where a steel pipeline is to cross a major obstacle such as a railway, river, etc., pipe of increased wall thickness should be considered in preference to sleeving. A sleeve should be used only when required to facilitate construction of a carrier pipe, under particular circumstances, when reference should be made to IGEM/TD/1.

Note: No additional sleeving is required where the pipeline has been designed to clause 5.8.1.

5.12 ABOVE-GROUND INSTALLATIONS (AGIs) AND PRIs

In general, an AGI on a pipeline comprises one or more of the following:

- line valves and branch connections
- pigging stations
- overhead pipe crossings
- multi-junction stations with or without in-line metering and which can include pig traps and/or line valves.

Note: Information on pipework stress analysis is provided in IGE/TD/12.

5.12.1 Any AGI or PRI should, where reasonable and practicable, be located away from public highways and railways and be at least to the minimum distances defined in this Standard and in IGE/TD/12 or IGEM/TD/13, respectively. Where there are hazards due to traffic movement, barriers designed to appropriate standards shall be installed.

The location and layout of the installation should be selected to preserve the natural amenities of the area, due regard being given to screening, by trees or artificial means, architectural features and decorative colour schemes to meet the requirements of the local authority.

5.12.2 Where large volumes of gas may have to be vented, the site shall be chosen so that safe dispersal can be assured. Reference should also be made to IGEM/TD/13 for a PRI.

Note: Information on venting is given in IGE/SR/23 and guidance on hazardous area classification is given in IGEM/SR/25.

5.12.3 Appropriate arrangements should be made to ensure equipment and the site are secure and safe from unauthorised operation.

5.12.4 Reasonable road access shall be provided up to, and within, the site for the purposes of construction, maintenance and fire fighting precautions. Due regard should be paid to the need for vehicles to turn. Installed plant should be sufficiently clear of roads so as to avoid damage from moving vehicles and loads.

5.12.5 Where electrical equipment is installed on site, appropriate explosion-protected electrical apparatus shall be provided in areas where gas may be present.

5.12.6 Consideration shall be given to the need for providing anchorage for the pipework system. These should be designed to be effective under all operational conditions.

5.12.7 Consideration shall be given to welding or fusing all joints between the main pipeline and the first valve, to the AGI/PRI.

Note: This would be to restrict possible future leakage which would not be capable of isolation by closure of the valve.

5.12.8 The number of small diameter connections to the main pipeline should be restricted to a minimum. Such connections should be of robust design.

5.12.9 Where necessary, pipework with branches designed to allow the passage of pigs should have guide bars fitted. Design requirements for guide bars should be taken from a suitable standard. Special care shall be taken to ensure thermowells or other insertion devices are not installed on a pipeline that is to be pigged when reference should be made to IGEM/TD/13.

5.13 STRATEGIC VALVES

Strategic valves are, usually, required for a pipeline of MOP exceeding 2 bar. However, they may also be considered under special circumstances for lower pressure pipelines.

5.13.1 Strategic valves shall be installed to permit the safe operation of the system for maintenance purposes and to allow for speedy isolation in the event of damage. The location and interval between valves shall reflect the risk associated with maintaining the gas supply, to limit inventory loss and to facilitate maintenance, repair, modification, testing and commissioning. They shall facilitate rapid control of any situation in any part of the system.

Note: 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.

5.13.2 In determining the spacing of strategic valves, consideration shall be given to the following factors:

- MOP of the pipeline
- diameter of the pipeline
- time taken to arrive at the site of the valve
- probability of leakage
- proximity to normally-occupied buildings
- areas of high population density, such as residential areas
- industrial and commercial areas
- 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 within the pipeline section between valves
- significant natural conditions that may affect the operation and security of the pipeline, for example ground movement, flooding etc.
- time to blowdown/vent the isolated section of pipeline in case of emergency or maintenance
- sections required for hydrostatic pressure testing of the pipeline
- the requirements of the adopting GT.

5.13.3 In industrial and commercial areas, and residential areas of high population density, the interval between valves should be reduced.

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

5.13.4 Strategic valves shall be installed:

- either side of a major river or estuary crossing where the pipeline could be damaged by a ship's anchor or scouring of the river bed
- either side of special crossings
- at locations associated with pressure reduction apparatus
- at strategic offtakes
- at other specified locations.

5.13.5 Any strategic valve should allow the passage of a pigging device.

5.13.6 Where practicable, any strategic valve shall be installed below ground with the valve-operating device readily accessible from above ground. A stem extension can be used to elevate the valve operator above ground and consideration shall be given to extending the sealant/lubrication and valve vent pipework for ease of access.

5.13.7 Any strategic valve shall be supported suitably to prevent any settlement that could affect the integrity of the pipeline system.

5.13.8 Where necessary, suitable pressurising bridle/bypass and vent connections shall be provided either side of any strategic valve in order 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 a vent and/or a bypass is required, its sizing shall be determined in consideration of allowing a section of pipeline to be depressurised as rapidly as practicable during an emergency situation.

5.13.9 Any strategic valve intended for isolation purposes should include a block and bleed facility. If a valve also has a flow stopping purpose, reference should be made to clause 8.4.2.1.

5.14 CONSTRUCTION VALVES

Construction valves are used solely for the purpose of aiding the process of connecting pipeline systems.

If a construction valve is not supplied integrally with the branch fitting, a suitable valve shall be installed to aid the under pressure connection. The valve shall be selected depending on its future intended duty. If it is proposed to use it as a strategic valve, arrangements shall be made to enable pressure and rider points to be fitted before commissioning of the offtake, and access points at the ground surface to be constructed as soon as practical. If the valve is for construction purposes only, it shall be buried, the control mechanisms shall not be accessible from the ground surface and it shall not be used for controlling the gas supply system.

Where the pipeline is to be capable of being pigged, any construction valve left in place should allow the passage of a pigging device.

5.15 PIGGING

Where a pipeline is to be pigged as part of a routine maintenance regime or statutory requirement, its design should be in accordance with the appropriate parts of IGEM/TD/1, IGE/TD/12 and IGEM/TD/13 and full bore fittings shall be used.

SECTION 6 : CONSTRUCTION

6.1 PLANNING

6.1.1 Pipeline integrity

The integrity of a pipeline shall be ensured by correct design, material selection, sound construction practices and appropriate programmes of operation, maintenance and monitoring.

Note: Regulatory bodies increasingly require pipeline operators to provide positive demonstration that pipeline integrity is being monitored and maintained.

6.1.2 Safety management

All employers have a duty to 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, members of the public and property that might be affected by the works.

6.1.2.1 Risk assessments shall be carried out on all aspects of construction activities and the results retained until the project is completed.

Operatives must be provided with all necessary personal protective equipment (PPE) for the work to be undertaken.

Note: Regulations exist in the use and provision of personal protective clothing, aimed to assist in reducing risk to personnel by increasing their visibility and protecting them from inclement weather. For example, safety helmets need to be worn when there is a danger of head injury. In GB, the Construction (Head Protection) Regulations require head protection to be worn during the building operation and works of engineering construction, unless there is no foreseeable risk of injury to the head other than by the person falling.

6.1.2.2 Procedures shall be formulated for working in close proximity to plant belonging to any utility. These should include the reporting of any damage and any measures to be taken to protect plant.

Each utility will have specific guidance for working in the vicinity of such plant and should be contacted for further details.

6.1.2.3 Procedures shall be in place outlining the actions to be taken by personnel, including contractors, in the event of a gas escape or other incident.

Note: Further advice is contained in HSG47, IGEM/SR/29 and IGE/GL/8.

6.1.2.4 If damage is caused to a live gas pipe or if a smell of gas is detected, the emergency service provider (ESP) shall be contacted immediately. Neither a constructor nor its agents shall attempt to carry out repairs to live plant without the permission of the GT.

6.1.3 Method statements

6.1.3.1 The constructor shall produce a detailed method statement that covers each intended area of work. It should include detailed procedures to enable GTs to ensure compliance with relevant construction standards.

6.1.3.2 Method statements and/or procedures shall be prepared for the work activities being undertaken and be available on site. These activities include:

- materials handling, storage, inspection and quality control
- dealing with defective materials
- excavation and backfill

- pipe laying, including pipe location, depth and clearance from other plant
- pipe jointing and quality control
- steel welding and quality control
- corrosion protection
- pressure testing, including the type of equipment/calibration
- work in the vicinity of a GT's plant, including arrangements for emergencies and the reporting of damage (refer to IGE/SR/18)
- purging and commissioning
- installation, testing and commissioning of any PRI when particular attention should be given to the following:
  - tightness testing according to IGE/TD/13 after installing into the network
  - checking thoroughly that all packaging has been removed
  - performing a functional check on the PRI, recording settings and retaining copy inside the housing
  - commissioning and installing according to the manufacturer's instructions.

Note: The above list is not exhaustive.

6.1.4 **Quality control**

6.1.4.1 Quality Control (QC) procedures shall be prepared and should cover:

- the company's policy on quality, for example BS EN ISO 9000. This should include the management structure which clearly identifies roles, responsibilities and levels of authority. It should also include, where appropriate, contractors, sub-contractors, consultants, etc.
- competence of persons responsible for QC
- monitoring and audit of QC processes
- on-site inspections, detailed checklists and frequency of checks
- compliance with method statements and competency verification of on-site personnel
- accuracy and adequacy of records such as test certificates, materials traceability, as-laid plans, etc.
- procedure for the control and monitoring of critical phases of construction, i.e. pressure testing, purging, etc.
- calibration and checking procedure for equipment, for example test equipment
- materials storage, quality and conformity checks and controls
- control of deviations and variations from validated designs
- conformity of any PRI and housing.

6.1.5 **Materials**

6.1.5.1 Materials and equipment shall be selected to ensure safety and suitability for the conditions of use and, where appropriate, be in accordance with relevant legislation, standards and technical specifications.

6.1.5.2 Materials and components should be obtained from suppliers operating a quality system in accordance with BS EN ISO 9000, with the aim of ensuring products consistently achieve the required levels of quality.

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

6.1.6 **Inspection**

Particular emphasis should be placed on the inspection of materials, welding, fusing, pipe coatings, lowering in, backfill, drainage, reinstatement, testing and pigging operations (see clause 3.2.3).

6.1.7 **Site survey**

6.1.7.1 Prior to laying a pipeline, a detailed survey shall be undertaken to establish the most suitable line along which to lay. During this survey, the position of surface boxes, marker posts, recent excavations, etc., should be noted and compared with details of apparatus, including gas pipes and overhead power lines, previously supplied by utilities. Further checks should be made, using suitable instruments, to locate and define other underground apparatus not indicated by plans. The presence of buildings and structures which could be affected by the works, and the location of any underground voids, should also be noted.

6.1.7.2 Where a utility offers an on-site location service, advantage should be taken of this facility. Consideration shall be given to an inspection along the route, jointly with representatives of interested parties.

Note: This may include the highway authority, police, the street manager (for private roads), and the owner or tenant where land in private ownership is involved. This will enable the following to be identified:

- *any existing defect*
- *any need to re-route pedestrians or move bus stops*
- *any need for temporary traffic control measures or traffic diversions*
- *any need to provide additional signage.*

Photographic evidence may also be of future use should any claims for damage arise, provided it is possible to establish, subsequently, that such photographs were taken immediately prior to the commencement of works.

6.1.7.3 Where trees are present, advice should be sought from the highways authority's arboriculturist, or independent advice should be obtained on the precautions to be taken when working near tree roots (see NJUG Volume 4).

6.1.7.4 Where works are likely to have a major impact on local businesses, schools or colleges, early consultation should take place to ensure any special access requirements are met.

6.1.7.5 Where works are likely to have a major impact on traffic flow, for example affecting major traffic routes, consideration shall be given to extending working hours, although an assessment of the impact on the local community needs to be made and a balance reached.

6.1.8 **Resource planning**

6.1.8.1 Consideration shall be given to the siting and delivery of plant and equipment, vehicles, materials, etc., along the proposed route and agreement should be sought from the highways authority or landowner for the temporary stacking of pipe, to facilitate pipe laying. Such pipe shall be stacked safely and in a position that minimises inconvenience to pedestrians and does not invite vandalism. Traffic movement should not be restricted unnecessarily.

6.1.8.2 Vehicles will be required for transporting operatives, pipelaying materials, tools and equipment, disposing of excavated soil and for importation of reinstatement materials. Consideration shall be given to the provision of welfare facilities in vehicles used by operatives and to facilities for handling of equipment and heavy plant.

6.1.8.3 Equipment shall be maintained and tested regularly. Where necessary, calibration shall be carried out. Special attention shall be given to adherence to any statutory requirements. Records shall be kept of testing, maintenance and calibration. Only instruments with current certificates shall be used.

6.1.8.4 All tasks shall be carried out by competent personnel. Adequate training should be given and understood by operators. Where training is required, it should be recorded.

6.1.8.5 Careful planning of all resources shall be undertaken to cope with the rate of progress when rapid excavation techniques are employed.

6.1.9 Pre-construction considerations

6.1.9.1 Work must satisfy the requirement of relevant legislation, for example CDM.

6.1.9.2 Notification of the proposed works, in accordance with statutory or local procedures, shall be given to the highways authority and other authorities owning structures or plant along the route of the pipeline.

6.1.9.3 Prior to the commencement of works, agreement should be reached with the highways authority and other persons who may be concerned with the programme of work. Methods of construction, access ways, traffic control, reinstatement specification and any special road signs should be considered.

6.1.9.4 Risk assessments covering all aspects of the work shall be carried out.

6.2 SAFETY AND PROTECTION OF EXCAVATIONS

6.2.1 General

6.2.1.1 All works shall be carried out in a safe manner and due regard must be paid to appropriate safety legislation. In particular, work at or near railway crossings or other special hazards should be carried out in consultation with appropriate parties.

6.2.1.2 Road signs, warning lamps and barrier systems shall be provided to any operative required to work in a public highway or other work locations which are accessed by pedestrians or vehicles. These safety and protective systems shall be used to protect the operatives and the general public, particularly the blind, elderly and infirm. Types and specification of the items required must be in accordance with current regulations, issued by the appropriate highways or transport authorities. In GB, signing and guarding practice must conform to NRSWA and incorporate the Code of Practice on Safety at Street Works and Road Works, issued by the Department of Transport.

6.2.1.3 Traffic signals or warning lights should not be displayed in the vicinity of railways, airports or navigable waterways, without prior consultation with the appropriate authorities.

6.2.1.4 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 to third parties and to comply with Regulations (see clause 4.2.23).

6.2.2 Site surveillance

Arrangements shall be made for periodic checks to ensure that any site remains safe and secure. Any inadequacies identified in this way, or through notification by the public or other authorities, should be made good as soon as is practicable in order to ensure the continued safety of the public.

6.3 STORAGE AND HANDLING ON SITE

6.3.1 Steel and PE pipe fittings shall be handled, transported and stored in accordance with IGEM/TD/1 Edition 5 Supplement 1 or IGEM/G/8, as appropriate.

Note: The incorrect handling of loads causes large numbers of injuries and can result in pain, lost time and, on occasions, permanent disablement. In GB, The Manual Handling Operations Regulations apply to any manual handling operations which may cause injury at work. Those operations are identified by the risk assessment carried out under the Management of Health and Safety at Work Regulations. They include not only the lifting of loads, but also lowering, pushing, pulling, carrying or moving them, whether by hand or other bodily force. Manual Handling Assessment Charts (MACs) are available from HSE. MAC is a tool, which covers the initial assessment of manual handling tasks.

6.3.2 Steps shall be taken to avoid damage to pipes, fittings, valves, etc. In particular, valves shall be left in the open position and water/contaminants prevented from entering the valves.

6.4 EXCAVATION

6.4.1 Care of other services and safety of operatives

6.4.1.1 The requirements of approved safety practices and procedures, for example HSG47, shall be complied with where excavation and construction work is anticipated near to other underground services.

6.4.1.2 In GB, under NRSWA, at least one member of the team and any supervisor working in the highway must have been suitably trained and accredited for the type of activity undertaken.

6.4.1.3 Prior consultation should take place with other utilities, so that adequate measures for protection of their plant can be agreed.

6.4.1.4 Site operatives shall be provided with all available information on the position and location of all plant determined from the initial site survey. This should be compared with the result of site surveys produced by a plant location instrument capable of locating buried cables and pipe systems. Where discrepancies occur or where other utilities' apparatus is likely to be affected, investigation should proceed by hand-excavated trial holes.

6.4.2 Trial holes

6.4.2.1 Trial holes should be opened in advance of trench excavations to prove the proposed route. They should be excavated to a depth of at least 250 mm below the proposed pipe bed, to ensure that there is no existing apparatus close to and/or below the proposed bed of the pipe.

6.4.2.2 The depth, position and size of any obstacle should be recorded and the route of the pipeline modified if necessary.

6.4.2.3 The general public shall be safeguarded from open trial holes, by placing suitable barriers around the excavations and/or covering with suitable, anchored, plates.

6.4.3 Site precautions

6.4.3.1 Underground equipment shall not be disturbed or altered, in level or alignment, without the prior consent and approval of the owner or authority concerned.

6.4.3.2 All services and other apparatus shall be treated as "live", unless the owner certifies them as "dead".

6.4.3.3 Adequate provision shall be made for the effective temporary support of pipes, cables and other apparatus during the progress of the work and for their permanent support where the ground has been disturbed. Any damage to equipment shall be reported immediately, even where this damage may appear superficial, as unrepaired damages can often lead to premature failure of apparatus.

6.4.3.4 Where it is necessary to cross or run close to any other apparatus, sufficient clearance should be left to enable future repairs to be made.

Note: A minimum clearance of 250 mm is recommended.

6.4.3.5 Care shall be taken to prevent other utilities' apparatus, not exposed but adjacent to deep excavation, being affected by ground movement, particularly when moving trench supports.

6.4.3.6 Care shall be taken to prevent contact or arcing between cranes or other plant and overhead electricity or telecommunication cables, to prevent the risks of both damage and electric shock to personnel. "Goal posts" should be provided either side of the line of overhead apparatus, to indicate its position. Precautions advised in HSE GN GS6 should be applied.

6.4.3.7 Pipes shall not be stacked or handled near overhead power lines.

6.4.4 Gradient and level

Where there is a risk or possibility of water or other liquids entering or being deposited in the pipeline system, arrangements shall be considered for the collection and removal of such liquids. Syphons or dip pipes (see Sub-Section 6.10) should be installed at any low point on the route of the pipeline and the pipeline should be laid to a fall of at least 1 in 200 each side of the low point.

6.4.5 Depth of cover and locatability in the future

6.4.5.1 Minimum depths of cover should be as given in Table 7 and, as far as practicable, the location of the pipelines should be as shown in Figure 4, relative to other plant.

Note: Information is provided in NJUG Volume 1.

Wherever the depth of cover cannot be achieved, a risk assessment shall be carried out to determine whether additional protection is required. The assessment shall include consideration of:

- other services present and the likelihood of damage to the pipeline while working on the services
- the likelihood of new services being added in the future
- MOP of the pipeline.

Note: Figure 3 shows commonly used forms of impact protection.

LOCATION OF PIPELINE	**MOP**		
	≤ 2 bar	**> 2 ≤ 7 bar**	**>7 ≤ 16 bar**
Carriageways	0.75 m	0.75 m	1.1 m
Paved footways	0.6 m	0.6 m	1.1 m
Verges	0.75 m	0.75 m	1.1 m
Open fields and agricultural land	1.1 m	1.1 m	1.1 m

TABLE 7 - MINIMUM DEPTH OF COVER

6.4.5.2 Polyethylene pipes should not normally be laid at depths exceeding two metres, however if this depth is to be exceeded, a structural evaluation shall be undertaken.

Note: Guidance can be found in BS EN 1295.

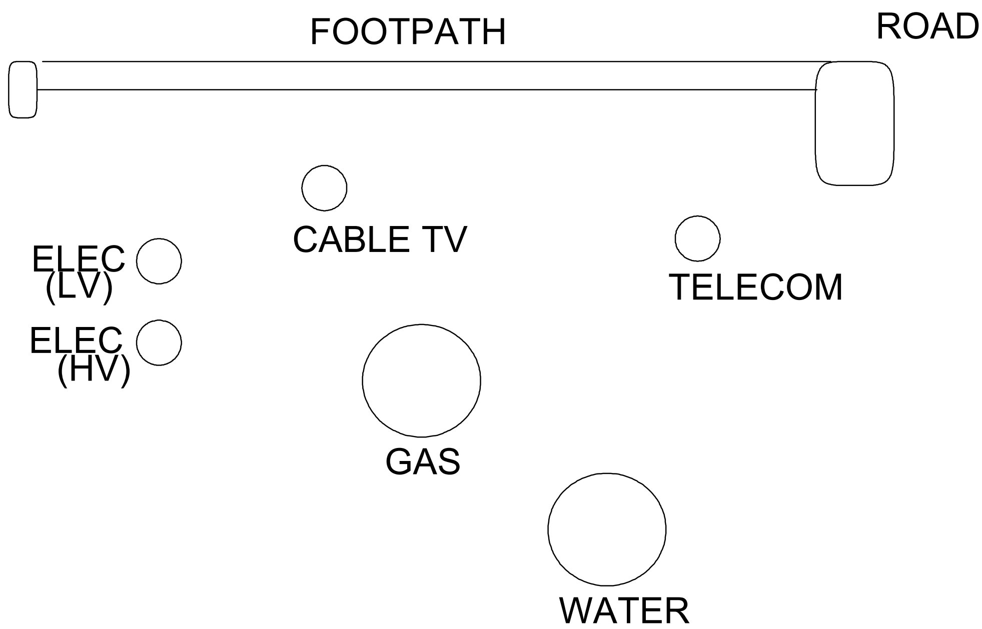


FIGURE 4 - TYPICAL SECTION OF PLANT IN FOOTWAYS

6.4.5.3 Pipes should not be laid within the road construction level.

6.4.5.4 Where open cut techniques are used, a warning tape shall be laid at least 150 mm above the pipe to give advance early warning to anyone subsequently excavating by hand or machine.

6.4.5.5 The location of pipes shall be recorded adequately, via suitable administrative records, to ensure future locatability.

Note: This may be through detailed drawings or use of detectable marker tape or suitably positioned marker posts (such as at field boundaries and crossing points).

6.4.6 **Adverse conditions**

6.4.6.1 Where water-logged ground conditions are encountered and water-removing equipment is not adequate to maintain safe working conditions, specialist advice should be sought from an engineer experienced in such work.

6.4.6.2 Consideration shall be given to the supply of a suitable non-corrosive material for the bed and surround of pipelines. Where pipes are to be laid in ground which shows evidence of chemical or industrial wastes, the ground shall be checked to determine if it is aggressive to pipe materials. If it is, the aggressive material should be removed and replacement material for the bed and pipe surround should be imported.

6.4.6.3 Trenching in made-up ground, or in conditions in which hard points may be expected, should be avoided as far as possible to eliminate any hard spots that would put unacceptable bending stresses onto pipes and may damage PE pipes or pipe coatings. Care shall be taken, in areas of recent excavation, that future settlement would be unlikely to put unacceptable stresses onto pipes.

6.4.6.4 When excavating in the vicinity of a landfill site, the excavation shall be checked regularly with a suitable methane detector. The use of a detector and gas alarm shall be considered, to warn operatives of any gas concentrations approaching unsafe levels.

Note: An alarm, which triggers at 20% LFL, would give adequate warning.

The possibility of oxygen deficiency in the vicinity shall be considered.

6.4.7 Preparation of trenches

6.4.7.1 The width of any trench should be kept to a minimum, consistent with the method of construction.

6.4.7.2 The bottom of any trench shall be trimmed to enable the pipeline to be bedded evenly and consistently, throughout its length, at the correct cover. Sharp stones should be excluded from the base of the trench and, where laying across rock or ground of irregular consistency, the trench should be excavated to 75 mm below the required depth, to enable the pipe to be laid on a bed of suitably compacted material.

Note: Further information can be found in the HSE publication L101.

6.4.8 Support of excavations

6.4.8.1 Where, because of the depth of the excavation, the nature of the ground or any superimposed loading, trench sides may become unstable, adequate precautions must be taken to prevent the collapse of the excavation.

6.4.8.2 Trenches which are left open shall be inspected at regular intervals and by a competent person.

6.4.9 Excavated material

6.4.9.1 Surface material should be kept separate from the sub-soil, so that these may be replaced in the correct order. Normally, the excavated material should be stacked alongside, but clear of, the trench side.

6.4.9.2 If excavated material is to be heaped in a gutter, precautions shall be taken to prevent the material entering any drainage gulley. Suitable channels shall be provided for the run-off of surface water.

6.4.9.3 Where the re-use of excavated materials is proposed, reference should be made to the HAUC Code of Practice "Reinstatement of openings in the highway". Technological advances in this area may give further opportunity for the re-use of these materials and these should be considered.

6.5 PIPE LAYING WITHOUT TRENCHING

Trenchless or minimum excavation techniques can reduce the installed cost of pipe laying operations, since both excavation and reinstatement costs can be saved.

6.5.1 The location of other apparatus shall be identified and the position of such apparatus pre-located on the pipelaying route.

6.5.2 The nature of the sub-soil and the extent of apparatus along the proposed route shall be assessed to determine whether trenchless pipelaying is viable and, if so, which particular technique is applicable.

6.5.3 Initial investigation of the proposed route should establish whether there is sufficient clearance from other underground plant to avoid damage to such plant and that the pipe can be laid at sufficient depth under roads and footways to avoid cracking of paved surfaces due to ground heave. Where there is any doubt on the location and depth of other plant, it shall be located by hand-excavated trial holes prior to work being carried out.

Note: Guidance on "no dig" techniques is contained in IGEM/SR/28.

6.5.4 The use of trenchless techniques provides potential environmental benefits, especially with respect to noise, dust and disposal of waste materials. Prior to selecting the preferred method of construction, an assessment of these benefits, cost, risk, etc., should be carried out.

6.5.5 The range and type of equipment available to lay pipelines by non-open-cut methods to minimise excavation are varied and are improving with the technology of the day. Reference should be made to specialist equipment manufacturers for details.

Note 1: Further advice is contained in IGEM/SR/28.

Note 2: Where the laying of a new pipeline is as a replacement for an existing pipeline or where redundant pipework can be utilized, insertion techniques may provide the least disruptive and most cost-effective solution. A number of techniques are available which include dead insertion, live insertion and close fit insertion. These methods are only applicable where a smaller diameter pipeline is required. Consideration needs to be given to the sealing of any annulus when pipes have been inserted.

Size-for-size insertion, which involves splitting the existing main with a suitable burster or splitter, leaves a bore of diameter similar or larger than the diameter of the original pipeline.

6.6 PIPE LAYING BY OPEN CUT TECHNIQUES

As with trenchless technologies, there have been great improvements in the variety and performance of equipment available to carry out excavation in the highway.

6.6.1 General

Consideration shall be given to ensuring that the correct equipment is used. Some of this equipment is expensive to purchase and availability limited, leading to long timescales. This should be considered at the planning stage of the project and availability checked with suppliers and hirers.

6.6.2 Excavation techniques and equipment

Equipment most commonly used includes mechanical excavators, rockwheels and chain trenchers which allow the rapid excavation of significant lengths of ground. Reference should be made to equipment manufacturers for details of the latest availability.

6.7 PIPELINE CONSTRUCTION

6.7.1 General

6.7.1.1 All pipes and fittings shall be examined for obvious physical defects. Faulty material should be marked clearly and removed from site. Damage to protective coatings, wrappings or sheathings shall be made good immediately. A further inspection shall be made prior to using the materials.

6.7.1.2 Coiled pipe shall be supplied with the bore clean and temporarily stopped, to prevent the ingress of foreign material. Cut coils that are to be kept for future use shall be re-stopped after cutting. The bore shall be visually inspected before jointing to ensure that it is clear of foreign matter.

6.7.1.3 When laying is not in progress, particularly overnight, any open pipe end shall be capped securely or plugged to avoid the ingress of water and other contaminants.

6.7.1.4 During lowering of a pipe into a trench, persons shall not be allowed to stand underneath the suspended pipe.

6.7.2 PE pipe

6.7.2.1 Residual tensile stresses can appear in PE pipe systems when the normal operating temperature of the pipe is below the temperature at which the pipe was constructed or when it has been towed under a high pulling force. The time of connecting newly constructed systems to existing pipes shall be arranged such that residual tension in completed lines is minimised.

6.7.2.2 As PE pipe has a high coefficient of linear thermal expansion, suitable temporary and permanent anchorage methods shall be considered.

6.7.2.3 Coiled pipe not exceeding 32 mm diameter is generally capable of being manually handled on site. Dispensing shall take place under the direction of a trained and competent person with a minimum of three persons for dispensing pipe 90 mm and above and a minimum of two persons when dispensing smaller sizes.

Coiled pipe stores a great deal of energy and will spring out as the banding is cut. It is important the banding shall be cut in the correct sequence to prevent serious injury. The work area shall be restricted to essential personnel who shall wear appropriate PPE (see clause 4.2.18).

Note: *Further guidance on the transportation, handling and storage of PE pipe and fittings is contained in IGEM/G/8 and appropriate manufacturers' equipment instructions.*

6.7.2.4 The minimum installed bend radius of PE pipe shall be in accordance with the limits in Table 8.

SDR	**MINIMUM BEND RADIUS**	
	Without joint in bend	**With joint in bend**
11	15D	25D
17	15D	45D
26	35D	45D

D = nominal diameter of pipe.

TABLE 8 - MINIMUM BEND RADII OF PE PIPE

6.8 JOINTING OF PE PIPE SYSTEMS

6.8.1 General

6.8.1.1 The number of joints shall be minimised by using pipe in coiled form or, if straight pipe is used, the longest practical length. Preference shall be given to jointing processes which maintain homogeneity of the pipe system, i.e. butt fusion or electrofusion.

Note: *Where this is not possible, mechanical joints are available.*

The principal objective should be that the resultant joint performance is as good as that of the pipe itself, under all normal operating conditions.

6.8.1.2 Jointing shall be undertaken by competent operators and using approved procedures, equipment and material. Reference should be made to the manufacturer's specifications.

6.8.1.3 An appropriate QC system shall be used to ensure that fusion jointing is carried out in accordance with the specified procedures and monitored by competent personnel.

6.8.2 Fusion jointing procedures and equipment

6.8.2.1 Properly constructed joints should not fail within the lifetime of the pipe system. However, adverse circumstances or installation constraints may arise which could affect the joint performance and, therefore, due cognizance shall be taken of the following points, to ensure good joint integrity.

6.8.2.2 Formal jointing procedures shall be developed for each fusion method, in conjunction with the manufacturers of pipe, fittings and equipment. These procedures shall cover safe working practices, preparation of the joint, alignment, clamping, temperature, time pressure control and appropriate cooling periods.

6.8.2.3 Power sources shall be chosen to meet the energy requirements of the jointing equipment.

6.8.2.4 Operators shall be trained under a formal programme to cover the execution of the jointing procedures. They should be assessed for competence prior to undertaking such work and re-assessed periodically thereafter.

6.8.2.5 Formal procedures for the operation, maintenance and calibration of fusion equipment should be developed with the equipment manufacturers.

6.8.2.6 Equipment for fusion jointing shall be examined at regular intervals and immediately prior to use. Particular attention shall be paid to the condition of heater faces, temperature indicators and mechanical methods of achieving alignment clamping within set limits.

6.8.2.7 Methods of inspection and testing of fusion joints, for example dimensional, visual appearance, melt bead removal and examination, destructive testing, ultrasonics, etc., should be included in the quality control procedures for system construction.

6.8.2.8 All fusion machines should have a facility for printing records or electronically downloading data from the jointing process. Quality control procedures shall include the inspection of fusion jointing printouts or data downloads.

6.8.3 Butt fusion jointing

Butt fusion is a jointing method which allows on-site jointing of PE pipes. It is a thermo-fusion process which involves the simultaneous heating of the ends of two pipes to be jointed, in a dedicated butt fusion machine, until a melt state is attained at each contact surface. The two surfaces are then brought together under controlled pressure for specific fusion and cooling times and a homogeneous joint is formed. The resultant joint is fully resistant to end load and has identical performance under pressure to the pipes used for the joint. It is used for both PE 80 and PE 100 grades of material for pipes of size 90 mm and above and of the same material grade and Standard Dimension Ratio (SDR).

The jointing process is vulnerable to the effects of wind chill, and contamination due to dust or water. If butt fusion jointing is to be undertaken in these conditions then a shelter or tent shall be used and end stoppers fitted to all pipe ends.

Butt fusion jointing should not be carried out at temperatures below -5°C and if necessary space heating should be provided to the shelter.

Note 1: Butt fusion joints can also be susceptible to inclusions of foreign matter and failure of a poorly made joint can result in a full circumferential break with a substantial release of gas.

Note 2: Equipment that offers automatic control and data retrieval facilities which provide joint construction records and assist future traceability is available and is preferred.

6.8.3.1 Fully automatic butt fusion machines shall be used for pipe up to 500 mm. For pipes greater than 500 mm, if available, a fully automatic butt fusion machine should be used.

6.8.3.2 Jointing shall not be undertaken with pipes of differing material grades or wall thickness. Pipe end alignment and ovality shall be within prescribed limits to ensure integrity.

6.8.3.3 Jointing shall be in accordance with the appropriate parameters prescribed for the pipe size, wall thickness and material, obtainable from the pipe manufacturers and equipment suppliers.

Prior to commencing site butt fusion jointing, the cold heater plate shall be thoroughly cleaned, using clean water and lint-free cloth or tissue. Grease and oil films may be removed using suitable alcohol wipes.

6.8.3.4 Joints shall be examined visually to check that the bead is the correct shape and size and that excessive misalignment of the pipes has not occurred. Suitable bead gauges are available for this purpose.

Note: It has been demonstrated, that on occasions, the first butt fusion made on site can result in poor joint quality. This has been attributed to fine dust particles which are attracted to a cold PTFE heater plate by electrostatic charge. However, the plate will lose this charge when hot.

Even though washing may remove large deposits of dirt, residual fine particles of dust may remain on the heater plate. To remove this, a trial or "dummy joint(s)" shall be made at the start of any jointing session, change in the pipe diameter or when the heater plate has been allowed to cool.

Note: It is not necessary to complete a full joint and the procedure can be discontinued after the heating cycle is completed. Pipe ends can then be re-planed following the prescribed cooling time.

6.8.3.5 All external beads shall be removed using suitable equipment, which does not cause damage to the pipe, as a means of assessing joint integrity.

Consideration shall be given to the removal of the internal bead to allow for smooth flow of gas and, hence, to reduce any friction factoring that will reduce capacity.

6.8.3.6 The underside of the external bead shall be checked for signs of contamination. Following repeated bending of the weld bead, there shall be no signs of any circumferential slit defect (as shown in Appendix 7). If any contamination, or slit defect, or lack of fusion, is observed, the weld shall be cut out and retained for futher investigation.

6.8.3.7 Tensile test specimens from butt fusion joints can be produced in the laboratory and "pulled" to failure in a tensile testing machine. For a weld to be considered satisfactory, the fracture surfaces of the tensile specimens shall show a high degree of ductility.

Note: The procedures for tensile testing are given in BS ISO 13953 (see also GIS/PL2-3).

6.8.3.8 When submitting joints for tensile testing, beads should be left intact and pipe cut at a minimum distance of 150 mm either side of the joint.

Note 1: Thin sections cut across the butt fusion weld can also be assessed by examination of their microstructure under an optical microscope and using polarised light.

Note 2: The use of radiography may detect large defects such as porosity, shrinkage cavities, cracks and inclusions but will not detect those resulting from cold fusion or incorrect fusion parameters.

6.8.4 Electrofusion jointing

Electrofusion involves the use of fittings with integral heating coils which, when energised from an electrofusion control unit (ECU), melt the outside of the pipe and the inside of the fitting. Melt pressure develops at the interface, promoting good mixture of the molten surfaces and the formation of a homogeneous joint.

Electrofusion is suitable for jointing pipes and fittings of different grades of PE and is independent of the pipe wall thickness.

A partial or lack of movement of the fusion indicators would indicate that insufficient melt pressure had been developed between pipe and fitting or insufficient heat had been generated. This would result from incorrect assembly, inadequate clamping or the heating time being too short.

Excessive movement of the fusion indicators would indicate that too much heat has been applied to the fitting. This would result from the heating time being too long or relative movement occurring between pipe and fitting during heating.

6.8.4.1 Electrofusion requires accurate control of the heating and cooling cycles and automatic control units with data retrieval facilities are to be preferred. Fittings shall be retained in their protective wrappings until immediately before fusion.

Note: Automatic recognition systems for electrofusion fittings are available. Where they are used they will need to be in accordance with an appropriate standard, for example ISO 13950.

Alignment and anchorage during the fusion cycle are especially important and movement during the fusion process shall be prevented by the use of alignment clamps which shall not be disturbed until completion of the cooling time.

The jointing process is vulnerable to the effects of wind chill, and contamination due to dust or water. If Electrofusion jointing is to be undertaken in these conditions then a shelter or tent shall be used.

Electrofusion fittings manufactured to GIS/PL2 Part 4 will have demonstrated their capability of being jointed at ambient temperature between -5°C to (+)23°C when using electrofusion control units to GIS/ECE1. When operating outside this temperature range the fittings manufacturer shall be consulted with regards to the fusion parameters required.

6.8.4.2 The ovality of pipe is crucial to the performance of an electrofusion joint. Pipes shall be checked for ovality prior to electrofusion and a re-rounding tool should be used where necessary for a minimum of 10 minutes prior to preparing the pipe.

Note: Appropriate alignment clamps can be used to maintain the roundness and alignment during the electrofusion process.

6.8.4.3 Pipe ends shall be cut square and the outer pipe surface scraped, beyond the fusion area, in order to remove the oxide layer. Over-scraping should be avoided. This operation should be left until immediately before jointing.

Note: The use of mechanical tools which remove a thickness of between 0.2 and 0.4 mm as a continuous ribbon, are preferred.

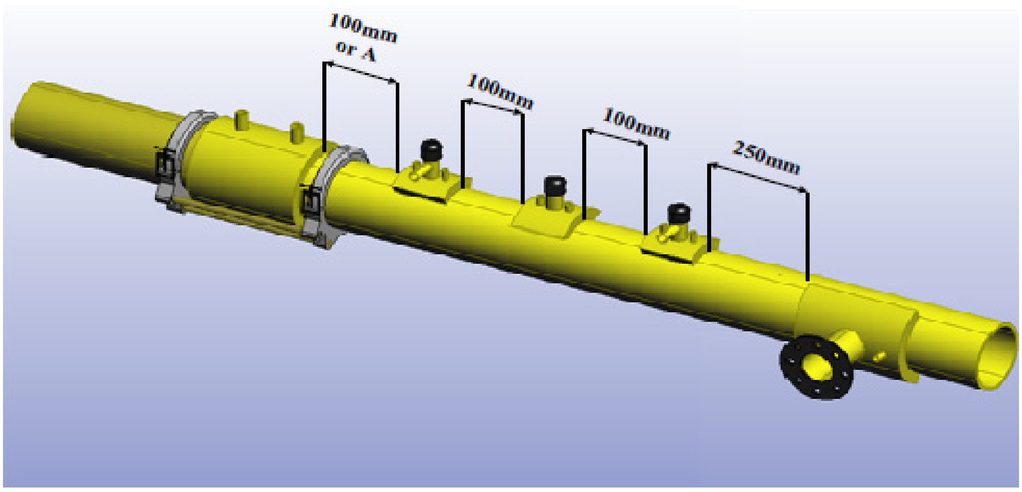
6.8.4.4 Care shall be taken to ensure that the pipe end spigots are pushed into the centre of the coupler and cover all the heating coils.

Note: Failure to ensure adequate penetration can lead to uncontrolled flow of molten PE.

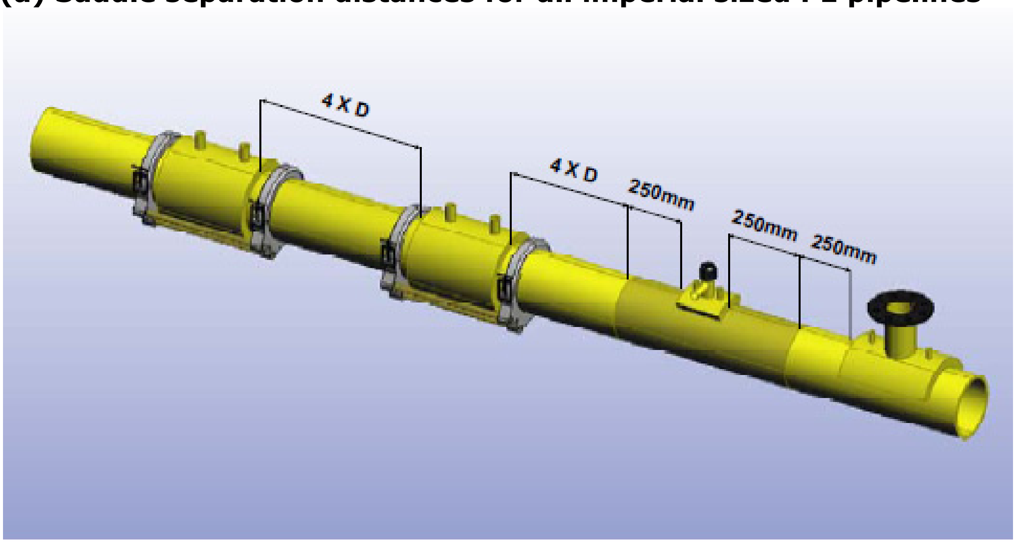
6.8.4.5 Where electrofusion couplers are used in conjunction with thin-walled pipes or there is the need to mechanically revert the pipe ends, metal or plastic inserts shall be used when recommended by the manufacturer to retain dimensional stability during the fusion process.

6.8.4.6 Where required for quality control, the strength of electrofusion joints should be assessed on test samples by drop weight and crush strength tests (for saddle fittings) and peel testing (for socket fittings) in accordance with GIS/PL2-4. The fracture surfaces should show a high degree of ductility.

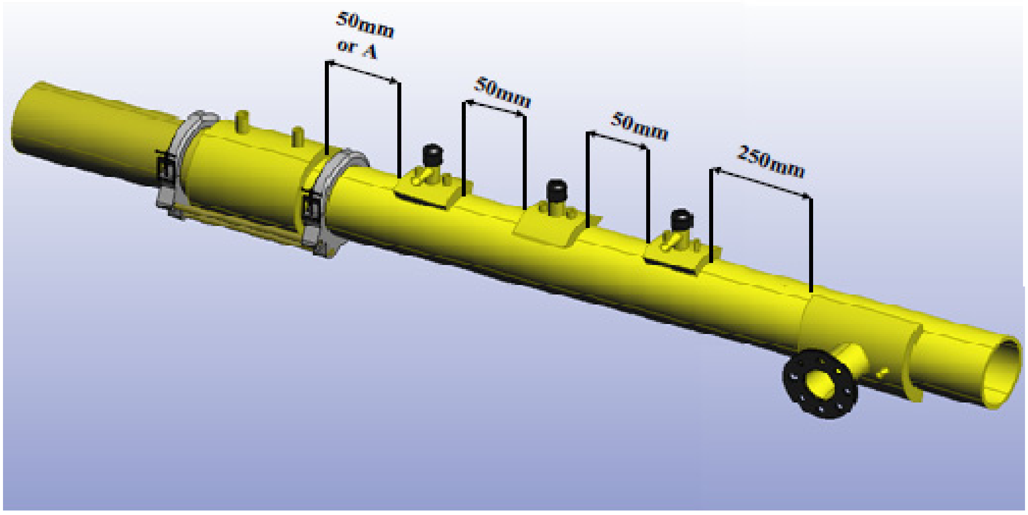
6.8.4.7 The minimum distance between pipeline fitting, butt weld or a cut should be as given in Figure 5.



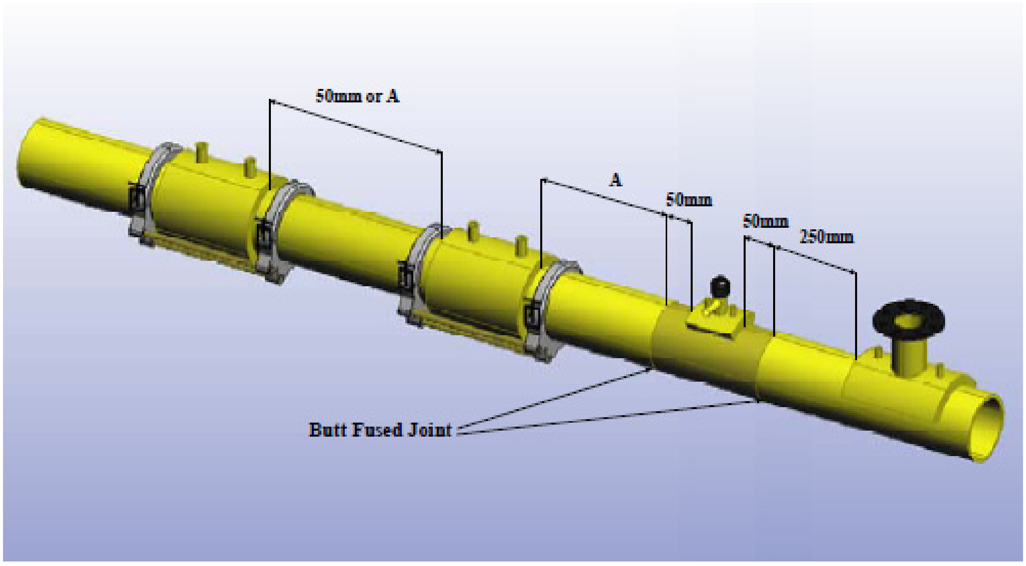
(a) Saddle separation distances for all imperial sized PE pipelines



(b) Other fitting separation distances for all imperial sized PE pipelines



(c) Saddle separation distances for all metric sized PE pipelines



(d) Other fitting separation distances for all metric sized PE pipelines

Note 1: Where there is any uncertainty over the pipe material size then the dimensions from (a) and (b) have to be used.

Note 2: PE Branch saddles cannot be fitted to close fit or swage lined pipes, for example, those PE pipes with an SDR of 26, as the fusing process will potentially melt through the pipe wall.

Note 3: D = External Diameter of pipe, A = 50mm or the minimum distance required to fit an alignment clamp, whichever is the greater.

FIGURE 5 - MINIMUM DISTANCES BETWEEN FITTINGS OF PE PIPE

6.8.5 Mechanical jointing

Mechanical methods of jointing are employed where fusion methods are impracticable, where materials or dimensions are unsuitable for a particular fusion method or for the transition from PE to pipes of other materials.

6.8.5.1 Mechanical fittings shall be installed in accordance with the manufacturer's instructions and using approved tools and equipment. Due regard shall be given to the correct positioning of any inserts, gaskets or seals and the achievement of the recommended bolting torques.

6.8.5.2 Mechanical fittings shall be end-load bearing.

Note 1: Designs using elastomeric seals or those based upon controlled compression of the pipe wall are preferred. Usually, such systems incorporate a supporting liner on the reactive surface of the pipe wall opposite to that to which the load is applied.

Note 2: There are three principal jointing methods:
- *the use of controlled external collapsing rings, which cause the PE to cold flow onto the internal support liner to provide both sealing and end loading*
- *the controlled internal expansion of the internal support liner against a fixed ring, utilising the PE to seal*
- *the compression of an elastomeric seal onto the pipe, to form the seal with additional internal or external locking devices.*

Note 3: GIS/PL-3 provides a suitable specification for such fittings.

6.8.5.3 Fittings shall be free of rough or sharp edges likely to damage the PE pipe.

6.8.5.4 During pressure testing, or where unrestrained mechanical fittings are used, restraint against pressure-induced thrust shall be provided.

6.9 STEEL PIPE SYSTEMS – JOINTING, COATING, WRAPPING AND CORROSION PREVENTION

Steel systems may be joined by welding or mechanical jointing, having due regard to the pressure rating, route and design of the system.

6.9.1 General

6.9.1.1 Jointing shall only be undertaken by competent operators and using approved procedures and materials.

6.9.1.2 Appropriate QC systems shall be used to ensure that welding and any other jointing is carried out in accordance with the specified procedures and monitored by qualified personnel.

6.9.2 Welded joints

6.9.2.1 Pipes and fittings shall be prepared, welded and inspected by qualified personnel and in accordance with a suitable specification.

In particular, surfaces to be joined shall be clean and dry with pipe and fittings having the appropriate end preparation.

6.9.2.2 When lining up for welding, pipes shall be supported adequately with sufficient clearance around the pipe to facilitate welding. Care shall be taken at all times to avoid damage to the pipe and coating.

6.9.2.3 Cut pipes should have details of pipe reference numbers transferred to each cut end. The cut ends should be checked for laminations.

6.9.2.4 Methods of inspection and testing of welded joints, for example ultrasonic testing, dye penetration, radiographic, etc. shall be included in the QC procedures for system construction.

6.9.2.5 The use of non-destructive weld tests prior to wrapping and laying is recommended. Radiographic inspection shall be planned in relation to other work to ensure safety and to avoid delay.

For MOP exceeding 7 bar, 100% radiography should be employed.

Note: For MOP not exceeding 7 bar, this may be reduced to a minimum of 10%.

6.9.2.6 Before welding to a "live" pipeline, the pipe wall thickness shall be checked ultrasonically for adequate thickness and for lamination.

6.9.2.7 Pipe and fittings should be prepared, welded and inspected in accordance with a suitable specification such as BS EN 12732.

6.9.2.8 Welding should be completed above ground wherever possible, so that welds and joint wrapping may be inspected easily.

6.9.2.9 When lining-up for welding, pipes shall be placed on timber skids suitably cushioned on top and with sufficient clearance under the pipe to facilitate welding.

6.9.2.10 Pipes may be bent cold in the field but this work shall be undertaken only by competent operators. Bending should be performed, without wrinkling, on a suitable machine. In the finished bend, the angular deflection measured along any axial length equal to the diameter of the pipe should not exceed 1.5^o (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).

6.9.2.11 Each pipe that is bent shall incorporate a minimum length of 1.25 m of straight pipe before and after the bent portion. A bend shall not be made within two pipe diameters of a girth weld, which has already been made. When longitudinally welded pipes are used, the weld shall be at about 45^o to the plane of the bend and longitudinal welds of consecutive cold bends shall not coincide.

6.9.3 Pipe coating and wrapping

6.9.3.1 Uncoated external portions of pipeline joints shall be protected to a standard at least equivalent to, and compatible with, the linepipe coating. Coating and wrapping applied before bending should be examined and any damage made good.

6.9.3.2 Steel pipe shall be laid so that the protective coating is not damaged. Regular checks should be made to determine whether such damage is occurring. Immediately before the 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 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 shall be kept of such damage (unless very minor) and should be included in the construction records.

6.9.3.3 If disbonding of the coating is suspected at any point, it shall be removed, replaced and re-tested.

6.9.3.4 Where any coating damage is detected, the pipe itself shall be inspected for associated damage such as dents, gouges, grooves, notches, arc burns, etc. Such damage shall be assessed by a competent person and repaired as necessary.

6.9.3.5 Prior to backfilling the trench, the coating and wrapping shall be re-inspected and, where necessary, repaired.

6.9.4 Corrosion prevention

6.9.4.1 The installation of a CP scheme, utilizing either sacrificial anodes or impressed current, shall be as detailed in clause 5.7.3.2. As soon as possible during construction, CP should be applied to the pipeline in accordance with BS 7361.

Note: Attention is particularly drawn to the following aspects of BS 7361:

- *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 protection of sleeves*
- *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, etc.*
- *induced AC corrosion.*

6.9.4.2 CIPS of the entire pipeline shall be undertaken as soon as possible after complete commissioning of the CP system, in order to fully validate and provide a fingerprint of the CP system.

6.9.4.3 Permanent records should be maintained of all corrosion control measures. These should include:

- type of internal coating
- types of external factory or field applied coating
- disposition and type of CP components and bonds
- CP monitoring results
- state of interference bonds and shared schemes
- paint system performance
- results of inspection surveys, for example Pearson, CIPS, nitrogen sleeves, etc.
- remedial work carried out
- details of all sleeves, including any protection arrangements.

6.9.5 Mechanical jointing

6.9.5.1 Mechanical fittings allow for the jointing of pipes of different diameter and/or wall thickness or where the preferred jointing method is not practicable. The fitness for purpose of such fittings shall be confirmed prior to installation.

Note: Types of fittings include couplings and flange adapters, (which seal by compression of an elastomeric seal onto the pipe) and full encirclement fittings, having circumferential seal (which are used to take branches from existing live pipelines).

Joints should be made using approved fittings and installed in accordance with the manufacturer's recommendations.

6.9.5.2 Pipe ends shall be free of any pits and other surface defects.

6.9.5.3 Flanges shall be checked before installation, to ensure that boltholes and faces are aligned correctly and that the faces are clean and free from pitting and other surface irregularities.

6.9.5.4 Where the fitting forms part of a cathodically-protected system, electrical continuity should be maintained.

6.10 SYPHONS, DIP PIPES AND DIP PIPE COLLARS

Where necessary, provision should be made for the removal of condensate and other liquids from the system, by the installation of syphons, dip pipes or dip pipe collars located at low points. They should be positioned so as to ensure unrestricted access to the standpipe, for condensate removal and maintenance.

6.11 INSTALLING STRATEGIC VALVES

6.11.1 Pressure and rider points shall be installed on each side of any valve, together with greasing points.

Note: The provision of a surface-accessed bleed point for double block and bleed valves is preferred so that positive isolation can be achieved without additional works.

6.11.2 Any valve shall be so positioned as to ensure unrestricted access for its operation and maintenance.

6.11.3 Consideration shall be given to providing sufficient support for any valve. This would include allowance for changes to stresses imposed on the valve.

6.11.4 Consideration shall be given to fitting valve locking or immobilising devices to any accessible valve, to improve security.

6.11.5 A strategic reference system for valves shall be employed. Details such as the type of valve and the number of complete turns of the spindle between fully open and fully closed shall be recorded, together with the direction of rotation.

6.11.6 All valves shall be uniquely identified and any ¼ turn valve should be identified clearly that it is a ¼ turn valve.

6.11.7 Corrosion protection shall be provided for all valves and associated metallic flanges.

6.12 SURFACE BOXES

6.12.1 Syphon standpipes, valves, etc., should be covered by a box marked "GAS".

Note: Marker posts (see Sub-Section 6.14) or plates may be installed as an aid to location and identification.

6.12.2 The top of any standpipe or valve spindle should terminate 100 mm below the underside of the lid of the box, with sufficient room being available to operate the line or branch valve or to open the valve on top of the standpipe.

6.12.3 Any surface box should be selected, constructed and installed to withstand the maximum static and dynamic loads to which it will be subjected.

6.13 ANCHORAGE

6.13.1 Unless the system is fully welded, consideration shall be given to the provision of permanent anchorage for any pipeline, particularly those of MOP exceeding 75 mbar. Systems should be all-welded or fused as appropriate, or have mechanical joints that are resistant to end loads.

Note: Where the system is fully welded, anchorage is not, normally, required.

6.13.2 Where external anchorage is required, for example when using compression type jointing for a PE to a metallic main, anchor blocks may be used provided the ground conditions are suitable to bear any transmitted loading.

Anchor blocks shall not be attached to, or built around, existing apparatus, nor shall they encase mechanical joints. Sufficient clearance shall be allowed to provide access to any mechanical joint for maintenance. Anchor blocks to existing apparatus should not be disturbed.

6.13.3 Where ground conditions are unstable, and particularly where floating of the pipe may occur, suitable anchorage should be provided at all bends, tees, plugs, caps and valves, to resist forces from internal pressure and to provide negative buoyancy along the pipes themselves.

Note: Specialist advice may have to be obtained, regarding the type of anchorage needed in any particular case.

6.13.4 Where connections are made to existing systems that do not have anchorage, caution shall be exercised.

6.14 MARKER POSTS

For any pipeline of MOP exceeding 2 bar, and not located within a highway, the position of the pipeline shall be indicated at suitable intervals by the means of marker posts. These should be at field boundaries, at all crossings and, where practicable, at changes in direction. Where fitted, a marker plate on the post should indicate the operator/owner and the location of the pipeline after reinstatement of the ground. For any pipeline of MOP exceeding 7 bar, consideration shall be given to the provision of marker plates that are specifically designed and located to enable observation during an aerial survey.

6.15 REINSTATEMENT

6.15.1 General

6.15.1.1 The reinstatement of excavations in footways and carriageways should be designed to replace, as far as possible, the stiffness and density of the existing structure. The design of carriageway reinstatements should take account of the traffic levels and should conform to recognised design principles. Completed interim and permanent reinstatements should be, substantially, flush with adjacent surfaces and should exhibit no significant deviation from the profile of the adjacent surfaces.

6.15.1.2 Materials that are typically organic, perishable, hazardous, frozen, combustible or highly plastic are not suitable and should not be used.

6.15.1.3 In GB, reinstatement must be carried out in accordance with the Regulations and Codes of Practice issued in accordance with Section 71 of NRSWA.

6.15.2 Finefill and pipe surround

Cohesive or granular materials which are free from sharp stones shall be used for the pipe surround.

6.15.3 Backfill and sub-base materials

Excavated materials but excluding unsuitable materials (see clause 6.15.1.2) may be suitable for use as sub-base materials if stored correctly.

6.15.3.1 Imported granular materials can be used as a unified sub-base and road base in flexible roads. The moisture content of these materials should be controlled in order to achieve a good standard of reinstatement.

6.15.3.2 Material stabilisers have been developed to permit increased use of excavated materials. Their acceptance for particular applications should be checked with the highway authority before use.

Note: Foam concretes and mortars which flow freely can be used as reinstatement materials up to base course level. These materials have the advantage of not needing compaction.

6.15.4 **Base and wearing course material**

6.15.4.1 Hot laid dense bitumen macadam, hot rolled asphalts and cold laid bituminous emulsion macadams may be used as base and wearing course materials. The suitability of the various aggregate sizes and binder properties should be ascertained by reference to relevant specifications.

6.15.4.2 Hot-laid materials should be maintained at the correct laying temperature.

6.15.5 **Compaction**

6.15.5.1 Rigorous requirements for compaction of excavated materials, graded granular material and bituminous materials shall be enforced to achieve minimum settlement of the reinstated excavation.

Note: Compaction density may be tested with an appropriate impact tester.

6.15.5.2 There is a large variety of equipment suitable for compaction of reinstatement materials. The equipment should be assessed to ensure that it is suitable for the application.

SECTION 7 : PRESSURE TESTING, COMMISSIONING AND DE-COMMISSIONING

7.1 GENERAL

7.1.1 All new and replacement pipework shall be strength tested (using water, air, or inert gas) and tightness tested using an appropriate test method.

Note: The selection of each test method will be dependent on a number of factors, including the pipework material and MOP. A successful test confirms that the installation is fit for purpose.

The strength test pressure (STP) should exceed MIP, and the tightness test should be carried out to confirm that there is no significant leakage at a tightness test pressure (TTP) of at least MOP (see also clauses 7.1.7 and 7.4.2).

Note 1: Suitable strength test methods are hydrostatic (see Sub-Section 7.3) and pneumatic (see Sub-Section 7.4). For pneumatic testing, subject to consideration of safety and risk and only for MOP not exceeding 2 bar, a strength and tightness test may be carried out simultaneously i.e. combined (see clause 7.1.5).

Being safer than pneumatic testing, hydrostatic testing is preferred, irrespective of STP. HSGS4 states that hydrostatic testing takes precedence over pneumatic testing, unless the former is not practical. Problems associated with the removal of water and drying of the pipework (which is essential) will often mean that a pneumatic test is used for lower STPs and pipe sizes, subject to a satisfactory risk assessment and the provision of an exclusion zone around the pipework during the test.

Methods for drying systems are outlined in IGEM/TD/1.

Note 2: Advanced systems are available for pneumatically testing PE pipelines, for example those that use acoustics to measure temperature variations which in turn enables a reduction in test times.

A final tightness test shall be performed during final commissioning on any previously un-tested tie-in sections (see clauses 7.1.11 and 7.4.3).

Note: A preliminary pneumatic integrity test may be performed at a pressure not exceeding 350 mbar before burying pipework. This test does not replace the tightness test.

7.1.2 During a tightness test, the rate of pressure change is used to check that there are no leaks. While the test pressure will drop due to a leak, it can also change with temperature which can lead to misinterpretation, suggesting phantom leaks or masking real leaks. The effect of any change in temperature should be taken into account.

Note: For larger pipework volumes, test times are longer, hence significant changes in temperature are more likely.

7.1.3 For PE pipe, the creep effect may cause a change in pipework volume during the test. The pressure change caused by creep decreases with time. Therefore, a suitable conditioning period shall be allowed to permit creep expansion to diminish prior to the tightness test. Appendix 4 provides further background and a table for determination of appropriate permissible pressure drops.

Note: Creep can occur whenever there is a substantial pressure change. Recovery occurs on de-pressurisation, which means that creep can still be a problem for the pneumatic tightness test, even after hydrostatic testing.

7.1.4 The maximum permissible pressure change during a tightness test, compensated for temperature change and creep effects (for PE), shall be chosen such that, if a defect remains undetected, the resultant leakage would not be hazardous.

Note: Adjustments to the allowable drop may also be required to compensate for the difference in leakage which would occur at TTP compared to MOP (if the two are different) and for the different flow characteristics between air and gas.

7.1.5 For pipework of MOP not exceeding 75 mbar, integrity may be proved by a combined strength and tightness pneumatic test.

For pipework of MOP exceeding 75 mbar but not exceeding 2 bar, integrity may be proved by a combined strength and tightness pneumatic test. However, the risk of a pipework failure (with the potential consequences associated with a sudden release of a large volume of air) shall be assessed. The assessment shall take into account such factors as location, pipework material, method of construction, QC procedures, cover applied to the pipework and STP.

Note: As a result of this assessment, it may be necessary for the strength test to be hydrostatic and to precede the tightness test.

For pipework of MOP exceeding 2 bar, a hydrostatic strength test should be carried out before the pneumatic tightness test.

7.1.6 The selection of the test method, the test medium and STP/TTP shall be dependent on the pipework material, the type of joints and the intended application.

7.1.7 Where a previous strength test has not been carried out, for example on connections between existing and new pipework, TTP should be OP of the system.

7.1.8 The same instrument shall be used for all the test readings and shall capable of being read to 3 mbar.

Note: Typically, tests instruments used on pressure tests up to 10.5 bar will have an absolute accuracy of 3 mbar (for an instrument with a range 0 - 10.5 bar the accuracy required will be 0.0285%) or greater and a resolution of 0.1 mbar.

7.1.9 Before pipework is commissioned, a satisfactory tightness test shall be carried out.

7.1.10 Consideration shall be given to protecting metallic surfaces by wrapping or coating to prevent corrosion, following a successful test.

7.1.11 After pressurisation, and prior to final commissioning, any joint not subjected to a tightness test shall be confirmed as sound, at OP, for example by using Leak detection fluid (LDF).

7.1.12 The strength test is successful if there is no pressure loss recorded that cannot be accounted for by the effects of temperature change or creep. For tests on systems having PE content, STP should be held for at least 2 hours. After safe and complete removal of any water, a tightness test should be carried out.

Note: On systems constructed entirely of steel, a test period of 24 hours can be used, as prescribed in IGEM/TD/1. Owing to the higher integrity and quality of construction of an all-welded steel system, the need for a subsequent tightness test is then at the discretion of the responsible person.

7.2 SAFETY

7.2.1 A risk assessment shall be carried out and a written procedure shall be prepared. The written procedure should include the test method, STP/TTP, test period, minimum soak/conditioning period, test medium, test instrument acceptance criteria, allowable pressure and volume variation, minimum and maximum pressure in any existing system, leak detection systems, release of the test medium and the provision and disposal of any water.

7.2.2 Test equipment, including flexible connections, shall comply with appropriate standards or specifications and have valid certification or certificates of calibration, as appropriate.

7.2.3 Testing shall not be carried out against closed valves. Any pipework that does not have end-load resistance should be restrained against movement. All pipework being tested shall be physically isolated from the system pipework except when testing the connections between new and existing pipework.

7.2.4 Normally, pipework under test is buried. However, if pipework is exposed, it shall be secured adequately and protected against temperature variation.

7.2.5 Adequate barriers or other physical demarcation shall be positioned at a suitable distance from the test site. This distance shall be calculated to take account of the potential of stored energy release under pipe failure. The projected maximum distance of flying objects from the pipe under test shall be contained within the exclusion zone.

While the test pressure is being introduced, persons shall be prevented from entering the test area. Consideration shall be given to displaying warning notices indicating that the pipework is under test and to patrolling road crossings or areas of public access.

7.3 HYDROSTATIC STRENGTH TESTING

This test method requires the pipework section to be completely filled with water.

7.3.1 The pipework to be tested shall not be connected to the gas supply system.

7.3.2 STP shall be greater than MIP and, wherever possible, should be at least 1.5 MOP (see Appendix 4).

Note: A preliminary pneumatic integrity test may be performed at a pressure not exceeding 350 mbar before carrying out a hydrostatic strength test. This test does not replace the tightness test.

7.3.3 Adequate clean water should be available and, if required, water quality certificates should be obtained. Water shall not have an aggressive effect on the section components. Any necessary consent shall be obtained from the relevant authorities before commencing filling of the section. Arrangements shall be made for the safe disposal of the water after completion of the test.

7.3.4 Any change in elevation of the pipework section to be tested shall not cause over-pressurisation at the lowest point.

Note: Normally, a maximum change of 60 m in elevation is applied.

7.3.5 Suitable relief valves, set at 5% over the test pressure, should be fitted to all pressurisation points to avoid the possibility of unacceptable high pressures occurring during pigging. However, if the pipework is to be filled and emptied using gravity rather than pigging, consideration shall be given to the fitting of tappings at high points (to enable air to be vented) and at low points (to enable water removal).

Consideration shall be given to using a settling tank to reduce aeration of the water and due regard must be taken of the local water authority's regulations.

7.3.6 The water pumping system for filling the pipework should reduce air entrainment to a minimum and should be capable of overcoming any hydraulic head.

7.3.7 Where practical, water should be introduced into the pipework at the lowest point. Where difficulties exist in the introduction of, and eventual disposal of, the water, suitable pig launching and receiving units should be fitted at both ends of the pipework.

7.3.8 While filling the pipework, a continuous and even flow of water shall be maintained until the pipework is filled completely.

7.3.9 When the pipework has been filled with water, the pressure shall be increased slowly until STP has been reached. Consideration shall be given to calculating the volume of air trapped in the pipework to ensure that such volume is less than 0.2%. If this volume is exceeded, the pipe should be emptied and re-filled.

Note 1: The hazard to personnel with higher levels of included air is greatly increased due to the stored energy.

Note 2: Specialist advice may have to be obtained to calculate volume of trapped air.

7.3.10 When testing PE pipework, and if necessary, the pipework should be regularly re-pressurised to overcome the effects of creep.

7.3.11 Consideration shall be given to the eventual operating conditions that the pipeline will experience in order to determine the in-service dryness requirements. If OP is such that the formation of hydrate is possible, a drying regime should be incorporated in the commissioning programme (see IGEM/TD/1).

Note: If formation of hydrate is not possible, it will only be necessary to de-water using gravity, foam pigs or swabbing pigs, dependant on the pipework configuration and internal dimensions.

7.3.12 Pigging is used primarily in association with hydrostatic testing prior to and during water filling stages and finally as part of the water removal/drying phase. Pigging may be used to prove the unrestricted bore of the constructed pipeline. An initial test of 350 mbar test should be applied prior to undertaking any pigging operations and the pig driving pressure should be maintained as low as possible and shall not exceed the maximum pipe design pressure.

Many of the safety considerations that apply to testing also apply to the pigging process namely:

- the connection of the pigging/testing ends to the pipeline section start and end points shall be fully end load-bearing
- suitable end restraint force (D) shall be applied at both ends
- each pig trap/test end should have sufficient tappings to facilitate, air entry (A), air exit (B) and water exit/entry (C)
- the pressure in the system shall be monitored at both ends and should be kept to a minimum by controlling volume of the air entering and leaving the system. As with testing pressure relief valves shall be fitted on the test standpipes.

Note: A diagrammatic representation of the process is shown in Figure 6.

Care shall be taken in selecting the appropriate type of pig for the pipework under consideration. Information on the minimum internal diameter, minimum bend radius, tees and branches, any projections into the pipework, for example weld bead or melt, etc., shall be considered. The type and performance of the pig shall be matched to the pipework being de-watered.

Consideration shall also be given to the safe handling of pigs, in particular their controlled reception and the handling of displaced water.

Pigs shall be discharged into a suitable receiver under controlled conditions and not ejected from open ends of the pipework.

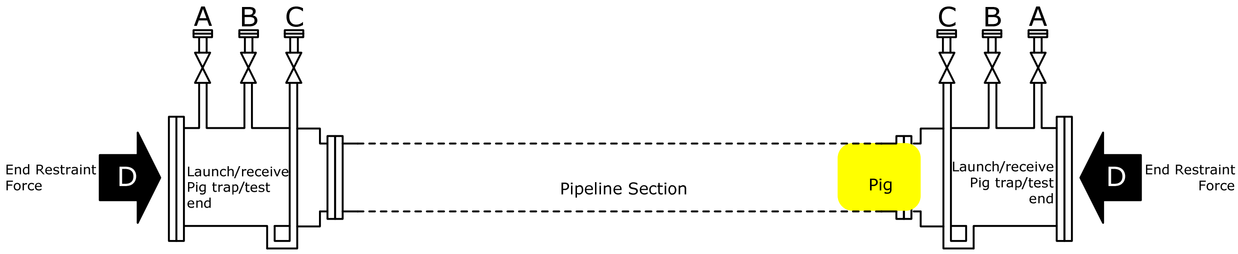


FIGURE 6 - PIGGING PROCESS

When pigging is being planned, considerations shall be given to the following:

- the dimensions of the pigging/testing traps
- the type of pig to be used in the process
- the type of fittings installed on the pipeline e.g. full bore valves, radii of bends etc
- special consideration should be applied in respect of tees which may influence the type of pig and may require the installation of guide bars (steel systems only)
- the contents of the pipeline to be pigged i.e. water, debris, dust, soil etc
- the speed of the pig shall be optimised by controlling the rate of air exit (exhaust) and ensuring any adjustments are made to the inlet flow so as to avoid over pressurising the system
- environmental consideration in respect of water/sludge/debris discharge consents.

Note: Further information on pigging is detailed in IGEM/TD/1.

7.3.13 It is important to consider the safe location and sizing of water discharge hoses due to potential energy contained in the system. Hoses shall be anchored securely to prevent whip and the potential of personal injury.

7.4 PNEUMATIC TESTING

7.4.1 General

7.4.1.1 The pipework to be tested should not be connected to the gas supply system (see also clause 7.4.2.2).

7.4.1.2 A standpipe shall be connected at one end of the pipework to be tested and shall incorporate a relief valve set to lift at 5% above STP. Gauges should be fitted as appropriate. Consideration shall be given to the fitting of pressure recorders.

7.4.1.3 Test instruments shall be fitted such that they can be read and operated without entering the trench or standing in line with the end of the pipework.

7.4.1.4 Air or inert gas shall be introduced under controlled conditions into the pipework until STP/TTP is reached.

7.4.1.5 While the test pressure is being raised and during the test period, no one shall be permitted to enter the excavation(s).

7.4.1.6 Where creep allowances are to be applied to PE pipework, the pipework should be maintained at the test pressure for a conditioning period before commencing the test period (see clause 7.1.3).

7.4.1.7 The temperature of the air inside the pipe should be stable before commencing the test.

Note: Temperature stabilisation after pressurisation can take up to 2 hours for PE/Steel and will be indicated by a stable pressure reading.

7.4.1.8 No other work shall be carried out on the pipework under test while the test is being undertaken.

Note: Where a test of long duration is to be applied, consideration may be given to taking intermediate test readings to assess whether the pipework will, ultimately, fail the test.

7.4.2 Tightness test

This test is carried out following a strength test (see also clause 7.4.3) or when a connection has been made between new and existing systems where joints are exposed for testing.

7.4.2.1 When this test is carried out following a strength test, TTP should be any value up to MIP and exceeding OP (see Appendix 4).

7.4.2.2 When this test is used on connections between new and existing pipework i.e. not strength tested, TTP should be OP of the system (see Sub-Section 8.6.5).

7.4.3 Combined strength and tightness test

7.4.3.1 For pipework of MOP not exceeding 75 mbar, a test pressure of 350 mbar should be applied.

7.4.3.2 For pipework of MOP exceeding 75 mbar, but not exceeding 2 bar, a test pressure of 3 bar should be applied.

7.5 LEAK DETECTION

7.5.1 If a tightness test fails, the source of leakage shall be located prior to commissioning the pipework. Before carrying out any remedial works, a risk assessment shall be carried out. It may be necessary to examine connections, plugs and joints for possible leakage and this shall only be carried out upon receipt of written authorisation. Due consideration shall be taken of the pressure inside the pipework under test and a reduction in the pressure within the pipework of 15% shall be considered before carrying out any examination of the pipework.

Note 1: If no obvious leakage path is found, a re-test may be considered appropriate.

Note 2: If further test failures are experienced, further investigations using trace gases can be used. Trace gases normally used are Sulphur Hexafluoride (SF_6), Helium or Ethyl Mercaptan. It may be necessary to divide the pipework into sub-sections and to separately test each sub-section to determine the location of the leakage.

7.5.2 When all sources of leakage have been located and repaired, a further test shall be carried out on the complete section of pipework.

7.6 TEMPERATURE

To minimise the effects of temperature variations during tightness testing, the pipework should be backfilled.

Note: The temperature of the pipework can be monitored during tightness testing by using ground temperature probes and an assessment can be made on whether any variation in temperature has affected the pressure readings. A change of 1°C will result in a pressure change of 4.5 mbar for pipework at TTP of 350 mbar, 13.3 mbar for pipework at TTP of 3 bar and 26.7 mbar for pipework at TTP of 7 bar.

7.7 BAROMETRIC PRESSURE

Consideration shall be given to correcting pneumatic test readings for variations in barometric pressure. Variations in barometric pressure can occur within short distances of the site and any readings should be taken and recorded as close to the site as possible.

Note: Test instruments with readings in absolute pressure do not require correction for barometric pressure.

7.8 CRITERIA

7.8.1 Pneumatic tests

The maximum pressure loss that should be permitted is related to the volume of pipework and the duration of the test. The relationship between these, for different test scenarios and a derivation of it is outlined in Appendix 3. Appendix 4 provides information on the calculation of test duration, conditioning period and PE pipe creep effect allowance.

Note: If a test failure is indicated, it is permitted to extend the test period to confirm that the "failure" is not attributable to falling temperature or creep effects. However, the extension is not permitted if the ambient temperature is rising.

7.8.2 Hydrostatic strength tests

When testing PE pipework, STP can be affected substantially by the creep characteristics of the pipework. STP should be maintained within 80% of the required test pressure, re-pressurising as necessary. This could take up to 48 hours. When the pressure decay and time elapsed between each pressurisation is declining and is not exceeding 5% of STP per hour, the test result can be considered satisfactory.

7.9 TEST RECORDS

7.9.1 A test certificate shall be prepared after successful completion of the tightness test and should include, but not be limited to, the following details:

- pipeline operator
- person performing the test
- location and description of test section
- date of test
- test instrument number
- MOP of the system
- test method
- TTP
- test medium
- test period
- test result and test certificate of pipeline components, if required
- test instrument calibration records and traceability, where appropriate.

An example test certificate is given in Appendix 5.

7.10 COMMISSIONING AND DE-COMMISSIONING OF PIPELINES

7.10.1 A written procedure shall be prepared, detailing the sequence and the actions required during the complete operation.

Note: For work of a repetitive nature, written procedures can take the form of detailed standing orders.

7.10.2 Precautions shall be taken to reduce any hazards arising from commissioning or de-commissioning operations. Suitable safety equipment shall be provided on site.

7.10.3 Detailed commissioning and de-commissioning recommendations are contained in IGE/SR/22 and IGEM/TD/1 either of which should be consulted before undertaking any purging operation.

Note: For a pipeline of MOP exceeding 7 bar, IGEM/TD/1 may be more appropriate.

7.11 PERMANENT DE-COMMISSIONING OF PIPELINES OR SECTIONS OF PIPELINES

7.11.1 General

A pipeline or section of pipeline that is no longer to be used for the conveyance of gas should be taken out of service, with all hazardous fluids removed, and the following considered:

- use the pipeline or section for another purpose or
- remove the pipeline or sections or
- leave the pipeline or section 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 or section leading to pipe wall collapse or becoming a channel for the conveyance of water or gases.

For pipelines or sections of pipelines left in-situ, consideration shall be given to residual liabilities with the owner or operator of the pipeline, which may remain in perpetuity.

Note: There may be a continuing duty to monitor the condition of the pipeline or section and a requirement for maintenance or remedial action, for example to ensure that the route remains safe and without danger as a result of de-commissioning.

7.11.2 Taking a pipeline or section of pipeline out of service

The following steps shall be taken when taking a pipeline or section of pipeline out of service:

- purge any flammable gas, vapour or residue in accordance with IGE/SR/22
- physically separate from other parts of the system and isolate from all possible sources of gas
- dismantle and remove - recommended for all above-ground sections

  Note: Economic considerations may limit this option to short sections of buried pipeline.

- where required in extreme cases only, fill remaining pipeline sections with inert material, for example grouting, especially large diameter pipelines at road and rail crossings or at other locations sensitive to subsidence. Where it is not practicable to fill a large diameter pipeline section with grout, the section should be charged with an inert gas and the vent and fill points sealed permanently. Leakage tests should be carried out and pressures checked periodically and re-charged as necessary. CP will need to be maintained to avoid the pipe deteriorating through corrosion and collapsing, thus creating a void and possible ground subsidence.

  Note: Practical and economic considerations may limit this to short sections of buried pipeline.

7.11.3 **Records of permanently de-commissioned pipelines left in-situ**

Records of de-commissioned pipelines left in-situ shall be maintained.

SECTION 8 : ALTERATIONS AND CONNECTIONS TO LIVE PIPELINES

This section provides guidance and recommendations for planning and undertaking alterations and connections to live pipelines. The scope of works includes stopping-off operations, diversion of pipelines, end connections, insertion of tees and live branch connections. It covers both metallic and PE materials.

8.1 GENERAL

8.1.1 All works shall be carried out in accordance with approved written procedures, supplemented as necessary by permits to work, risk assessments and method statements.

Safe pressures shall be maintained in the supply system while carrying out pipeline alterations and connections. Such operations shall be carried out at the lowest possible system pressure (to reduce the risk to persons to as low as possible).

Note1: Guidance on the preparation of procedures and permits to work is given in IGEM/GL/6.

Note2: For work of a repetitive nature, written procedures may take the form of detailed standing instructions or standard operating procedures.

Reference should be made to HSG253 ("The Safe Isolation of Plant and Equipment"). In addition, clause 9.7.7 provides recommendations on pipeline isolation which should be followed where appropriate.

8.1.2 It may be necessary to make connections to PE pipelines which have been installed by insertion inside an existing metallic carrier pipe.

To make such connections a specialist process referred to as "the window cutting technique" shall be used to access the live pipeline.

The "window cutting technique" utilises a frame or guides to enable accurate circumferential and longitudinal cuts to be made on carrier mains.

To avoid damaging the live main, it is particularly important that the depth of cut is very accurately controlled. Two circumferential and two longitudinal cuts at the most appropriate position for the orientation of the connection are undertaken, removing two coupons fully exposing a section of the live pipeline.

A detailed method statement, approved by the respective GT shall be obtained prior to commencement of any window cutting operation.

Where peelable pipes are installed, the cut window should be large enough to remove the skin and accommodate the fitting. In accordance with the manufacturers' instructions a special tool shall be used to slice through the outer layer so it can be removed. The pipe exposure tool (PET) is supplied with spare knife blades and is used without a frame or guiding system.

8.1.3 Due regard shall be paid to the maximum safe operating pressure of any stopping-off equipment and fittings proposed for use.

Test and construction records shall be consulted to ensure that the pipeline is of appropriate construction and wall thickness for the chosen stopping-off equipment.

8.1.4 For a pipeline of MOP exceeding 2 bar (or a pressure of 2.7 bar or more under fault conditions), any alteration or connection should be carried out in accordance with IGE/GL/5.

8.1.5 For work on a pipeline, permission shall be obtained from the GT/operator in accordance with IGEM/GL/6.

Note: Such involvement may also be required to adjust supply pressures in the surrounding network for the duration of the operation.

8.1.6 Where it is necessary to maintain continuity of supply, a by-pass of sufficient capacity should be fitted.

Note: Although records may indicate that a by-pass is not required for immediate supply purposes, such records are not always accurate and pipelines can be blocked or restricted.

Where it is not possible to install a by-pass in such circumstances, the precautions to be taken to ensure that supplies are maintained shall be specified in the written procedure (see clause 8.1.1).

8.2 PLANNING

8.2.1 A detailed site survey shall be carried out prior to starting work, to establish the location of relevant gas pipelines and plant, the location and nature of other utilities' plant and to plan any necessary traffic management schemes, etc.

8.2.2 A detailed schematic system diagram shall be prepared for inclusion in the written procedure (see clause 8.1.1) showing all relevant valves, connections, pressure test points, significant gas loads, PRIs, etc.

Note: This schematic may also form part of the modifications approval process for compliance with any relevant pressurised systems regulations or statutes.

8.2.3 The characteristics of the pipeline shall be established, including such detail as material, diameter, ovality, wall thickness, MOP, OP and whether it is lined or inserted.

8.2.4 If the pipeline is protected by an impressed current CP system, arrangements shall be made to de-activate the system for the duration of the work and for the de-activation to be confirmed prior to commencement of works. Sufficient time shall be allowed for the system to de-polarise.

The CP system should be re-commissioned as soon as possible after completion of the works.

8.2.5 Any by-pass shall be protected, by location and/or suitable barriers, from foreseeable mechanical damage; and also from interference when the site is unattended

The by-pass shall be of appropriate construction for the system pressure and should be subjected to a tightness test (see Section 7) prior to being commissioned. For by-passes operating at pressures greater than 2 bar, consideration shall be given to carrying out a strength test (see Section 7).

8.2.6 The use of stopping-off equipment which is not "gas-free", within confined spaces, should be avoided if possible. Where such use is unavoidable, risk assessments shall be undertaken and additional safety and ventilation measures put in place.

8.3 SAFETY

8.3.1 General

8.3.1.1 "No-gas to atmosphere" techniques should be used when carrying out under-pressure operations to ensure that uncontrolled gas is not allowed to escape into the immediate working site environment.

Occasionally, particularly where a pipeline of irregular section is encountered, it may not be possible to use "no-gas" techniques, in which case additional precautions must be taken against poisoning, asphyxiation, fire and explosion. The gas pressure in such a pipeline should be reduced to the minimum level practicable.

8.3.1.2 All necessary measures, increased supervision, assessed risks, procedures, safety equipment (including PPE), air movers, fire control measures, first aid provision, access and egress provision, contingency actions, etc., shall be included in the written procedure (see clause 8.1.1).

8.3.2 Anchorage

Consideration shall be given to the need to ensure adequate anchorage of pipes before, during and after any cut-out operation. Pressure-induced thrust should be restrained at various stages of the operation when:

- excavating onto or near an existing installation, including one of another utility, where anchor blocks or supporting ground would restrain thrust
- applying a stopping-off device, when a thrust proportional to the cross section area of the pipe will be transmitted to the pipe
- removing a pipe section, tee or bend during the cut-out operation.

The necessary thrust restraint should be maintained or established throughout the operation. Guidance on anchorage is provided in Sub-Section 6.13.

8.3.3 Equipment on site

8.3.3.1 All necessary safety equipment, materials, plant, tools and personnel shall be available on site. A checklist shall be included in the preliminary works section of the written procedure (see clause 8.1.1), signed by the responsible site officer, verifying that all items are available and in operable condition.

8.3.3.2 Safety equipment shall include, but not be limited to, air breathing apparatus, fire protective clothing, adequate and appropriate fire extinguishers and electrical continuity bonds (for metallic pipelines).

8.3.3.3 Water should be available in sufficient quantities to minimise the risk of sparks when breaking out metallic pipelines and to remove the surface static charge on PE pipelines.

8.4 METHODS OF ISOLATION

There is a variety of proprietary equipment available for stopping-off the flow of gas in pipelines in the absence of, or in conjunction with, isolation valves.

Typical methods of isolation are:

- semi-supported bag stop
- mechanical line stop
- iris stop
- squeeze off.

8.4.1 **General**

8.4.1.1 The appropriate equipment and method shall be selected for the pipeline material, internal condition and OP. Reference should be made to the equipment manufacturer's published data for suitability for purpose, operating method, maintenance specification and associated technical and material requirements. The method of operation shall be incorporated within the written procedure (see clause 8.1.1) for the stopping-off operation.

8.4.1.2 Total reliance should not be placed upon a single stopping-off device.

Note: Ideally, it is best to provide two stopping-off devices in tandem with a vent to atmosphere fitted between them. Such installations are described as "double block and bleed" and may be incorporated in a single valve body with two sealing faces. This method ensures that the secondary stop-off device is not subject to line pressure and cannot pass gas.

8.4.1.3 Any vent pipe fitted between primary and secondary flow-stopping devices shall be metallic and of adequate capacity to fully relieve the pressure between the devices.

8.4.1.4 For a line-stopping operation, any vent pipe shall be extended to a point not less than 2.5 m above ground level, be supported securely and shall terminate with a suitable flame trap.

Reference should be made to IGE/SR/22 and IGE/SR/23 (Natural Gas only).

8.4.2 **Valves**

8.4.2.1 Where it is intended to use a valve for flow-stopping, it should be designed to provide a double block and bleed facility. However, any valve without this facility should have a secondary stopping-off device installed downstream, as close to the cut out area as possible, and an intermediate vent to atmosphere shall be installed.

8.4.2.2 Any valve shall be tested as part of the written procedure (see clause 8.1.1), to prove that an effective seal can be achieved.

8.4.2.3 Any valve scheduled to be operated in any procedure shall be fitted with pressure gauges or recorders on both sides of the valve and the pressures monitored during the procedure by the designated valve operator.

Such valves shall be subjected to at least partial operation, prior to commencement, to prove operability.

8.4.2.4 Any valve remote from the work site shall be locked to prevent unauthorised operation.

8.4.3 **PE pipelines**

8.4.3.1 A PE pipeline can be stopped-off using either "squeeze-off" or "bag-stop" equipment. The most appropriate method for the pipe material (PE 80, PE 100 etc.) OP and SDR, shall be chosen.

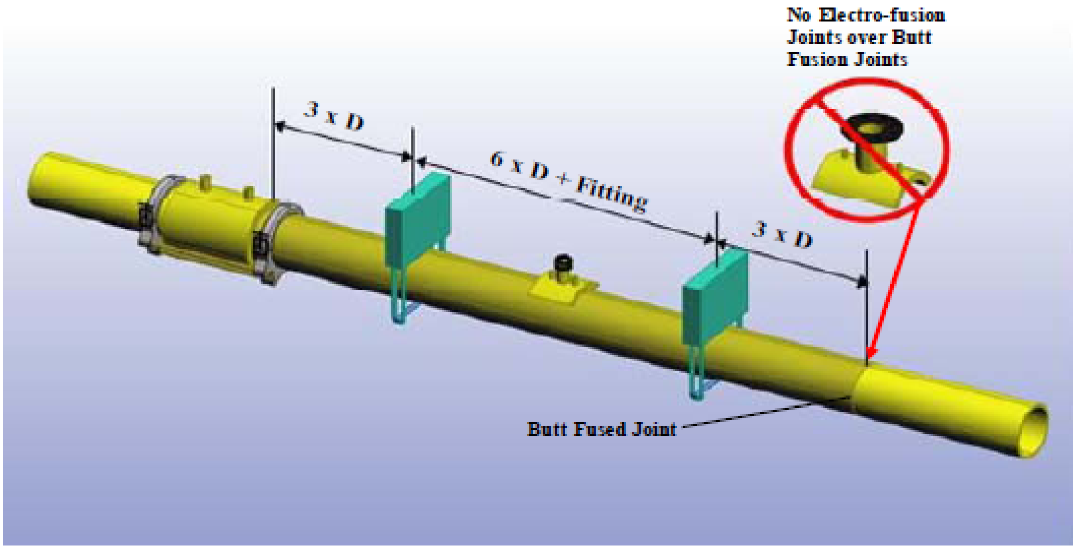
Note: Alternative methods of isolation for PE pipelines utilising semi-supported inflated bags and mechanical or hydraulically operated stopple and shortstopp devices are currently being developed. Before considering the use of alternative means of isolation the relevant GT/pipeline operator needs to be contacted for advice and approval to proceed.

8.4.3.2 A single squeeze off tool shall be used only in the following circumstances:

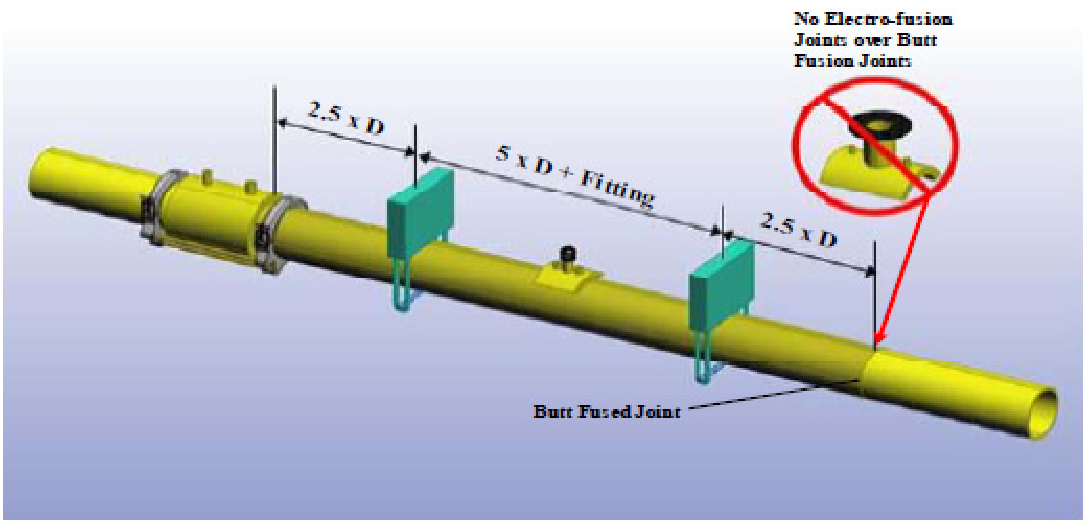
- for pipelines of diameter ≤ 180 mm and OP ≤ 75 mbar
- for pipelines of diameter ≤ 63 mm and OP ≤ 2 bar.

Any pipeline of larger pressure/diameter should have two squeeze-off units, with a facility for venting between them, on each side of the cut out section.

The minimum distance between a squeeze-off tool and a pipeline fitting, butt weld or a cut should be as given in Figure 7.



(a) All imperial sized PE pipelines



(b) All metric sized PE pipelines

Note 1: Where there is any uncertainty over the pipe material size then the dimensions from (a) have to be used.

Note 2: A squeeze off tool can only be applied within 2.5D of any type of PE joint if the joint has been visually examined by a competent person and no concerns about the welding process or joint quality are apparent. If there is any evidence that the joint is substandard, then further advice needs to be sought.

Note 3: D = External Diameter of pipe.

FIGURE 7 - PE MINIMUM SQUEEZE OFF DISTANCES FOR PE80 AND PE100 OPERATING AT UP TO AND INCLUDING 2 BAR

8.4.3.3 Any squeeze-off tool should be fitted with adjustable stops relating to the specific diameter and SDR combination and should be fitted with a mechanical locking facility to prevent premature release.

8.4.3.4 Reference should be made to the relevant pipe manufacturer for specific advice regarding squeeze-off operations on PE 100 pipe (stress cracking could occur and mechanically-aided re-rounding would be required).

8.4.3.5 Prior to fitting any squeeze-off equipment, the pipe should be carefully inspected in the region of the pinch points for any damage and where evident, remedial action or an alternative location should be selected.

8.4.3.6 Consideration shall be given to the risks associated with using squeeze off equipment adjacent to leaking or potentially defective butt or electrofusion joints where they have been identified on the network.

8.4.3.7 A potentially defective butt fusion joint maybe where:

- the external fusion bead is still intact or
- partially de-beaded or
- there are slit defects visible or
- significant misalignment.

A potentially defective electrofusion joint maybe where:

- the melt wells/indicators have not risen or
- multilayer pipe skin is within joint melt area or there is no evidence of pipe scraping or
- there is significant misalignment.

Suitable measures should be put in place if any of the items listed are evident.

Note: Such precautions may include establishing an alternative flow stop methodology, reducing system pressure as low as reasonably practical, providing additional restraint to pipework and/or apply additional control measures.

8.4.3.8 When squeezing off peelable pipes, the pipe skin must be removed from the full pipe circumference a distance of 0.5 times the pipe diameter on either side of the squeeze off location.

8.4.3.9 On completion of the squeeze-off operation, the pipe should be mechanically re-rounded and the squeezed area inspected for any damage which may have been sustained during the process and any necessary remedial actions taken where such damage has been identified.

8.4.3.10 The location of any pipe which has been squeezed-off should be identified with suitable marker tape. Squeeze-off shall not be applied to the point on the pipe which has been previously squeezed-off.

8.4.4 Metallic pipelines

8.4.4.1 For a pipeline of OP not exceeding 75 mbar, the equipment used for stopping-off shall utilize semi-supported bags for a nominal bore ≤ 300 mm or fully-supported inflated bags for larger bores. Unsupported bags shall not be used.

For a pipeline of OP exceeding 75 mbar and not exceeding 2 bar, the equipment used for stopping-off shall utilize fully-supported inflated bags and the bag inflation gas shall be inert.

For a pipeline of OP exceeding 2 bar, mechanical or hydraulically-operated line stoppers shall be inserted through an encirclement fitting and the gas to inflate the secondary bag shall be inert.

8.4.4.2 Any mechanical line-stopping device shall be supplemented by a secondary stopping-off device and intermediate vent. Where the primary device does not give a negligible risk of failure, the secondary device shall be capable of restraining line pressure (in the event of a failure of the primary seal).

8.4.4.3 Stopping-off equipment that is specifically designed to operate safely at the maximum line pressure to which it could be subjected should be selected, installed and operated only as prescribed by the manufacturer.

8.4.4.4 For an inflated bag-stop operation, at least one spare bag per insertion tube shall be available on site. All bags shall be inspected and tested for tightness, prior to use. The inert gas supply shall be separate from that used for purging. When this inert gas is supplied from a high pressure source, the final stage regulator shall have either an integral creep relief valve or a relief valve on its immediate outlet. It shall be sized adequately to protect the bag from accidental over-pressurisation.

8.4.4.5 Any pipeline shall be adequately restrained to support the weight of the stopping-off equipment and to prevent potential movement due to thrust loading.

8.4.4.6 Injection of expanding foam provides another method of stopping-off a pipeline. Injecting the foam into a specially designed bag can control the spread of foam inside the pipeline. The stop-off is permanent, so the technique is only suitable where a pipeline is to be abandoned or where the capped end is not to be reconnected. The foam seal may allow gas to pass after a period of time, therefore permanent caps shall be fitted immediately after the cut out operation (to prevent gas escaping).

8.5 PREPARATION FOR THE CUT-OUT

8.5.1 Excavation and working area

8.5.1.1 There shall be adequate room in the trench or working area for safe access and egress, installation and operation of stopping-off equipment and fitting of any by-pass, vent or gauge.

For any welding and pre-heating operation, a minimum 2 m wide clear working area should be provided.

8.5.1.2 Trench supports, where required, shall be arranged to permit unrestricted handling of pipe, valves and stopping-off equipment.

8.5.1.3 When work is being carried out on a large diameter pipeline, appropriate measures shall be taken to prevent ground movement as the sides of the excavation may have to support lifting equipment.

8.5.1.4 Consideration shall be given to arranging the work site such that each set of stopping-off equipment is in a separate excavation from the excavation in which the cut-out is to be made.

Note: This will limit the effects of any possible failure, provide better support for the pipeline, assist in restraining end-thrust effects and obviate the possibility of stopping-off equipment being disturbed by the cut-out operation.

Alternatively, thrust restraint and pipeline support shall be arranged to allow work to proceed safely in a single excavation.

8.5.2 **Installation of flow-stopping equipment**

8.5.2.1 Flow stopping equipment, and any by-pass, vent or gauge should be installed in accordance with the manufacturer's recommendations, having due regard for the required spacing of such equipment and the maximum permitted drilling size for the pipeline diameter and material.

8.5.2.2 Generally, the maximum hole size which may be drilled directly into a metallic pipeline should be limited to one quarter of the nominal bore of the pipeline.

Note: For a pipeline of less than 200 mm nominal bore, a larger drilling is permissible in accordance with Table 9.

NOMINAL BORE OF PIPELINE (mm)	(in)	MAXIMUM TAPPING DIAMETER (inches BSP)
----	3	¾
100	4	1 ¼
----	5	1 ½
150	6	2
----	7	2

TABLE 9 - MAXIMUM TAPPING DIAMETER IN A METALLIC PIPELINE LESS THAN 200 mm (8 inch) NOMINAL BORE

8.5.2.3 For a steel pipeline, a minimum wall thickness of at least 4 mm should be available for direct drilling. The actual wall thickness shall be established by ultrasonic testing or a suitable alternative method.

Note 1: Larger holes may be drilled through full encirclement fittings around the pipeline or through "weldolets" for a pipeline of minimum 4 mm wall thickness.

Note 2: Steel reinforcement plates, of adequate size to accommodate drilling equipment, may also be welded to a steel pipeline to locally increase wall thickness.

8.5.2.4 Care shall be taken to ensure that the bore of the pipe is not unreasonably restricted through use of a screwed connection of a comparatively large branch.

8.5.2.5 Any hole in an iron pipeline shall not be sealed with a taper-threaded plug. Either a parallel-threaded fitting with elastomeric sealing gasket or a "non-tap" type plug in an untapped hole, should be used, depending on the tapping diameter.

8.5.2.6 A non-tap plug shall not be used to seal a threaded hole.

8.5.2.7 Where a connection to an iron pipeline is close to an existing tapping, an axial distance of 3.5 times the nominal bore of the larger hole shall be allowed between the centres of the two tappings.

8.5.2.8 Screwed pipe wall connections shall not be made to a PE pipeline.

8.5.2.9 Where a pipeline has been lined, the means of connection to the pipeline should be such that gas cannot enter the annular space between the pipeline and its liner.

8.5.3 **Preparation for cutting out**

8.5.3.1 Having established the fitting(s) and plant to be installed, the length of pipeline to be cut out shall be determined accurately.

8.5.3.2 The points at which the pipeline has to be cut shall be cleaned thoroughly externally, to facilitate subsequent jointing.

Any pipe coating or wrapping shall be removed carefully prior to cleaning.

Note: It may be necessary to grit blast a metallic pipeline.

8.5.3.3 The cut positions shall be marked clearly and re-checked prior to the cutting operation.

8.5.3.4 The pipeline on each side of the cuts shall be supported adequately in a manner such that the supports are not disturbed during cutting and subsequent re-assembly.

8.5.3.5 The pipeline shall be measured carefully for diameter and ovality to ensure compatibility of fittings.

8.5.3.6 Cutting shall be by use of cold cutting equipment such as saws, wheel cutters or mechanical rotary cutters, as appropriate to the material of the pipe.

8.5.3.7 Additional precautions for hot working shall be as given in clause 8.5.4 and these should also be observed whenever it is to be carried out in the operations procedure.

8.5.3.8 Expanding stoppers shall be available to be used immediately the cut section has been removed. These shall be tested before use.

8.5.3.9 In the event that the connection will not be completed, caps shall be available to be fitted to open ends for security.

8.5.4 Precautions when welding a steel pipeline

8.5.4.1 Welding shall be considered appropriate only where mechanical line-stopping methods are used. It shall be subject to stringent risk assessments, paying due regard to the hazards that may arise during hot works.

8.5.4.2 Appropriate welding procedures shall be selected. When welding fittings to a live steel pipeline, procedures to avoid excessive pipe wall penetration shall be implemented.

8.5.4.3 Additional precautions shall be taken to protect against the potential effect of a source of ignition being introduced into the immediate work site.

8.5.4.4 Any flow-stopper should be positioned at least 10 m from the source of ignition.

8.5.4.5 Where bags are to be used, they shall be inflated with inert gas, regardless of diameter, and pressure relief devices should be used to prevent their over-pressurisation.

8.5.4.6 The section of pipeline between the flow stoppers shall be filled with inert gas.

8.5.4.7 Additional holes should be drilled adjacent to each of the inner flow stoppers to enable a flow of inert gas from the upstream to downstream tappings which should be fitted with suitable vents, flame traps and sampling points.

8.5.4.8 A continuous flow of inert gas shall be maintained throughout the welding process and should be sampled regularly.

Particular care shall be taken against inhalation of inert gas during this activity.

8.5.4.9 A hot work permit shall be issued for all hot cutting and welding operations.

8.5.4.10 The atmosphere shall be checked for the presence of fuel gas immediately prior to, and at regular intervals during, hot work.

8.5.4.11 Where hot work is to be carried out on pipes that previously carried fuel gas, an internal atmosphere check shall be made prior to introducing any source of ignition.

Due regard shall be paid to the possible presence of oil residues.

8.6 THE CUT-OUT OPERATION

8.6.1 Isolating a section of pipeline

8.6.1.1 Prior to the closure of line valves or the insertion or operation of stopping-off equipment, a competent person shall be made responsible for observing pressure at each pressure point stated in the written operations procedure.

8.6.1.2 A reliable means of communication shall be established between sites to ensure efficient and safe operation.

8.6.1.3 Any installed by-pass, pressure gauge or vent shall be checked for correct fitting and satisfactory operation immediately prior to commencing the stopping-off operation.

8.6.1.4 Line and bag inflation pressures and vents shall be monitored continually throughout the operation to prove a satisfactory stopping-off seal, correct operation of any by-pass and the integrity of system pressures.

8.6.1.5 Pressure gauges and/or recorders shall be connected to the parent pipeline (not the by-pass) to avoid inaccurate or misleading readings.

8.6.1.6 For a metallic pipeline, where necessary, the invert of the pipeline shall be cleaned in the flow-stopping location to remove swarf or residual fluids (in order to obtain an effective seal). This should be done using proprietary equipment only under a "no gas to atmosphere" operation.

8.6.1.7 Any bag, flow-stopper or squeeze-off unit shall be inserted and/or operated in a sequence as prescribed by the manufacturer or as detailed in the written procedure (see clause 8.1.1).

8.6.1.8 In general, primary seal effectiveness shall be established before inserting or operating any secondary device and opening any intermediate vent.

8.6.1.9 Before final cutting of a metallic pipeline, it shall be confirmed that an electrical continuity bond had been installed and that any impressed current CP system has been de-activated and has de-polarised.

The CP system shall be re-commissioned as soon as possible after completion of works.

8.6.2 Cutting and removal of a section of pipeline

8.6.2.1 When the preliminary works (see clause 8.6.1) are complete, cutting through the pipeline may proceed.

During any cutting by hand, water should be liberally used on cutting tools and care shall be taken to ensure that any electrostatic charge, built up on clothing, is discharged to earth.

Note: In the case of metallic pipe, this can be achieved by regular contact with the pipe wall. For PE pipe, this can be achieved by covering the pipe with wet cloths in contact with the earth.

8.6.2.2 If possible, the cut section of pipe should be removed without breaking.

Note: In addition to the section end cuts, an intermediate circumferential cut will provide additional lateral clearance and facilitate removal without undue force being applied to the pipe.

8.6.2.3 If it is necessary to break out a cast iron cut piece, water or an approved oil should be used liberally on the pipeline. Breaking tools and the impact area should be covered with wet sacking or cloth.

As soon as the piece of pipe has been removed, the pipeline end(s) should be plugged with expanding stoppers.

8.6.3 Re-connecting pipework

8.6.3.1 The cut ends of a pipeline shall be thoroughly cleaned to receive the new joints in accordance with the manufacturer's recommendations for the appropriate fitting.

Note: Additional preparation may be necessary if the pipeline has been lined.

8.6.3.2 Before any pipe or fitting to be inserted is placed in position, the expanding stoppers shall be removed and a check made to ensure that no tool or other material has been left in the open ends of the pipeline, or in the fitting or pipe to be inserted.

8.6.3.3 As tie-in joints cannot, normally, be strength or tightness tested at the required test pressure, additional measures shall be taken to prove the integrity of these joints prior to their being commissioned.

Note: Such measures may include suitable NDT techniques for welded steel joints and QC records for fusion welded plastic joints.

8.6.3.4 The location of all tie-in joints shall be recorded for inclusion in system construction records such that further integrity tests can be undertaken if the system OP is changed.

8.6.4 Withdrawal or release of stopping-off equipment

8.6.4.1 When all joints have been completed and, if necessary, allowed to cool, the flow-stopping equipment shall be withdrawn or released in accordance with the manufacturer's instructions, or as stated in the written procedure (see clause 8.1.1).

Note: The general method is to remove any secondary stopping-off device followed by the primary devices.

8.6.4.2 Before the penultimate flow-stopping device is withdrawn or released, the air or purge gas between the stoppers should be expelled with gas. Immediately thereafter, all holes in the pipeline shall be plugged or otherwise sealed.

8.6.4.3 The system shall be checked for satisfactory operation prior to permanently disconnecting any by-pass.

8.6.4.4 Where squeeze-off has been applied to a PE pipeline, the pipeline should be returned to its original form by a re-rounding tool. The position of the squeeze-off shall then be marked suitably with pre-printed adhesive tape or similar means.

8.6.4.5 If necessary, a PE 100 pipeline shall be fitted with a permanent re-rounding clamp to prevent stress cracking.

8.6.5 **Testing**

8.6.5.1 On completion of work, all connections, plugs, etc., shall be tightness tested at OP using LDF.

Care shall be taken that LDF that could be detrimental to the long term strength of PE is not used on PE pipe and fittings.

8.6.5.2 If there are any visible signs of leakage, necessary remedial action or re-work shall be carried out and the joint re-checked to confirm tightness.

8.6.5.3 Re-wrapping and application of corrosion protection measures shall be undertaken only after confirmation of satisfactory leak testing and removal of any residual LDF.

8.6.6 **Removal of supports**

Removal of pipe supports shall be carried out before backfilling and compaction under and around the pipeline.

8.7 PRESSURE CONNECTIONS

Connections may be made to a live metallic pipeline by direct drilling and tapping using proprietary fittings and "no gas to atmosphere" drilling equipment.

Note: Clause 8.5.2 provides guidance on maximum drilling diameters and on the need for reinforcement of steel pipelines.

Connections can also be made to a metallic pipeline by drilling through a valved branch connection (under-pressure tee), fitted to the parent pipeline.

For a metallic pipeline, the branch connection fitting is, usually, a split collar arrangement with an elastomeric compression seal against the parent pipeline.

For a steel pipeline, either a semi or full encirclement saddle is welded to the parent pipeline.

For a PE pipeline, a range of "electrofusion" type saddles exists to effect offtake connections, normally up to 63 mm diameter outlet connection. Larger branch saddle connections can also be made to PE pipelines of up to 400 mm diameter using an "electrofusion" type welded saddle encirclement or saddle fitting with a valved branch.

Under-pressure connections using valved branch tees or saddles provide for offtake diameters up to the diameter of the parent pipeline. Such connections shall be made only under the controlled gas conditions referred to in clause 8.3.1.

8.7.1 A standard operating procedure or method statement shall be written for the work, including a check list to be completed by the responsible person.

8.7.2 Initially, a small diameter pressure point should be connected to the parent pipeline immediately adjacent to the proposed offtake, to ensure the pipeline contains gas at the correct pressure.

8.7.3 The parent pipeline shall be cleaned and prepared in accordance with the branch fitting manufacturer's instructions.

8.7.4 The branch fitting shall be installed using the appropriate procedure and tooling.

8.7.5 If not integral with the branch fitting assembly, construction valves should be installed to aid underpressure connection.

8.7.6 For a pipeline of MOP not exceeding 7 bar, the branch fitting should be pressure tested at 1.5 MOP and, for a pipeline of MOP exceeding 7 bar, at MIP (the test being evaluated by both a pressure gauge of sufficient resolution and by use of LDF).

Note: The test may be applied with the drilling machine in place, or with a blank flange fitted to the valve, according to the type of installation.

8.7.7 Before drilling, it shall be ensured that:

- the drilling machine is rigidly attached to the branch valve, is adequately supported and is pressure tested to ensure it is jointed effectively
- the drill is of the correct length to drill through the pipe wall, but not to reach the opposite wall
- the drill has a mechanism to retain the piece of pipeline cut out (coupon)
- the valve is open
- the drill can pass freely through the branch socket and valve
- the valve can seal the branch when the drill is in the retracted position
- the drill, when entered into the pipeline, will not adversely affect gas flows and downstream pressures. If such problems are envisaged, consideration should be given to drilling at a time of low gas demand.

8.7.8 After drilling, the drill shall be withdrawn and the valve closed.

8.7.9 Before unbolting the drilling machine, it shall be ascertained that an effective valve seal has been achieved. The coupon should be withdrawn if not already removed.

Note: When drilling a metallic pipeline, examination of the coupon can give an indication of the pipe wall condition and thickness.

SECTION 9 : OPERATION AND MAINTENANCE

9.1 GENERAL

9.1.1 Operation and maintenance of pipelines designed, etc. and constructed in accordance with IGEM/TD/3 Edition 5, should be carried out in accordance with this Edition of IGEM/TD/3. Where a pipeline was constructed before the publication of this Edition of IGEM/TD/3, the operation and maintenance of such a pipeline can be carried out in accordance with the appropriate Edition of IGEM/TD/1 or IGEM/TD/3. However, all diversions, modifications, repairs and uprating of existing pipelines should be in accordance with all relevant sections of this Edition of IGEM/TD/3.

9.1.2 Operational work such as testing, purging and connecting to live pipes shall be controlled by the use of written procedures, validated and, where appropriate, approved by the GT.

Note: Further information is provided in IGE/GL/5, IGEM/GL/6, IGE/TD/4, and IGE/SR/18.

9.2 MANAGEMENT

9.2.1 Administration

9.2.1.1 Where appropriate, given the material, MOP and location, a system of surveillance/inspection/maintenance shall be established for any pipeline and its ancillary equipment. It should set out schedules, routine procedures and instructions under which the activities should be carried out.

Note: IGEM/TD/13 deals with the operation of PRIs.

Such schedules, procedures and instructions should embrace all aspects, including liaison with other departments, third parties and those responsible for gas movement or control. These shall be reviewed and updated as appropriate.

9.2.1.2 A separate Emergency Procedures Manual (EPM) shall be provided to deal with situations which necessitate emergency action.

The EPM should include details of the organisational response to emergencies, the safety precautions to be observed in preventing loss of life and damage to property and the means of resourcing specialist services and equipment.

The preparation of the EPM should take account of local authority emergency plans.

9.2.2 Safety

9.2.2.1 *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. Adequate telephone answering facilities should be manned at all times in order to receive calls reporting gas escapes.

Note: IGEM/SR/29 provides further guidance.

9.2.2.2 *Equipment*

Personnel engaged in activities on a pipeline shall be issued with suitable protective clothing and equipment.

Any vehicle used shall be equipped with all necessary communication and safety equipment.

Measures shall be taken to ensure that, whenever necessary, appropriate safety equipment is used.

Note: Site personnel have a duty to use the safety equipment provided. See also clause 4.2.21 for information on DSEAR.

9.2.2.3 *Permit to work system*

A documented permit to work system shall be in place to supplement other job instructions when the work:

- is of a non-routine nature, i.e.;
  - flow stopping
  - under-pressure connections
  - under-pressure connections involving welding
  - any other activity which could affect the normal operation of gas handling, storage and pressure-controlled installations, telemetered supply or have an impact upon a significant part of the network supply system
  - any works that may present risks to operatives, members of the public or gas supplies that are not covered by routine procedures
- may be potentially hazardous and a risk to personnel and others
- 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 activity. Attention should also be given to factors which may change so requiring the issue of a new permit to work.

A permit to work system should include:

- 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
- requirements for monitoring and auditing to ensure that the permit to work system operates as intended.

Where excavation works are proposed in close proximity to pipelines, reference should be made to HSG47 and IGE/SR/18.

9.2.2.4 *Non-odorised gas*

Procedures shall be in place to counter the additional hazards associated with non-odorised gas, particular attention being paid to enclosures, confined spaces and the awareness of the public in the event of gas escapes.

9.2.2.5 *Inspection and maintenance*

(a) Smoking, naked lights and other sources of ignition, such as mobile phones, shall not be allowed in the vicinity of the work and prohibitive notices to this effect should be displayed. Fire fighting equipment shall be available on site. The positioning of powered plant shall be considered carefully, as such equipment can be a source of ignition.

(b) In circumstances where a pipeline, such as a cross country pipeline, is in a remote location, appropriate communication routes shall be established between the site and the operational control centre.

(c) Before starting work, the site shall be examined for gas leakage. If a significant gas presence is found, the requirements in clauses 9.2.2.6 and 9.2.2.7 should be applied. In these circumstances, a safe working area, based on gas concentration measurements, shall be established and monitored to ensure a safe working environment.

(d) Entry shall not be made to any building, trench or other confined space, for example a valve chamber, where gas may be trapped or which may be oxygen-deficient, until the space has been ventilated and the atmosphere checked. Particular regard shall be paid to the danger of asphyxiation and explosion. Monitoring shall be carried out during the operation to ensure a continuing safe environment.

(e) The necessary equipment shall be available to ensure safe access to and egress from the work area and the necessary precautions should be taken to exclude third parties.

(f) Where it is necessary to cut into a commissioned or de-commissioned pipeline, cold cutting equipment shall be used until it has been confirmed that there are no hazardous substances present.

(g) A final leakage check shall be carried out on completion.

9.2.2.6 *Works of a non-routine nature*

Written procedures should be prepared and additional precautions applied as follows:

- at least two operatives should be present. Under certain circumstances, extra operatives may be required (for example in a deep pit)
- sufficient sets of appropriate breathing apparatus should be available and ready for use on site
- where a deep pit or confined space is involved, safe means of access should be provided, harness and life lines should be available and at least one operative should be detailed to observe others working in such spaces
- at least one of the team should be experienced in first aid and rescue operations.

9.2.2.7 *Emergency procedures*

The following apply for emergency procedures:

- both operative and supervisory staff levels 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 escape and enable mobilisation of the appropriate resources as soon as is reasonably practical
- the procedures should be established, tested at regular intervals, reviewed periodically, updated as necessary and all operational personnel should be made aware of them including any requirement of themselves under such procedures.

Reference should also be made to IGEM/SR/29.

9.2.2.8 *Venting of gas*

The volume of gas vented should be minimised in order to reduce environmental impact.

Note: IGE/SR/23 provides guidance on the venting of gas.

9.2.2.9 *Electrical continuity*

When making a break in a metallic pipeline or dismantling associated equipment, a temporary continuity bond shall be fitted across the intended break.

Any impressed current CP system shall be isolated but should be restored as soon as the work is complete.

Note: Attention is drawn to the possibility of induced currents being present which are independent of CP systems. Also, CP currents can take time to dissipate after isolation.

9.3 OPERATIONAL PRESSURE LIMITS

9.3.1 General

9.3.1.1 The system shall be designed, maintained and operated to ensure that the stated safe operating limits are not exceeded.

The operating pressure of a system is a key factor in this assessment process.

Note: Pressure changes can affect:
- *the hoop stress on the pipe and fittings, giving rise to an increase in the likelihood of failure*
- *the amount of gas released, impacting on the consequence of failure.*

9.3.1.2 Re-assessment of the safe operating level may be required in the light of changing circumstances either increasing or decreasing the operating pressure. However, under no circumstances shall the operating pressure exceed the original design pressure unless justified through a suitable safety assessment (see clause 9.3.3.3).

9.3.1.3 Any system comprised mainly of older metallic pipes should be operated at pressures as low as demand allows, throughout the year, to reduce the effect of leakage. In doing so, the system operator shall take into consideration the consequences of pressure cycling materials, particularly ductile iron, which could give rise to a sudden failure.

9.3.2 Changes in operating circumstances – steel at MOP ≤ 7 bar and all PE

Over time, it is quite likely that the circumstances in which a system operates may change. The system operator may initiate some changes while others may be totally beyond the operator’s control. If changes are identified, either through routine or non-routine monitoring, consideration shall be given to the need for re-assessment and appropriate action as outlined in clauses 9.3.2.1 or 9.3.2.2, as appropriate.

9.3.2.1 *Change in proximity*

Over time, developments may take place adjacent to the pipeline, for example:

- additional buildings may be constructed
- buildings may be modified, extended or have their use/function changed
- open ground may become sealed or paved.

Where such events have a significant effect, the continued operation and maintenance regime of the system shall be reviewed.

9.3.2.2 *Change in operating pressure (OP)*

Minor pressure fluctuations in OP caused through the normal day-to-day or seasonal operation of a pipeline do not require any special precaution or generate the need for action, provided the pipeline still operates within its designated operating range.

Where consideration is being given to increasing OP above the designated range, action shall be taken to ensure the pipeline is capable of operating safely at the higher level as outlined below.

Note: Regulatory bodies may need to be consulted prior to increasing pressure, relating to increase in risk.

(a) ***Safety assessment***

An assessment should be carried out to identify all hazards relating to the pipeline with the potential to cause an incident. The risks from those hazards should be evaluated and mitigation measures adopted.

Note 1: Most assessments are carried out to satisfy specific requirements of health and safety legislation and there may be a need for results to be reviewed by the relevant statutory body.

Note 2: More detailed guidance on risk assessment methods is available in Appendix 3 of IGEM/TD/1 Edition 5.

Where numerous services are connected to the pipeline under consideration, the above procedure may prove too onerous and not cost effective.

(b) ***Construction records***

The original construction records, or suitable electronically scanned records, where available, should be examined to determine the type and specification of all pipe and fittings used for the construction of the pipeline, any service and any other associated pipework connected to the system.

(c) ***Test certificates***

The original test certificates, or suitable electronically scanned records, where available should be examined. The test records for a pipeline may show the pressure at which the strength and tightness of the pipeline was proven at the time of the original test, but these cannot be taken as testimony to the current condition.

(d) ***Maintenance records***

All available sources of leakage and maintenance records should be examined to provide an indication of the integrity of the pipeline. These should include leakage history, details of any repairs, results from leakage surveys and records from any CP system.

Note: It may also prove necessary to carry out a walking leakage survey of the system using suitable sensitive, i.e. parts per million (PPM), equipment.

The nature of historical repairs should be assessed, as fittings suitable for the prevailing pressure operation might have been used which will not be suitable for operation at a higher pressure.

(e) ***Physical inspection***

This may be the least preferred option due to the likely cost but circumstances may dictate that this option be taken. Consideration shall be given to exposing the pipeline at frequent intervals to examine the condition of any coating, to measure the wall thickness, to assess pipe/soil potential/soil type/soil resistivity, water table, etc. or to carry out appropriate NDT. Other considerations shall include checking pipe/soil potential, soil type, soil resistivity, height of water table, etc. However, the results of local testing should be treated carefully as localised problems can exist elsewhere, not evident at the point of exposure. Internal inspection by instrumented pig, or CCTV, shall be considered where circumstances permit.

(f) ***Anchorage***

As-laid records should be used to identify changes in direction where anchorage may prove necessary or existing arrangements validated.

Note: Anchorage can be provided by the installation of thrust blocks or alternative methods of jointing.

(g) ***Proving tests***

The testing requires decommissioning of the pipeline followed by strength and tightness tests, as detailed in Section 7. If it is not possible to decommission, special procedures should be put in place to demonstrate the strength and tightness of the live system, to the required standard, at the new pressure.

If any non-compliance with the foregoing requirements is found, it should be dealt with before proceeding to operate the pipeline.

9.3.3 Changes in operating circumstances - steel at MOP > 7 bar

9.3.3.1 *General*

MOP should be in accordance with the IGEM Standard to which the pipeline is operating (see Sub-Section 9.1).

Note 1: Prior to the date of publication of IGE/TD/3 Edition 4, pipelines of MOP exceeding 7 bar were designed to IGEM/TD/1.

Note 2: MOP may become limited by:

- *the design section of the particular Standard to which the pipeline is being operated*
- *infrastructure development, adjacent to the pipeline, which alters the proximity and/or the population density*
- *the materials used for the construction of the pipeline and the most recent in-service performance of these materials*
- *the pressure rating and acceptability of any equipment added to the line since construction*
- *the most recent pressure test data, inspection results or risk analysis*
- *any significant changes to the parameters used in risk assessments carried out as part of a safety assessment of the pipeline.*

Note 3: Other factors which may limit the MOP are:

- *temporary operational constraints*
- *previous operating conditions*
- *operating temperature*
- *ground movement*
- *fatigue*
- *interference*
- *pipeline defects*
- *internal and external stress corrosion cracking*
- *legislation.*

MOP should be determined and declared annually, based on the most recent pipeline audit and using the pipeline pressure history and all relevant information arising from surveillance, inspection, maintenance and operation.

An audit of the pipeline, to confirm MOP, should be carried out at intervals determined via a risk assessment analysis. If a risk assessment is not carried out, the audit frequency should be not more than 4 years.

Infringements resulting from changes in proximity, population density and traffic density shall be evaluated. Where necessary, MOP should be reviewed and revised.

9.3.3.2 *Restoration of MOP to a previously declared level, not exceeding the original design pressure*

The revised MOP shall be specified clearly. All the requirements of clause 9.3.3.1 should be satisfied before MOP is increased to a higher level. The revised MOP should comply with the design criteria set out in Section 5 and, if the hydrostatic test is not to be repeated, the previous test should meet the criteria set out in Section 7.

Reference should be made to the records of design, construction, testing, modifications, subsequent operation, maintenance and any other works carried out. This review shall include a detailed survey of any PRI and any other attachment to the line.

The pipeline shall be examined for structural faults using either internal inspection or hydrostatic testing 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. If necessary, a further internal inspection or hydrostatic test should be undertaken.

Where physical or gas supply constraints prevent structural examination using hydrostatic testing, consideration shall be given to the use of external inspection techniques. For a metallic pipeline, the following external inspection techniques shall be considered:

- 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 7361-1, an assessment of the remedial actions necessary should be carried out. This may include a Pearson Survey to locate coating faults or the installation of additional protective current sources. When remedial works are complete, a further CIPS should be carried out to ensure effectiveness
- where electrical interference on the pipeline makes CIPS inaccurate, a separate, simultaneously recorded, pipe-to-soil potential at an appropriate point on the pipeline can be used to aid interpretation
- where a pipeline is protected by sacrificial anode groups, a CIPS measuring "on" potentials, 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. These should only be used where it can be demonstrated that the associated risk is acceptable. Thereafter, the highest standard of external inspection should be carried out within 12 months of the proposed increase in pressure. 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.

The time interval between any external inspection and the restoration of the MOP should be minimised.

If all the above considerations are acceptable, the pressure shall be raised only in accordance with the following:

- immediately prior to raising of the pressure, the pipeline is surveyed to ensure that no operations are being carried out adjacent to the pipeline
- the pressure is raised in incremental steps not exceeding 10% of the original design pressure
- the pressure is held after each incremental step to allow sufficient time for the pipeline to be surveyed for any sign of leakage. This should incorporate the whole length of the pipeline, with particular regard being given to those lengths which are subjected to routine leakage survey. It should also incorporate installations and any attachments to the line.
- 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.

9.3.3.3 *Uprating MOP to a level exceeding the original design pressure*

If the proposed new MOP exceeds 16 bar, IGEM/TD/1 Edition 5 should be applied.

Note: Regulatory bodies may need to be consulted prior to increasing pressure, relating to increase in risk.

Where the proposed new MOP does not exceed 16 bar, the following control stages shall be adopted:

- viability - identification of any fundamental characteristic which may prevent uprating
- assessment - completion of design review and identification of all modifications necessary
- revalidation - confirmation that the pipeline condition is acceptable for the proposed MOP
- modification - completion of all necessary modifications
- pressure raising - increasing the pressure and confirmation of gas tightness.

To determine whether a proposed pipeline uprating is viable, exhaustive examinations of the records, physical characteristics and original design features are required. Where appropriate, the following shall be considered in assessing the viability of uprating a pipeline:

- original design criteria
- construction standards and procurement details
- previous test results
- metallurgical details of all pipeline materials and those of any attachments
- 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 on components included in, or attached to, the pipeline
- proximity of third party equipment
- special crossings and the requirements of rail, river or road authorities.

A complete survey of the pipeline should be carried out for any infringements of IGEM/TD/3 Edition 5 at the proposed revised MOP.

The information gathered under the preceding paragraphs of this section should be assessed against Sections 5 and 6, for the proposed revised MOP.

An assessment, including stress analysis if necessary, should be carried out of components included in, or attached to, the pipeline for the proposed revised MOP. Any changes to operating temperature that are likely to result from the proposed uprating, shall be taken into account.

Any infringement will be identified at this stage and a risk analysis of all infringements should be carried out, for the proposed revised MOP. If required by legislation, the level of risk must be agreed between the pipeline operator and the regulatory authority, taking into account the requirements in Section 5.

The results of all assessments shall be considered and all modifications necessary for the proposed revised MOP should be determined. It may be necessary to carry out repairs, replace components, relay or divert sections or carry out protection measures. All such modifications for the revised operating pressure should be carried out in accordance with this Standard.

Either internal inspection or hydrostatic testing shall be used to revalidate the pipeline.

An internal inspection should be carried out using an appropriate method. Any apparent defects or abnormalities should be further analysed, taking into account the proposed revised MOP of the pipeline. Appropriate fitness-for-purpose techniques should be used, to estimate any potential for the defect or abnormality to increase to a size which may affect the integrity of the pipeline.

Any defects or abnormalities identified previously shall be re-assessed for the proposed hydrostatic STP, using appropriate fitness for purpose techniques.

When the pipeline is suitable for uprating with modifications, the modifications shall be carried out before the hydrostatic test is undertaken.

The pipeline shall then be subjected to a hydrostatic test, consistent with the revised MOP, as described in Section 7.

If it is determined that the pipeline is suitable for uprating, the pressure shall be raised in accordance with the following:

- immediately prior to raising the pressure, the pipeline is surveyed to ensure that no operations are being carried out adjacent to the pipeline
- the pressure is raised in incremental steps not exceeding 10% of the original design pressure
- the pressure is held after each incremental step to allow sufficient time for the pipeline to be surveyed for any sign of leakage. This should incorporate

the whole length of the pipelines, with particular regards being given to those lengths which are subjected to routine leakage survey. It should also incorporate installations and any attachments to the line

- consideration is given to carrying out a leakage survey at the locations of all mechanical joints after one month of operating at the higher pressure.

If required, any changes to MOP must be notified to the appropriate regulatory authority.

9.4 MAINTENANCE PHILOSOPHIES

The maintenance of a pipeline should follow an approach which utilises any one or a combination of philosophies, such as:

- preventative
- planned
- breakdown.

Note 1: Preventative measures are preferred to remedial (breakdown) action.

Note 2: Guidance on the type and extent of the preventative measures required will be obtained by monitoring the system regularly.

Note 3: The objective of maintenance is to:

- *preserve the pipeline as an asset*
- *ensure a safe and adequate supply to the consumer*
- *deal with any leakage that may occur, quickly and effectively.*

Note 4: Information obtained from the monitoring and maintenance activities may result in a decision to replace or renovate sections of the system (see Sections 5 and 8).

Note 5: Pressures and flows may be monitored for the following reasons:

- *to ensure that the system operates within the specified margins of pressure and to give early warning of system performance trends*
- *to assist in the validation and possible modification of existing network analysis models. Accurate models can then be used with confidence to determine the effect of load growth, reinforcement policy and optimum system design*
- *to determine accurate peak demand data which will permit the confident application of network models*
- *to assist in determining optimum use of the total gas supply system including storage requirements. This includes high-pressure storage, low-pressure storage, LPG/air plants and interruptible consumers.*

9.5 PREVENTATIVE MAINTENANCE

When preventative maintenance forms part of the maintenance philosophy, the following requirements should be applied.

9.5.1 Permanent pressure monitoring

The system's critical pressure points (generally the network extremities) and regulator set pressures should be monitored continuously. These monitoring points should be located on the outlet of network source regulators and at the critical pressure points of the network.

9.5.2 Supplementary pressure monitoring

9.5.2.1 Supplementary pressure monitoring may be required to validate network analysis models. To achieve this, a short-term survey of pressure should be carried out during or near to the expected peak demands.

9.5.2.2 Supplementary pressure points will be required throughout the network, to assess the overall accuracy of the network analysis models. These points should be located at the terminal points of the major feeder pipelines of the network and at a number of other locations, so that an overall pressure profile for the network can be formulated.

9.5.3 Flow monitoring

9.5.3.1 Flow monitoring may be required to determine peak instant demand data for input to analysis models used to assess system performance. It is advantageous to do this in conjunction with the peak survey outlined in clause 9.5.2.

Estimates of peak instant demand data may be obtained from meter reading data. To obtain more realistic data, a flow survey can be performed.

To obtain peak instant demand data, the flow should be recorded at the following locations:

- areas of significant gas consumption
- network source inlets
- storage facilities.

Note: The existing metering equipment at "significant industrial and commercial loads" can be used to obtain peak instant demand data.

9.5.4 Recording of network data

9.5.4.1 Pressure and flow surveys should be carried out at periods of expected high demand. To assist in the adjustment of data to determine peak instant demand, ambient temperature data should be recorded.

9.5.4.2 Chart recorders, telemetry lines and dataloggers may be used for recording both pressure and flow. The responsibility for operation, maintenance and record collection should be delegated to one person for each survey.

9.5.5 Analysis and use of data

The method of analysing the monitored data will depend on the function and, therefore, the type of survey performed.

9.5.5.1 *Early warning of system malfunction*

The weekly records from permanent monitoring points should be compared with previous records. In this way, it will be possible to establish the trend in pressure levels and give early warning of system malfunction.

9.5.5.2 *Validation of network models*

Network models should be validated regularly such that they reflect the actual physical characteristics of the network, i.e. pipe material, length, size and configuration. They should also reflect actual pressures recorded at times of peak demand for as high as actually experienced.

Note: Data from as many surveys as necessary may be used. It may also be necessary to perform a further supplementary survey in the area of mismatch, to establish the exact location and cause.

9.6 PLANNED MAINTENANCE

When planned maintenance forms part of the maintenance philosophy, the following requirements should be applied.

9.6.1 General

9.6.1.1 The frequency of maintenance should be determined by a risk-based approach (provided that appropriate data is available) (see clause 9.6.4.7). If there is not sufficient data to support a risk-based approach, a prescribed frequency should be used as given in clauses 9.6.2 and 9.6.3.

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.

Note 1: It may be necessary to justify a risk-based approach to a regulatory body.

Note 2: PE is a resilient material and, providing it has been handled and installed correctly, routine planned maintenance is not, normally, required. Defects caused by a failure to handle or install correctly will, normally be identified under breakdown maintenance (see Sub-Section 9.7). In order to collect data on the long-term performance of PE pipelines, it may be advisable to collect and analyse samples of pipeline and/or joints when the opportunity arises during planned and non-routine works.

Steel pipelines are extremely strong and resilient to impact damage, but are very vulnerable to corrosion damage. It is, therefore, imperative that, in addition to strict standards being employed during their construction, an ongoing protection against corrosion is in place and maintained during the operation of the pipeline. This is achieved by the use of appropriate protective methods:

- *coating and wrapping system (below ground)*
- *painting system (above ground)*
- *ground entry point system*
- *CP system*
- *sacrificial anode*
- *impressed current.*

9.6.1.2 Risk-based determination of frequencies should take account of factors that will significantly influence the probabilities and consequences of failures occurring in a pipeline. The following shall be considered:

- the material and material grade
- the operating stress level of the pipeline
- the standard to which the pipeline was designed and constructed.

9.6.1.3 Maintenance activities often involve the use of substances which may be hazardous to health. Development work in this field results in new materials and processes being introduced.

Due note shall be taken of relevant legislation, and precautions shall be taken to minimise risk, including:

- avoiding the use of the substance, for example by replacing it with a less harmful substance or, if not practicable
- containing the substance to prevent contact or, if not practicable
- use of protective clothing and equipment to reduce exposure.

9.6.2 River or water crossings

9.6.2.1 All crossings should be surveyed at least once to determine as-laid profiles and the position of the pipeline within the watercourse. Once the initial survey has been completed, it can be used to determine re-survey frequencies as follows, based on the depth of cover of the pipeline beneath the bed of the watercourse:

- less than 0.5 m - re-survey annually (until remedial measures are applied)
- more than 0.5 m but less than 1.1 m - re-survey three yearly until trends are identified i.e. no changes
- more than 1.1 m - re-survey every five years.

Note 1: Watercourses that have recently been subjected to severe flooding may be prioritised first.

Note 2: It is the position of the pipeline within the crossing that is of most concern and not necessarily the extent or nature of the watercourse.

Note 3: Major tidal or navigable water courses where there is the potential for river bed erosion may need to be surveyed on a more frequent basis. Advice on the suggested frequencies for these types of water crossing can be found in IGEM/TD/1.

9.6.2.2 If a pipeline laid below a watercourse is found to be exposed, it shall be reported immediately and protection or remedial works carried out urgently.

9.6.3 Exposed (above ground) crossings

9.6.3.1 Exposed crossing points shall be inspected for security, mechanical defects, condition of supports and associated structures and foundations, paintwork, protective wrap and guards.

Particular attention shall be paid for the condition of the carrier pipe at pipe support locations.

9.6.3.2 Concrete parts of pipe supports shall be inspected for any degradation, for example cracking or powdering of the concrete caused by an alkali-silica reaction. Refurbishment should take place as necessary.

9.6.3.3 The frequency of inspections should be set by a risk-based approach. If this is not practicable, the inspections should be at least annually.

9.6.4 Condition monitoring

9.6.4.1 *General*

The condition of the pipeline shall be established periodically. The condition monitoring regime for a pipeline 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 pipeline deterioration. Specialist advice should be sought for each of the potential damage mechanisms.

The condition of any pipeline should be monitored to determine the integrity of the overall system in relation to its operations and environmental requirements. Particular consideration shall be given to the following objectives:

- to confirm whether or not the pipeline is able to continue operation at its designated OP
- to ensure the safe operation of the system, particularly in areas where a pipeline failure could have serious consequences
- to ensure that the protection afforded to a pipeline laid in private land or public highway is not affected by adjacent building or construction activity
- to confirm the integrity of a pipeline prior to road burning operations and other highway construction activities
- to assess the need for, and monitor the effectiveness of, general programmes of maintenance and replacement
- to identify particular parts of the system where the rate of deterioration indicates the need for maintenance or replacement activity and to determine the effectiveness of particular planned maintenance activity.

Note 1: The immediate environment affects the condition of pipelines. Monitoring the environment for gradual or sudden changes enables assessments to be made of the condition of a pipeline. These may be indicative of deterioration, or may increase the probability of premature failure.

Note 2: Various methods are available for monitoring pipelines. These may be used in isolation or combination.

9.6.4.2 *Damage control*

Effective liaison should be established with other parties who are responsible for operations which may affect a buried pipeline.

Note: These include construction, mining and significant changes in vehicular traffic patterns.

Details of all proposed operations shall be examined at the planning stage, before work commences. Monitoring procedures should be established in accordance with IGE/SR/18. Where it is considered that the proposed works will affect a pipeline, appropriate measures shall be taken to afford protection to the pipeline.

Note: These measures may include de-commissioning a pipeline for the duration of the proposed operations, diversion of the pipeline, special protection to the pipeline or changes to the proposed operations.

Where it is considered that a pipeline may be at risk from adjacent construction activity, the works should be supervised to ensure that the protective measures which have been agreed are observed and that the method of construction is as intended.

9.6.4.3 *Route inspections*

Inspection of a pipeline shall be carried out to ensure that the pipeline is not deteriorating. This should include:

- inspection of exposed crossings for security, mechanical defects, condition of protective coatings, etc.

  Note: Where a pipeline is exposed, the opportunity can be taken to examine and record the condition of the pipe. Where there is evidence of abnormal corrosion of ferrous pipes, it may be prudent to take core samples of cast iron pipe or carry out ultrasonic inspection of steel pipe, to confirm the wall thickness and condition where it is exposed.
- inspection of water course crossings, to identify any changes from the original state of both the pipeline and its immediate surroundings for example riverbeds, riverbanks, etc.
- identification of subsidence in the vicinity of the pipeline.

  Note: Subsidence associated with adjacent construction activity usually occurs following completion of the work. In addition, subsidence can be caused by:
  - *running water from leaking or broken drains, sewers, water pipelines and services*
  - *the movement of vehicles whose weights exceed that for which a particular road was constructed*
  - *tunnelling or mining operations.*

Route inspections may be undertaken, to monitor the long term effect of possible causes of ground movement and also to check that building, tree planting or construction activity has not taken place without prior consultation. These route inspections may be conducted informally by technical staff, as part of their daily routine, by being alert to significant changes of environment and the possible effect on a pipeline. In addition, formal inspections may be arranged for pipelines in particular situations, for example a pipeline in private land, a small diameter pipeline in a heavily trafficked route, a pipeline adjacent to a major highway construction which has taken place over a given period and a pipeline of MOP exceeding 75 mbar close to buildings.

The frequency and scope of route inspections should take into account the pipe materials in use, the age of the system, any previous history of subsidence, the quality of highway construction and the extent of adjacent works.

Route plans should be prepared to provide a logical route over all pipelines which are to be included to enable these formal inspections to be conducted.
For both formal and informal inspections, consideration shall be given to features which may be indicative of ground movement, including:

- surface running water on a dry day
- evidence of significant vehicular damage to footpaths, verges and sunken kerbs
- substantial depressions in otherwise even road surfaces
- substantial settlement of previously re-instated excavations and cracking of adjacent road surfaces and kerb edges
- erection of new street furniture, lamp columns, road signs, telephone poles, etc.
- evidence of mining subsidence
- tree planting adjacent to buried plant.

If the observed features could affect the long-term integrity of the pipeline, more detailed investigations should be arranged.

Note: These may include discussions with transport and highway authorities, trial excavations or leakage surveys. Discussions with land owners may also be necessary if there has been any encroachment by building works.

9.6.4.4 *System soundness surveys*

These surveys aim to establish whether significant amounts of gas are leaking from the system and whether such leakage constitutes any form of hazard. The surveys may be of two specific types.

(a) **Potential hazard surveys**

Potential hazard surveys should include pipelines which are assessed as being the most hazardous, taking into account the material of construction, pipe diameter, operating pressure, the proximity nature and occupancy of adjacent buildings and the incidence of gas ingress to buildings.

Note: Leakage from pipelines may be hazardous if there is a high probability of gas ingress into buildings in which there are ignition sources. The hazard is greatest when the rate of leakage is high, such as that associated with breakage of cast iron, through-wall corrosion of ductile iron, and leakage from other pipelines of MOP exceeding 75 mbar.

The frequency and timing of hazard surveys should be decided in relation to the general condition of the overall pipeline population and factors which influence, most significantly, the environment immediately adjacent to the pipeline.

Note: In particular, prolonged periods of abnormally low temperatures may cause migration of ground moisture and frozen ground. Prolonged periods of abnormally dry weather may cause some soils to fissure resulting in the formation of voids. Both of these environmental factors can lead to failure of pipes having low beam strength.

The emphasis of a potential hazard survey should be to detect large volumes of gas which result from broken pipes or other large sudden defects. Surveys should be carried out using PPM detectors (see (c) below) which have been fitted with a gas concentration threshold limiting device, so that only significant gas concentrations are indicated.

It is important that the location of each indication from the gas detector is identified and recorded. Any indications which suggest that a hazardous situation may exist shall be reported immediately.

Note: *In general, minor leakage from a pipeline is not hazardous. However, where a pipeline is adjacent to an unventilated void or building which may be unoccupied for long periods, gas ingress from minor leakage over a long period may result in combustible gas/air mixtures.*

Where there is a mechanically jointed or lead/yarn jointed pipeline in close proximity to a building which may be unoccupied for long periods, the perimeter of the building should be surveyed using PPM leakage detection equipment (see (c) below).

(b) **Leakage surveys**

The frequency of leakage surveys should be set by a risk-based approach.

If this is not possible for a pipeline of MOP exceeding 7 bar conforming to and operating to IGEM/TD/3 Edition 4 or 5, a leakage survey should be carried out annually at:

- sleeve ends not fitted with rigid end seals and
- points where impact protection has been provided and
- those sections of a pipeline which cannot be inspected by on-line pigging or a suitable overline survey technique.

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.

(c) **Maintenance surveys**

Sensitive leakage detection instruments, capable of detecting parts per million (PPM) of methane in air, may be used to examine more closely all or parts of the system. The emphasis on PPM surveys is to identify the need for maintenance or to support other forms of monitoring previously mentioned. In particular, they will assist to:

- identify a pipeline which may benefit from some form of treatment by gas conditioning or spraying
- identify a pipeline which is in need of systematic repair or replacement
- determine the condition of a pipeline prior to road resurfacing
- investigate the effect on a particular pipeline of adjacent works or of subsidence or settlement of the surface in the immediate vicinity of these pipelines
- determine the effectiveness of leakage control measures.

Maintenance surveys should be undertaken at slow speed, using either vehicle-mounted equipment or walking survey equipment. For both types of survey, suitable arrangements should be made to record the results and to take appropriate action where potential hazards are discovered.

9.6.4.5 *CP surveys*

The integrity of steel pipelines will be maintained if there is an effective system of corrosion protection, comprising pipe coating and a system of CP. Regular monitoring of the effective operation of the CP system shall be considered as this will help to highlight changes in the level of protection provided.

9.6.4.6 *Analysis of data*

Information and data collected from any condition monitoring activity should be used to assess the condition of a pipeline. In addition, historical data, including details of breakdown maintenance, should be analysed to determine any trend in the condition of a particular pipeline or parts of a network.

9.6.4.7 *Frequency of monitoring*

The frequency of condition monitoring activities should be set by a risk-based approach. If this is not practicable for pipelines of MOP exceeding 7 bar, the minimum frequencies, given in Table 10, should be adopted.

TYPE OF MONITORING	**MAXIMUM INTERVAL BETWEEN MONITORING**
Internal	Not to exceed 10 years
Above-ground	
a. For pipelines subject to internal inspection	Not to exceed 10 years to be carried out mid-way between internal inspections.
b. For pipelines not subject to internal inspection	Not to exceed 5 years
Hydrostatic test	Not to exceed 20 years

Note: Further information on monitoring is given in IGEM/TD/1.

TABLE 10 - MINIMUM FREQUENCY OF CONDITION MONITORING FOR PIPELINES OF MOP EXCEEDING 7 BAR

9.6.5 **Strategic valves**

9.6.5.1 The frequency of valve maintenance and operation should be set by a risk-based approach or, if this is not practicable, valves should be maintained, operated fully (also see clause 9.6.5.3) and their seals proved at least annually.

9.6.5.2 In maintenance operations involving the movement of a valve, consideration shall be given to the monitoring of pressures on both sides of the valve.

9.6.5.3 In the exceptional circumstance where the system does not allow for complete valve closure, the valve should be moved off the seat and closed partially. Due account should be taken of the permissible pressure drop across the valve.

Note: Where possible, valve body vents will have been installed with the vent valve located immediately off the valve. For buried valves, an extension may be fitted at ground level and a further valve fitted where it may be operated safely.

9.6.5.4 Special consideration shall be given to the maintenance of any valve which is normally closed for operational purposes.

9.6.5.5 Unless adequate precautions have been taken against corrosion, maintenance schedules should include a visual inspection of any valve body, accessible moving parts and adjacent pipework.

9.6.5.6 Where a valve is located in unfavourable conditions, such as in a valve chamber subject to flooding or general dampness, maintenance frequencies should be increased.

9.6.5.7 The cover on any valve chamber should be maintained to ensure that they can be removed quickly.

9.6.5.8 Checks shall be made to ensure that there is no gas build up in any valve pit.

9.6.6 External coating

9.6.6.1 Special procedures should be in place for corrosion monitoring of exposed pipe.

9.6.6.2 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 should be paid to pipe corrosion hidden by supports.

9.6.6.3 The paint system of exposed pipe should be examined on a planned and regular basis and rectified as necessary in an approved manner.

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.

9.6.6.4 Special consideration shall be given to the condition of any electrical insulation where deterioration could adversely affect an adjacent CP system.

9.6.7 Cathodic protection (CP)

9.6.7.1 The continued effective operation of a CP system is dependent on a satisfactory level of monitoring and maintenance, which should form part of the pipeline management system. Regard should be taken of ageing effects on the pipeline coating and on locations where the integrity of the CP system may become increasingly vulnerable.

9.6.7.2 The frequency of monitoring and the continuing suitability of representative test locations shall be reviewed periodically. Suitable procedures are given in BS 7361.

9.6.7.3 For a pipeline of MOP exceeding 7 bar, the following minimum routines shall be considered:

- for a sacrificial anode system, pipe/soil potentials at representative points and points of low protection should be checked at 6 monthly intervals. For an impressed current system, a status check should be made monthly to establish that the CP system power source(s) is/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
- 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

- after the commissioning period, and where practicable, a CIPS should be carried out over the total length of the pipeline and thereafter at intervals not exceeding 10 years
- crossing points with other cathodically protected structures (whether bonded or not) and any other interference bonds, should be tested annually to ensure that no adverse changes have occurred.

9.6.8 **Planned maintenance of cross country pipelines of MOP > 7 bar**

9.6.8.1 *Aerial and ground surveys*

Aerial survey of a pipeline should be undertaken every two weeks, unless the frequency is set by a risk-based approach.

Note: Where aerial survey is not practical, for example in urban areas, motor vehicle surveys can be undertaken.

Observers shall be notified of known encroachments. Observers shall record all other encroachments or likely encroachments and report them according to an agreed procedure.

9.6.8.2 *Vantage point survey*

As an alternative, or as a supplement, to an aerial survey, a vantage point survey should be carried out. This survey should be undertaken every two weeks unless the frequency is set by a risk-based approach. The survey should be undertaken from pre-determined fixed points along the route, by an observer. The points should be selected to ensure that all relevant parts of the route are visible.

Observers shall be notified of known encroachments. Observers shall record all other encroachments or likely encroachments and report them according to an agreed procedure.

9.6.8.3 *Owner occupier liaison*

Regular contact shall be maintained with owners, occupiers and tenants of land through which a pipeline passes.

Note: This can best be achieved by depositing, with the occupier, a plan showing the pipeline location and the easement/servitude width and by personal visits to the occupier and, if practical, the owner, on at least an annual basis.

Where appropriate, similar visits may be made to highway and river authorities and other utilities and contractors. A regular visit shall be made to local planning authorities and emergency planners to ensure they are aware of the existence of the high-pressure pipeline.

The objectives of these visits should be to determine:

- the accuracy of existing records, for example change of ownership or tenancy
- that the existence of the pipeline is known to the occupier and owner
- whether any work adjacent to the pipeline is planned in the future and whether any work has been done since the previous visit, without the knowledge of the pipeline operator.

9.6.9 **Planned maintenance of PE pipelines of MOP ≤ 7 bar**

Routine maintenance is not normally required.

9.6.10 Planned maintenance of iron pipelines

9.6.10.1 *General*

Consideration shall be given to the particular characteristics of iron pipelines when determining planned maintenance.

Note 1: The principal source of pipeline leakage is through the joints. This will have resulted from the introduction of gas that is dry which has low levels of aromatic hydrocarbons. In joints which rely on yarn for sealing, dry gas tends to cause the yarn to shrink and allow leakage, while low levels of aromatics can cause the rubber gaskets of mechanical joints also to shrink and leak.

To counter this effect, swelling agents may be introduced into pipelines. Glycols or water can swell yarn, although the latter is seldom used as it affects the CV of the gas. Suitable oils can swell rubber joint gaskets. Anaerobic sealant may be used to treat joints locally in carefully controlled circumstances.

Note 2: Both diethylene glycol (DEG) and monoethylene glycol (MEG) are effective in swelling yarn; neither is considered to have a detrimental effect on a PE pipeline. Yarn which is heavily tarred or which has deteriorated significantly is unlikely to be responsive to glycol.

Note 3: DEG has a longer lasting effect than MEG, but its lower vapour pressure severely limits the distance it can be carried as a fog at the gas velocities found in lower pressure systems. It is, therefore, not usually economic to use DEG when fogging.

DEG absorbs MEG, thus rendering it ineffective, and so should only be sprayed or poured into discrete parts of the system, which are not intended to be subsequently treated with MEG.

Note 4: Further DEG treatment is likely to be necessary after five to ten years or when monitoring indicates that joint leakage is increasing.

9.6.10.2 *Using MEG to treat pipelines with yarn joints*

A variety of equipment is available for introducing MEG into the gas flow, either directly as a vapour or as a fine fog which will vaporise as it travels with the gas. This is often known as gas conditioning or fogging. Even at 100% saturation, the amount of MEG present in the gas is low. Hence, treatment should be continuous and several months' treatment at the highest practicable saturation will be necessary to effectively reduce leaks.

Note 1: If treatment is stopped, the MEG will desorb readily.

Note 2: Gas conditioning with MEG is affected by:
- *gas temperature*
- *flow rates*
- *the pressure of the gas*
- *the presence of dust or DEG.*

To ensure gas conditioning plant is installed in the optimum location, consideration shall be given to using network analysis to understand and take the best advantage of flow conditions.

Note 1: Proportional controllers will compensate for the first three listed variables. Nevertheless, it is difficult to achieve 100% saturation and a target of 40% saturation or greater is recommended to maintain the condition of the joints.

Note 2: Saturation values drop, often considerably, when the pressure of treated gas is reduced. For this reason it is not advisable to use treated higher-pressure gas to treat joints in a lower-pressure system. The effect of gas temperature is particularly important, as illustrated in Figure 8.

Note 3: Gas temperature varies significantly through the seasons and drops after pressure reduction.

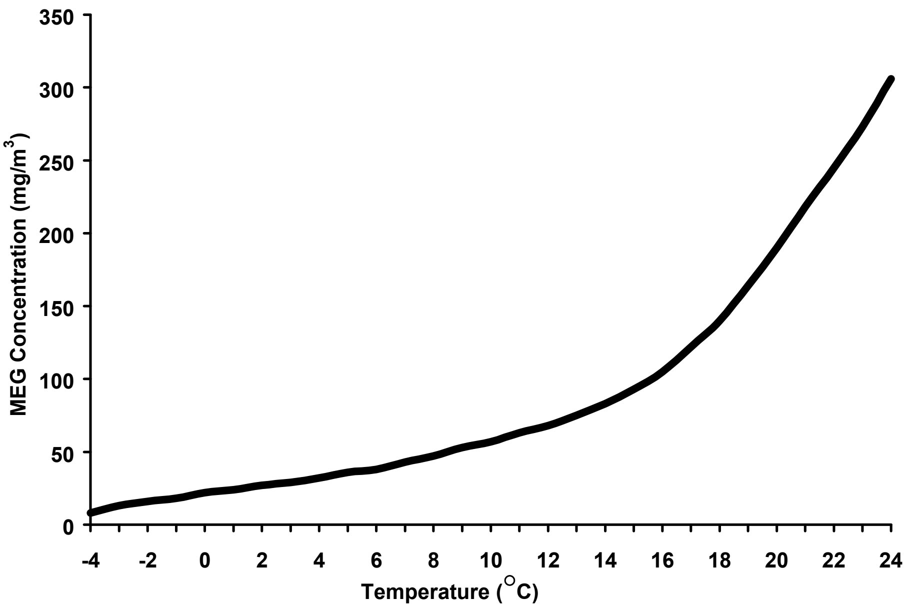


FIGURE 8 - SATURATION CONCENTRATION CURVE FOR MEG

To achieve best results when gas conditioning with MEG, the following actions should be taken:

- spraying pipes with MEG, whenever possible, to thoroughly wet the system
- avoiding the presence of DEG in a pipeline to be treated
- treating a pipeline of MOP not exceeding 7 bar independently from higher pressure pipelines
- wherever possible, introducing the MEG into straight sections of a pipeline
- maximising saturation, with at least 40% saturation at system extremities
- setting up and controlling equipment accurately.

Rates of injection should be controlled carefully to avoid excessive drop-out which could block the pipeline. Siphons and other low points should be checked regularly.

Note: Portable detectors allow rapid site investigations of MEG concentrations and assist in setting up loggers and controllers. The effectiveness of MEG conditioning can be measured in terms of lost gas savings and reduced joint repair activity. Repair activity can be easily monitored by mapping leakage sites.

Installations and running costs can be high, so these should be compared with the expected benefits from reduced leakage and maintenance activity.

9.6.10.3 *DEG spraying and pouring in pipelines with yarn joints*

DEG should be sprayed into the pipeline using a hose, or simply poured in.

Note 1: Such treatment can reinforce the effects of gas conditioning or can be effective in reducing joint leakage from discrete sections of small diameter pipelines.

Note 2: Normally, joints of up to 8 inches nominal bore can be sealed by capillary climb of the swelling agent from the bottom of the pipeline. In exceptional circumstances, a pipeline up to 12 inches nominal bore can respond to this treatment. The quantities of swellant required for a clean pipeline are shown in Table 11.

NOMINAL BORE		SPRAY RATE
inches	mm	(litres/10 metres)
3	75	2.5
4	100	3.0
6	150	4.5
8	200	6.0
10	250	7.5
12	300	9.0

TABLE 11 - QUANTITIES OF DEG REQUIRED FOR EFFECTIVE TREATMENT BY SPRAYING

A pre-treatment check on siphon and dip pipe records and a site survey should be carried out to identify any low points in the system, where pipelines might be blocked by excessive swellant. Where necessary, additional dip pipes should be fitted at low points in the pipeline before spraying or pouring is attempted.

Siphons should be pumped clear before spraying, immediately after spraying and one week after spraying. If liquid in any quantity is present on the last occasion, further pumping will be necessary.

9.6.10.4 *Using oil products to treat rubber joints*

(a) Oil products can be used to treat many types of rubber seals in mechanically jointed pipelines of MOP not exceeding 2 bar, using methods similar to those used in treating yarn joints. They react beneficially with the rubber, countering the absence of aromatic compounds in natural and other gases, causing the rubber to expand and reseal the joints. Synthetic rubbers, typically tipped with nylon sealing rings, do not respond to oil products. These substances soften PE, causing it to lose some strength causing premature failure.

Care shall be taken not to exceed recommended treatment levels to avoid:

- over-expanding the rubber and breaking corroded joint components
- stripping any bitumen coatings from pipe walls and depositing them on downstream equipment components
- affecting PE components by a softening or hardening process.

Note: Correct, low saturation, values will not cause these problems.

Oil products are flammable and suitable precautions shall be taken in accordance with recognised safety recommendations.

Suitable precautions shall be taken to minimise the effect of the substances on breathing and the skin.

Checks should be made of siphons and other low points and these should be monitored before and after spraying, to avoid gas supply problems.

Pouring of oil products should not be undertaken. This is to avoid over treatment and the consequent possibility of joint failure.

Oils introduced into gas systems can cover wide areas if the equipment is correctly sited. Treatment should be continuous, otherwise the oil will desorb from the rubber and leakage could recur.

(b) Light oil products with low boiling points, such as distillate or kerosene, may be introduced into the gas system by means of foggers or vaporisers. The objective is to have these substances in the gas in the vapour phase at up to 20% saturation (and no greater, for the reasons given in clause 9.6.10.5).

(c) Heavy oils, such as GM060 or Carnea 21, can be sprayed into a pipeline with natural rubber joints at the rate of 0.33 gals/inch diameter (0.0606 litres per mm diameter) per 10 m pipe length.

9.6.10.5 *Spraying of anaerobic sealants*

The spraying of anaerobic sealants into the joints of a metallic pipeline may be considered as a preventative maintenance technique, although economic considerations are likely to limit its use. The sealants are considerably more expensive than glycol or oils and a sophisticated joint location system should be in place. However, it has more permanent joint sealing properties than oil spraying.

9.6.10.6 *Pressure control*

The major maintenance requirement for an iron pipeline is gas leakage control. The operating pressure of the network directly affects the magnitude of any leakage and, therefore, consideration shall be given to reducing the OP to a minimum, to limit or reduce any gas leakage.

Note: Systems of automatic pressure control, for example Demand Activated and closed loop telemetry, are now commonplace. They maintain the minimum pressure in the network, while ensuring that there is adequate supply to meet consumer demand and maintain safe operating pressures over the whole network.

This is achieved by controlling the gas volume input into the network to maintain a minimum set pressure at the network extremities. The network extremity pressure can be monitored centrally by using telecommunications to monitor and relay the pressure, for example by closed loop telemetry control.

9.7 BREAKDOWN MAINTENANCE

Although a high standard of planned maintenance will reduce the possibility of breakdown, it will never completely eliminate the need to carry out repairs. Knowledge of a breakdown may arise from system monitoring, but it may also arise from a report of a gas escape.

Note 1: Guidance on responding to reports of gas leakage is covered by IGEM/SR/29.

Note 2: Failure of a pipeline can occur in a number of ways and there is a selection of repair techniques available. This section describes a number of the more commonly available techniques and does not attempt to set down a comprehensive listing of all techniques. The descriptions are necessarily brief and manufacturer's instructions apply in all cases.

When breakdown maintenance forms part of the maintenance philosophy, the following requirements should be applied.

9.7.1 General

All breakdown maintenance jobs shall be recorded, stating the reasons for the breakdown. The record should be maintained in a central maintenance records system.

Note: This can then be considered as part of the condition monitoring of the system. This will then allow a history of failure to be developed to ensure that any recurring events can be accounted for in any future requirement for planned or preventative maintenance.

9.7.2 Safety precautions

9.7.2.1 All naked flames and other sources of ignition, including static discharge and mobile phones, shall be avoided in the immediate work area.

9.7.2.2 Prior to starting repair work, the flow of gas escaping from any defect should be reduced if possible, for instance by lowering OP, and maintained to the minimum that is operationally possible to carry out the repair. If the leak cannot be contained at an acceptable level, the work shall be carried out under the direct control of an experienced supervisor.

9.7.2.3 Gas levels shall be monitored during the work on the gas escape using suitable gas detection equipment.

9.7.2.4 Safety equipment, appropriate to normal gas distribution operations, including dry powder fire extinguishers, air breathing apparatus, first aid kit including eye wash facilities, and a supply of water for washing purposes, shall be available at all times.

9.7.2.5 Appropriate air breathing apparatus shall be worn if a gas escape situation dictates its use, for example in a poorly ventilated trench.

9.7.2.6 Appropriate air breathing apparatus shall be worn if there is any risk of inhalation of fumes from the use of solvents, primer, resins, hardeners, etc.

Safe means of entry and exit for the excavation shall be maintained at all times. Where necessary, adequate trench support should be provided.

9.7.2.7 Precautions shall be taken in the storage of materials and must be in accordance with appropriate legislation.

Materials shall be stored in a safe place, away from the trench and secured against interference and from being tampered with by unauthorised persons.

Storage shall be away from naked flames and other sources of ignition, and in a well ventilated area.

9.7.2.8 In the event of spillage, all naked flames and sources of ignition shall be extinguished and any spillage should be contained and absorbed with sand and earth. Spent absorbent should then be collected into sealable containers for disposal.

9.7.2.9 Disposal of spent absorbent from spillages, used containers, other leakage repair materials and contaminated disposable items, should be disposed of in accordance with the manufacturer's instructions.

Note: Control limits for the substances used for joint repairs are provided in HSEH40.

9.7.2.10 In the event of accidental fire involving joint repair materials, care shall be taken to avoid the inhalation of fumes from the burning products (as these may be toxic).

Note: This is especially important for encapsulation.

9.7.3 Temporary repairs

A temporary repair should be made only if such action is safe. It shall be monitored until a permanent repair is carried out.

A risk assessment shall be carried to determine the monitoring frequency and maximum period allowed until a permanent repair is completed.

9.7.4 Methods of internal joint repair for ferrous mains

9.7.4.1 *Spraying of anaerobic sealant*

Several compounds covered by the generic term "anaerobic sealant" are available. Only compounds that have been evaluated and approved shall be used.

Note: Anaerobic sealants are a mixture of several organic compounds, capable of reacting in the absence of air and in the presence of metal or pipeline dust, to produce a flexible durable polymer.

Anaerobic sealants should be sprayed using a specialist system, which incorporates accurate joint location devices to target the sealing application.

9.7.4.2 *Mechanical sealing of joints*

The two basic methods of mechanically sealing a joint are bridging the joint gap with internal clamps and covering the joint with a polymeric sealant.

Note: Lining systems are considered to be pipeline renovation techniques.

An internal joint repair may require the pipeline being taken out of commission. Normally, a pipeline of 600 mm diameter or greater is sealed by personnel entering the pipeline. For this method, inspection and testing of the pipeline shall be carried out (as a full internal refurbishment of the pipe section should prove economic once it is decommissioned).

Any joint of less than 600 mm diameter may be sealed using equipment remotely controlled from outside the pipeline. It shall be ensured that such a joint can be located accurately.

9.7.5 Methods of external joint repair for ferrous mains

9.7.5.1 *General*

When carrying out an external joint repair on a mechanical joint, the gland ring shall not be removed.

Before any form of surface preparation is started, it shall be established visually, and by scraping, that the pipeline is not severely corroded and/or graphitised.

There are a variety of methods of surface preparation and, where considered appropriate, anti-spark tools should be used. Where grit blasting is employed, reference should be made to IGEM/SR/28.

The joint sealing operation should be carried out by a minimum of two persons, suitably trained and experienced in such work.

Although joint repair systems may involve the use of a number of different chemicals, general rules should be followed to ensure their safe handling:

- in all cases, read, understand and conform to the manufacturers' instructions and recommendations for use
- ensure that good ventilation is provided, to avoid breathing of harmful vapours. If necessary, wear air breathing apparatus
- wash hands after using any joint repair system
- do not use solvents for cleaning hands or clothing.

All operatives should wear as a minimum:

- protective boots to BS EN ISO 20345;
- overalls made from flame retardant and anti-static material to BS EN ISO 11612 and BS EN 1149 respectively;
- approved goggles or full face visor to BS EN 166, BS EN 167 and BS EN 168
- safety helmet to BS EN 397; and
- suitable gloves, gauntlets and/or protective sleeves to BS EN 378 (chemical resistance) and BS EN 388 (impact resistance).

Note 1: With certain materials, for example primers, resins, hardeners solvents, etc., impervious gloves will be necessary. These should have a resistance to permeability (breakthrough time) of at least 20 minutes and be of good mechanical strength.

Note 2: Fire suits, helmets, gauntlets etc. to be made available and worn as required.

9.7.5.2 *Anaerobic sealants*

Sealants may be flammable and hazardous to health, being both eye and skin irritants and giving off harmful vapours. Suitable protective gloves and overalls shall be worn. One and two part sealants are currently available, the latter requiring mixing prior to use.

Skin and eye contact shall be avoided and the general safety precautions detailed in clause 9.7.5.1 should be followed. Containers may become pressurised in stock or in transit and, hence, should be opened slowly to avoid accidental discharge of contents.

Leaking metallic joints may be repaired by the direct injection of anaerobic sealants into the joint. Where necessary, the top of the joint should be exposed to apply the sealant, although further injection points lower down the joint may be necessary, particularly on larger pipelines.

Before drilling is started, care shall be taken that the joint is not severely corroded and/or graphitised.

Note: Current methods of joint injection employ hand or gas-pressurised systems.

All equipment shall be compatible with the sealant used and any non-metallic component should be examined carefully prior to each injection operation to ensure that deterioration has not occurred.

The equipment used, including fittings and tubing, should have a safe operating pressure equivalent to 1.5 times the maximum attainable injection pressure.

When using a hand-pressurised injection gun, the gun should be enclosed to reduce contact with the sealant to an absolute minimum. The maximum sustainable injection pressure should be limited to 7 bar.

For a gas-pressurised injection system, a pressure-limiting device should be fitted to avoid over-pressurisation and the reservoir should be fitted with a manually-operated valve and vent to permit controlled depressurisation of the equipment after use.

On completion of injection, care shall be taken to avoid accidental spillage of the sealant when the injection equipment is disconnected and the injection point sealed.

Note: In particular, this is relevant for a pipeline of MOP exceeding 75 mbar and not exceeding 2 bar.

9.7.5.3 *Encapsulation*

Several methods of encapsulating or encasing leaking joints are available. All methods depend upon the adhesion of the sealing material to the surface of the pipe or joint and, hence, cleaning standards shall be high. Generally, this is achieved by grit blasting for which reference should be made IGEM/SR/28. Prior to application, it may be necessary to apply a primer to cleaned metal. It may also be necessary to temporarily seal the leak. A polymeric material may be injected into a mould to encapsulate the joint.

Both disposable and re-usable moulds may be used. Disposable moulds (which may be left in position after encapsulation) may require the use of metal or plastic straps or other types of fasteners and care shall be taken in fitting the moulds in accordance with the manufacturer's instruction.

Note 1: Usually, reusable moulds are of more robust construction and have to be cleaned before re-use. The application of an approved releasing agent, to assist the removal of the mould, may be advisable prior to use with certain techniques.

Note 2: Current methods of filling the mould employ, free pouring, pneumatic, or mechanical injection or a combination of these methods.

When injection is carried out by means of pneumatic pressure, the hoses, couplings, and regulating equipment shall be maintained in accordance with good engineering practice. In addition, air receivers shall be maintained and inspected in accordance with legislation. The injection gun should be tested, by the manufacturer, to a safe operating pressure of 1.5 times the maximum attainable pneumatic pressure. Injection guns should have the safe operating pressure marked on the body and be fitted with a manually-operated valve and vent to permit controlled de-pressurisation of the equipment after use.

The use of inert gas cylinders, for example nitrogen, with a suitable pressure relief system incorporated can be used as a pressure source. Care shall be taken when handling an inert gas in a confined space.

Note 1: A trowel-on encapsulant has potential economic advantages over mould systems, particularly for non-standard joints, due to the reduced quantity of sealant required.

Note 2: Lead/yarn joints may be sealed using a heated elastomeric material, which is compressed against the joint face.

Note 3: Sleeves of polyolefin material, with a mastic undercoat, may be wrapped around leaking joints. The application of heat shrinks the sleeve tightly over the pipe and joint. Great care is necessary when applying the heat source in a gaseous environment. The use of an integral heating coil is not considered to be safe in a gaseous atmosphere.

Encapsulation materials have comparatively low mechanical strength and, thus, careful consideration shall be given before using the technique to repair defective welded joints or other defects on a pipeline away from joints.

Caution shall be taken if it should become necessary to utilise solvents for cleaning purposes as these may be flammable, as indicated on the warning label, and may be eye, skin and respiratory irritants.

Manufacturer's instructions and the requirements of COSHH must be applied when using any cleaning solvent.

9.7.5.4 *Leak clamps*

External leak clamps, employing a rubber gasket as well as the seal, shall be considered for lead yarn joints and certain designs of mechanical joints.

9.7.5.5 *Other external repair methods*

Consideration shall be given to split or wrap-around fittings, which may be applied to circumferential pipe fractures, defective welds or areas of local corrosion.

Note: The jointing material is usually a synthetic rubber.

9.7.6 **Pipeline renewal**

9.7.6.1 When an individual repair or system treatment is not economic or appropriate, consideration shall be given to replacement or renovation of the defective section of pipeline.

Note: This assessment can be made as part of the condition monitoring process in view of the data collected in respect of the particular pipelines section.

The system operator shall consider current and future system capacity when assessing any replacement or renovation scheme.

9.7.6.2 In addition to conventional open cut pipeline replacement, consideration shall be given to "no dig" pipeline replacement and renovation techniques including:

- pipeline insertion
- pipeline splitting
- close fit lining
- membrane lining
- directional moling.

Note: IGEM/SR/28 provides guidance.

9.7.7 **Pipeline isolation**

9.7.7.1 When it is necessary to isolate a pipeline or part of a pipeline, in order to undertake breakdown maintenance, the appropriate level of safe isolation from all sources of danger shall be ensured. The risk of any uncontrolled release of gas shall be reduced to a minimum.

9.7.7.2 Attention shall be paid to the disconnection and isolation of any 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.

9.7.7.3 Procedures shall be established for pipeline isolation using techniques considered acceptable for the particular application.

9.7.7.4 When deciding on the isolation method, the following constraints should be taken into account:

- any requirement to keep the rest of the pipeline system operating while working on an isolated section
- the requirement to safely remove 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.

9.7.7.5 Pipeline isolation procedures should:

- 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 by physical disconnection, double-block-and-bleed, locking of valves (especially those which are remotely operable), etc.
- 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.

9.7.7.6 On completion of works, procedures shall be used to return the pipeline to its original safe condition. Special attention shall be given to ensuring that the work activity has been carried out and completed satisfactorily.

9.7.7.7 Any pipeline, or pipeline section, that is to be taken out of service for modification works, maintenance or repair shall be decommissioned to remove gas and other hazardous substances.

9.7.7.8 A detailed programme of works and procedures shall be prepared in accordance with IGEM/GL/6 and followed for all pipeline de-commissioning operations. Purging should be carried out in accordance with IGE/SR/22.

Pipes shall be cleared and purged of flammable gases, vapours and residues.

Reference should be made to IGE/SR/23 when NG is to be vented.

Any programmed pipeline surveillance should continue to be applied after a pipeline is taken temporarily out of service. Any CP system should be maintained.

Consideration shall be given to de-commissioning any pipeline or pipeline section that may not be used to flow gas for an extended period of time.

9.7.7.9 Prior to re-commissioning any pipeline, particularly one that has been de-commissioned for an extended period of time, measures shall be taken to establish the integrity of the pipeline to be assured that it continues to be fit for its intended purpose.

9.7.7.10 A detailed programme of works and procedures shall be prepared and followed for all pipeline re-commissioning operations. Purging should be carried out in accordance with IGE/SR/22.

9.7.7.11 For a 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.

9.7.7.12 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. Where applicable, pipeline external coating integrity and CP effectiveness should be established.

9.7.8 **Repairs to steel pipelines**

9.7.8.1 A steel pipeline may be repaired by welding, when care shall be taken to ensure that the atmosphere is not hazardous and that the pipe material is sufficiently thick and in good condition. Pipe wall quality and thickness checks should be carried out at the point of attachment of any fitting to the pipeline, for example by the use of ultrasonic equipment.

9.7.8.2 Appropriate corrosion protection measures should be taken as soon as the repair has been completed.

9.7.8.3 Whenever a pipeline is found to be defective or damaged, precautions must be taken to afford protection to employees, contracted personnel and members of the public.

9.7.8.4 When a pipeline defect is found, the type of damage should 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 caused by corrosion*
- *damage caused by ground movement, which may involve a combination of buckling, denting and cracking*
- *damage caused to protective coating requiring repair.*

When repairing a field-applied coating system, the system should be selected and applied in accordance with an appropriate procedure to reproduce, as far as possible, the factory-applied coating.

9.7.8.5 Suitable procedures shall be prepared for the safe inspection, categorisation and repair of any damaged or defective pipeline. Where necessary, specialist advice should be sought when drawing up the procedures.

Note: It may be necessary to develop damage categories, so that the procedures for inspection and repair can be appropriate for each case dependent on its risk and severity.

9.7.8.6 Whenever a pipeline is suspected of having been damaged or has become defective but a gas escape is not involved, 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, OP should be reduced as low as operationally possible, but to a maximum of 85% of the above level.

Depending on the severity of the damage (see clause 9.7.8.4), it may be necessary to reduce further the pressure. Before repair, it should be reduced to the operating minimum to ensure continuity of supply.

9.7.8.7 When a gas escape is involved, careful consideration of the risks associated with the escape shall be undertaken before working on any escape.

Where a defect or damage is combined with loss of gas, the safety precautions (see clause 9.7.8.6) shall be implemented, as a minimum. Further actions should be regulated by the particular circumstances of the incident. The requirements in clause 9.2.2.7 should 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.

9.7.8.8 Any temporary repair shall be capable of maintaining the pipeline in a safe condition until a permanent repair can be made.

Note: It may be necessary to reduce the OP 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.

The method of repair should be selected with reference to clause 9.7.8.6, the type and category of damage (see clause 9.7.8.4), the operating conditions of the pipeline and any requirements to maintain gas supply.

9.7.8.9 Where repair involves the use of under-pressure fittings, reference should be made to Sections 6 and 8.

A detailed programme of works and procedures shall be prepared and followed for all hot tap and stopple operations, in addition to those requirements in clause 9.2.2.5.

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 examination, consideration should 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 should be carried out at the point of attachment of fitting to the pipeline.

Where sections of pipeline are to be permanently de-commissioned, Sub-Section 7.11 should be observed.

9.7.9 Repairs to PE pipelines

9.7.9.1 Normally, any repair to a PE pipe system will be carried out as a result of a reported gas escape. The escape should have been investigated in accordance with IGEM/SR/29.

Note: Usually, the gas escape will be from a system fault or as a result of interference damage by a third party.

9.7.9.2 Any permanent repair of a system fault or interference damage shall be undertaken only while ensuring the integrity of the system is maintained. Any faulty or damaged section should be replaced by a new section of PE pipe using appropriate electrofusion couplers. Metallic components should not be installed as a permanent repair.

Note: For localised damage, it may be possible to make a repair using an electrofusion fitting over the defective area. However, the technique is not safe in a gaseous atmosphere. PE encapsulation methods have been developed and may be considered, if appropriate.

SECTION 10 : RECORDS

10.1 GENERAL

10.1.1 An effective record system shall be maintained for the design, installation, operation and maintenance of a system. A wide range of technical, positional and commercial information should be included so that the system can be operated effectively and demonstrated to be fit for purpose throughout its life cycle.

Note: Records systems may involve a large variety of formats, both paper and electronic. Paper examples include reports, certificates, photographs, maps, plans and drawings. Examples of electronic records include maps, databases, sketches and photographic images. Computer-based records need to be capable of being reproduced in a legible form.

10.1.2 Some records are essential for the continued operation and maintenance of the system and their loss or damage would cause serious difficulty. Such records shall be identified clearly and arrangements should be made for duplicate records to be maintained at separate locations.

10.2 DESIGN RECORDS

10.2.1 The design documentation shall be preserved as part of the overall project record. The design parameters, standards and methodology, together with calculations, surveys, safety assessments, special considerations and concessions, should be maintained. Where details of regulatory notifications and easements/servitudes are required, these shall be retained for the life of the system or section.

10.3 CONSTRUCTION RECORDS

10.3.1 A package of relevant construction documentation should be retained and selected from the following list, which is not exhaustive:

- construction contractor
- jointer's name and qualification
- principal dates of construction and commissioning, etc.
- type and specification of materials and fittings used with certification
- test certification package
- as-laid drawings including details of, for example, surface construction, depth of cover, pipe protection, etc.
- location of other underground plant and special features
- ground conditions
- construction methods, including trenchless techniques
- welding procedure specification
- welder qualification
- NDT records
- quality control procedures and documentation
- inspection records
- CP system location and records
- location of anchors, special features, etc.
- commissioning certificates
- handover documents
- connections to existing plant.

Note 1: Maintenance of accurate construction records is recommended to enable the fitness for purpose of the pipeline or system to be demonstrated and to provide an auditable trail so that regulatory requirements can be met.

Note 2: Future development of a system such as extension, upgrading or modifications will be assisted greatly by the existence of full, accurate and extensive records.

10.4 CROSS REFERENCING OF RECORDS

10.4.1 Any cross referencing method should define uniquely discrete lengths of underground pipe such that access to the records, either in map form or filing systems, can be readily obtained.

Note 1: Geographical Information Systems (GISs) benefit from the ability to link maps directly to supplementary databases holding required additional information.

Note 2: Some typical data capture methods include:

- ***grid co-ordinate referencing***
  A unique number is allocated to each junction or change of diameter, the unique reference number being based on a grid co-ordinate reference. Map information, which can be purchased from outside agencies, normally includes grid co-ordinate information. Where such maps are not available, it is recommended that a similar system be adopted to facilitate referencing of the underground system records to fixed grid co-ordinate data.

  With digital records, the grid co-ordinate referencing system will allow the transfer of alphanumeric data to map data using automatic drafting equipment.

- ***network node number referencing***
  A unique number is allocated to each junction or change of diameter and is, normally, associated with computerised flow analysis of networks.

  The main difference between network node number referencing and grid co-ordinate number referencing is that network node numbers are not associated with any given features on maps but are, normally, allocated at random.

- ***street number referencing***
  A unique number is allocated to streets, with all pipelines on a particular street being identified by means of the street reference number.

  The main disadvantage in this type of referencing system is that the reference data, i.e. the street reference numbers, will refer to more than one pipeline record and, therefore, a sub-referencing system is necessary to accommodate the situations where there is more than one pipeline in a street.

  The system has advantages, in that customer billing information is, normally, related to street reference numbers and, if the same numbers are utilised for pipeline records, a cross referencing system between the customer billing data and pipeline records is readily available if required, or allowed, under commercial arrangements.

- ***combined systems***
  When system record referencing is carried out using either the grid co-ordinate method or the network node number method, it is possible to cross relate this reference with street referencing data, to provide an interface with the customer billing data, where this is appropriate.

10.5 MAP-BASED RECORDS

10.5.1 The recording of information on pipes and associated plant and equipment, relative to fixed features, on a map, should be undertaken at a scale sufficient to show the approximate position of the pipe and other details.

Note 1: The following basic scales are suggested:

- *for built-up areas - not less than 1 to 1250*
- *for open-country routes - not less than 1 to 2500.*

Note 2: At complex interconnections or in congested areas, additional sketch maps of a larger scale may also be required to supplement the basic maps.

10.5.2 The method by which information on new works is transferred to the record maps should be by means of an as-laid plan of the work, to a scale not less than the scale used in the map records.

Note: It may also be appropriate to use digital data capture systems in the field as part of an integrated electronic records scheme.

10.5.3 Due consideration shall be given to the existence of any national or local codes or requirements in relation to recording of the position of pipelines in public streets.

Note: Special notifications to other utilities may also be required.

10.6 ALPHA-NUMERIC RECORDS

10.6.1 If required, the supplementary record to the map record, which contains all the data associated with the underground system, should be maintained using a paper file or computerised recording system.

10.6.2 Each individual record will be associated with a uniquely defined length of pipeline. Each individual record should be for a section of pipeline no greater than 1000 m in length for built-up areas. Consideration may be given, for open country routes, to individual pipeline section lengths of up to 10000 m. In a congested area, the pipeline section length will, normally, be less than 100 m.

10.7 OPERATION AND MAINTENANCE RECORDS

10.7.1 The typical information that needs to be accessible is:

- diameter
- MOP
- MIP
- test pressure
- material
- jointing method
- construction details
- location
- depth
- connections to other pipelines
- customers supplied from pipelines
- condition monitoring data
- valves and fittings
- associated plant.

Note: The operator of a pipeline is required to demonstrate that the pipeline is maintained in an efficient state, is in efficient working order and is in good repair. It is also required to ensure that any modification, maintenance or other work on the pipeline is carried out in such a way that its gas tightness and fitness for purpose for which it has been designed is not prejudiced. Further duties require the operator to minimise risk of damaging plant and incidence of injury to operatives, the public or to the environment.

Operating and maintenance records shall be readily available, kept up to date and be accurate.

Note: Due to the large volume of information, it is, usually, not possible for all the data for each system to be recorded on one map and the data cannot conveniently be analysed. Therefore, it is necessary to maintain a series of complementary record systems comprising different maps to record limited technical and positional data and support systems for recording the more detailed records and data. For more complex systems, electronic systems, digital mapping or more sophisticated GIS may be beneficial and more effective. Data and information relating to a particular pipeline section, or to a particular street or building, may be recorded on a computer file and displayed selectively either alpha-numerically or against a background map reproduced using computer graphics equipment.

10.8 PLANT AND EQUIPMENT RECORDS

10.8.1 Associated plant and equipment which form an integral part of the system, such as valves, siphons, test points and including CP systems, should be recorded as part of the pipeline system record. Details of all inspections and maintenance reports, as appropriate, should be kept.

10.9 CONDITION MONITORING RECORDS

10.9.1 While the two basic recording systems for underground plant records, i.e. map records and alpha-numeric records, are restricted to recording fixed information about the underground plant, it is advisable to maintain historical records for each pipeline length, so that details of all work undertaken are maintained.

The alpha-numeric record provides an ideal base for recording historical performance data and it is recommended that a sub-section of the alpha-numeric record be devoted to details of all aspects of condition monitoring as described in clause 9.6.4.

10.9.2 These records should include the results of all surveys and inspections and details of all work carried out on the system.

Note: Construction records and historical performance data can be used to confirm that a pipeline is able to continue operation at its designated operating pressure and can assist in identifying pipelines which require maintenance or replacement.

10.10 OTHER UTILITY RECORDS

10.10.1 Arrangements should be made with other utilities for access to their records.

Note: National regulations and guidance may be in force to encourage this co-operation between utilities and this liaison is important in avoiding damage to underground plant. Before site excavation work is undertaken, it is important to locate the exact route of existing plant on site.

10.10.2 Where site location services are not provided by utilities, it may be desirable to arrange for duplicate records of utility plant to be held. Under these circumstances, records should only be used as part of a careful on-site exploration, incorporating plant location equipment and safe digging practices.

Note: In particular, this is recommended for electricity cables.

10.11 DIGITAL RECORDS

10.11.1 Consideration shall be given to the use of digital maps which can be used to provide a common reference system for geographic, demographic, engineering and commercial data.

Note 1: Digital records systems enable data relating to customers, streets, plan, and any other geographically based information to be stored on computers and analysed, maintained and displayed against a common background map.

Note 2: Information can be exchanged between utilities or other parties, provided that the network and background map are supplied together.

10.12 AVAILABILITY OF RECORDS

10.12.1 Consideration shall be given to the availability and format of records for use by operational staff engaged on essential works out of normal office hours, or working away from the base location. Consideration should also be given to suitable archive periods and the provision of a document and data control system.

10.12.2 Consideration shall be given to the availability of records for use by third parties when excavating near to GT/operators plant.

10.13 RECORD UPDATING

10.13.1 It is important to maintain up-to-date records and, therefore, a suitable system shall be in place to control any modification, addition or deletion to the pipeline system.

10.13.2 Any changes to the system or supporting records held in databases should be updated as soon as possible following the change.

10.13.3 A formal system shall be in place to control these changes and any change shall be validated for accuracy before the record is amended.

10.13.4 A regular audit and review shall be carried out to ensure that the record system is maintained in an accurate and up-to-date condition.

SECTION 11 : ADDITIONAL MEASURES WHEN DEALING WITH LIQUEFIED PETROLEUM GAS

Commercial butane and commercial propane (defined as 3rd family gases) are specified in BS 4250 and either may be supplied as 100% commercial butane or propane or mixed with air to create a gas of a specified calorific value.

These requirements are applicable only to systems operating in the LPG vapour phase at MOP not exceeding 2 bar and are subject to the additional measures given below.

For LPG systems, MOP is, generally, restricted to a maximum of 2 bar to prevent liquefaction. For MOP in excess of 2 bar, the installation of trace heating may be necessary and specific reference is required to be made to the relevant Standard.

LPG has different properties to those of Natural Gas, some of which are outlined below. These differences shall be taken in to account when designing, constructing, testing, operating and maintaining pipelines conveying LPG.

LPG vapour and LPG/air mixtures are denser than air and will, normally, sink to the lowest level. The vapour may flow along the ground and into drains or trenches and can travel considerable distances. In still air, vapour disperses slowly and could be ignited some distance from the source.

The flammable range of LPG is, approximately, 2% to 10% in air. Within this range, there is a risk of explosion.

LPG vapour is slightly anaesthetic and may cause suffocation in sufficiently high concentrations.

LPG is, normally, odorised before distribution, enabling detection by smell at approximately 20% LFL, i.e. approximately 0.4% gas in air.

11.1 LEGAL AND ALLIED CONSIDERATIONS (see also Section 4)

11.1.1 In addition to the specific requirements of national legislation, CoPs and British Standards due regard shall be given to any local requirements for planning, construction and operation of an LPG system.

Note: Further guidance on design and installation practices can be obtained by consulting the extensive range of Codes of Practices published by UKLPG.

11.2 DESIGN (see also Section 5)

Pipe and joint materials and installation techniques shall be appropriate for use with LPG. Reference should be made to UKLPG Code of Practice 22.

Note 1: LPG and LPG vapours can have deleterious effects on certain jointing materials, sealing compounds and pipeline construction materials.

Note 2: Pipelines originally installed for use with 1st or 2nd family gases may not be suitable for conveying LPG vapour.

11.2.1 The safety assessment methodology described in Section 5 is based on data relevant to lighter than air gases and should not be applied directly to a pipeline conveying LPG.

11.2.2 The route selected for an LPG pipeline should avoid proximity to cellars, basements, pits, voids and other unventilated spaces. Where this is not practicable, additional measures should be considered to prevent leaking gas entering such areas.

11.2.3 Network analysis and pipe sizing software or techniques shall be checked to confirm the appropriate characteristics for the fuel gas in question.

Note: This may include calorific value, specific gravity, dynamic viscosity and gas temperature.

11.3 JOINTING (see also Section 6)

11.3.1 The number of joints in an LPG pipeline should be kept to a minimum and screwed joints should not be used below ground.

11.4 ALTERATIONS TO LIVE PIPELINES (see also Section 8)

11.4.1 Care shall be taken to prevent gas accumulation in trenches when carrying out work on a live pipeline.

Note: As LPG and LPG/air mixtures are heavier than air, the use of air movers is recommended to prevent accumulation.

11.4.2 Prior to electrofusion operations, the trench atmosphere shall be tested using an appropriately calibrated instrument. The process should not proceed if the atmosphere readings indicate gas is present in concentrations greater than 20% LFL.

11.5 COMMISSIONING AND DE-COMMISSIONING (see also Section 7)

11.5.1 Reference should be made to IGE/SR/22 and UKLPG Code of Practice 17.

Note 1: IGE/SR/22 deals primarily with the purging of NG systems and due cognisance will need to be made of the physical properties and characteristics of LPG vapour.

Note 2: Guidance on Permitry is given in IGEM/GL/6.

11.5.2 Where relatively large quantities of fuel gas are to be vented, consideration shall be given to flaring which may be carried out provided the operation is risk assessed and deemed to be acceptable.

11.5.3 Only instruments calibrated for LPG and suitable for use in a hazardous area shall be used to monitor and prove a fuel gas purge.

11.6 MONITORING (see also Section 9)

11.6.1 The route of a pipeline should be surveyed at pre-defined intervals to confirm the integrity of the system and to check easement/servitude accessibility, where applicable.

11.6.2 A gas leakage survey should be undertaken at pre-defined intervals, the frequency depending on OP, hazard location and assessed risk from system failure. Both high-speed (vehicle-based) and walking surveys using FID equipment should be used, as appropriate (see also Sub-Section 11.9).

11.7 MAINTENANCE (see also Section 9)

11.7.1 If necessary, gas conditioning should be used for an LPG system.

Note 1: The relatively higher CV and density, when compared to NG, mean velocities are low. This will limit the spread of the conditioning agent.

Note 2: Any LPG or LPG/air system containing lead-yarn or mechanical joints is unlikely to suffer joint leakage normally associated with a NG system, as the constituent components of commercial LPG contain natural joint swellants.

11.7.2 Joint and other repair methods or systems should be checked for compatibility with LPG and the use of anaerobic sealants should be avoided.

11.8 RECORDS (see also Section 10)

11.8.1 Construction, as-laid and maintenance records should be kept as recommended in Section 10.

Note: For MOP exceeding 500 mbar, local pressurised systems regulations may require additional test and traceability records.

11.9 GAS DETECTION

11.9.1 Only instruments calibrated for LPG shall be used to test for, monitor or detect LPG. Other instruments calibrated for methane or pentane may respond in the presence of LPG, but readings may be inaccurate and, therefore, should not be relied on to derive meaningful information.

Note: FID survey instruments that measure hydrocarbons by volume are compatible for use with LPG. However, as LPG vapour does not readily rise to the surface, surveys using FID equipment are of limited reliability.

11.9.2 When checking for the presence of LPG, samples shall be taken at low levels such as drains, basements, cellars and below suspended floors.

APPENDIX 1 : GLOSSARY, ACRONYMS, UNITS, SYMBOLS AND SUBSCRIPTS

GLOSSARY

All definitions except those detailed below 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 by downloading a printable version from IGEM's website.

Definitions of terms relevant to this Standard and not to be found in IGEM/G/4 Edition 2 are:

diethylene glycol (DEG)	A gas conditioning agent used to swell the yarn in lead/yarn joints.
monoethylene glycol (MEG)	A gas conditioning agent used to swell the yarn in lead/yarn joints.

ACRONYMS

AGI	above ground installation
CCTV	closed circuit television
CDM	Construction (Design and Management) Regulations
CIPS	close interval potential survey
COPA	Control of Pollution Act
COSHH	Control of Substances Hazardous to Health Regulations
CP	cathodic protection
CV	calorific value
DC	direct current
DEFRA	Department of Environment, Food and Rural Affairs
DEG	diethylene glycol
DP	design pressure
DTI	Department of Trade and Industry
EA	Environment Agency
EC	European Community
ECV	emergency control valve
EIA	environmental impact assessment
EPA	Environmental Protection Act
EPM	emergency procedures manual
ES	environmental statement
ESP	emergency service provider
FID	flame ionisation detection
GB	Great Britain
GIS	geographical information system
GS(M)R	Gas Safety (Management) Regulations
GT	gas transporter
HASAWA	Health and Safety Act at Work etc. Act
HAUC	Highways and Utilities Committee
HAZOP	hazard and operability
HDPE	high density polyethylene
HSE	Health and Safety Executive
IGE	Institution of Gas Engineers
IGEM	Institution of Gas Engineers and Managers
LDF	leak detection fluid
LFL	lower flammable limit
MAPD	major accident prevention document
MDPE	medium density polyethylene
MEG	monoethylene glycol
MIP	maximum incidental pressure

MIV	meter inlet valve
MRS	minimum required strength
MOP	maximum operating pressure
NDT	non-destructive testing
NJUG	National Joint Utilities Group
NRA	National Rivers Authority
NRSWA	New Roads and Street Works Act
OP	operating pressure
PC	personal computer
PCA	Pipeline Construction Authority
PE	polyethylene
PEX	cross linked polyethylene
PPE	personal protective equipment
PPG	pollution prevention guidelines
PPM	part per million
PRI	pressure regulating installation
PSR	Pipelines Safety Regulations
PSSR	Pressure Systems Safety Regulations
PVC	polyvinyl chloride
QC	quality control
SDR	standard dimension ratio
SEPA	Scottish Environmental Protection Agency
SMTS	specified minimum tensile strength
SMYS	specified minimum yield strength
STP	strength test pressure
TTP	tightness test pressure
UIP	utility infrastructure provider
UK	United Kingdom.

APPENDIX 2 : REFERENCES

This Standard is set out against a background of legislation in force in the GB at the time of publication. The devolution of power to the Scottish, Welsh and Northern Ireland Assemblies means that there may be variations to the legislation described below for each of them and consideration of their particular requirements must be made. Similar considerations are likely to apply in other countries and reference to the appropriate national legislation will be necessary. The following list is not exhaustive.

All relevant legislation must be complied with and relevant ACoPs, official Guidance Notes and referenced codes, standards, etc. shall be taken into account.

Where British Standards, etc. are quoted, equivalent national or international standards, etc. equally may be appropriate.

Care shall be taken to ensure that the latest editions of the relevant documents are used.

A2.1 **Acts**

- Ancient Monument and Archaeological Areas Act 1979
- Animal Health Act 2002
- Coastal Protection Act 1949
- Control of Pollution (Amendment) Act 1989
- Deer (Scotland) Act 1996
- Environment Act 1995
- Environmental Protection Act 1990
- Forestry Act 1991
- Gas Act 1986 and 1995
- Health and Safety at Work etc. Act 1974
- Local Government Act 2010
- Local Government (Scotland) Act 2003
- New Roads and Street Works Act 1991
- Noise and Statutory Nuisance Act 1993
- Oil and Pipelines Act 1985
- Protection of Badgers Act 1992
- Town and Country Planning Act 1990
- Transport Act 2000
- Water Resources Acts 1963 and 1991
- Wildlife and Countryside (Amendment) Act 1991
- Wild Mammals (Protection) Act 1996.

A2.1.1 **Regulations and Orders**

- Borehole Sites and Operations Regulations 1995
- Confined Spaces Regulations 1997
- Conservation (Natural Habitats etc) Regulations 1994
- Conservation (Natural Habitats, etc. Amendment Regulations 1997
- Construction (Design and Management) Regulations 2007
- Construction (Head Protection) Regulations 1989
- Construction (Health, Safety and Welfare) Regulations 1996
- Control of Noise at Work Regulations 2005
- Control of Substances Hazardous to Health Regulations 2004

- Control of Vibration at Work 2005
- Dangerous Substances and Explosive Atmospheres Regulations 2002
- Deregulation (Pipelines) Order 1999
- Electricity and Pipeline Works (Assessment of Environmental Effects) Regulations 1990
- Electricity at Work Regulations 1989
- Foot and Mouth Disease Order 2006
- Gas Safety (Management) Regulations 1996
- Health and Safety (Information for Employees) (Amendment) Regulations 2009
- Health and Safety (Safety Signs and Signals) Regulations 1996
- Hedgerows Regulations 1997
- Ionising Radiation Regulations 1999
- Lifting Operations and Lifting Equipment Regulations 1998
- Management of Health and Safety at Work Regulations (Amendment) 2006
- Manual Handling Operations Regulations 1992
- Personal Protective Equipment at Work Regulations 1992
- Pipelines Safety (Amendment) Regulations 2003
- Pressure Systems Safety Regulations 2000
- Provision and Use of Work Equipment Regulations 1998
- Public Gas Transporter Pipeline Works (Environmental Impact Assessment) Regulations 1999
- Reporting of Injuries, Disease and Dangerous Occurrences Regulations (RIDDOR) 2013
- Town and Country Planning (Environmental Impact Assessment) Regulations 2011
- Town and Country Planning Act (General Permitted Development) Order 1995
- Working at Height (Amendment) Regulations 2007.

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 and wild fauna and flora.

A2.3 **HSE ACOPs and GUIDANCE**

- HSE Reducing Risks, Protecting People
- HSE Tolerability of risk from nuclear power stations
- EH40/2005 Workplace exposure limits
- GS4 Safety requirements for pressure testing
- GS6/2013 Avoiding danger from overhead power lines
- HSG47/2014 Avoiding danger from underground services
- HSG48/2012 Reducing error and influencing behaviour
- HSE Risk Criteria for Land use Planning in the vicinity of Major Hazard Installations 1989
- INDG 401 Work at Height Regulations.

A2.4 **INSTITUTION OF GAS ENGINEERS AND MANAGERS**

- IGEM/TD/1 Edition 5 — Steel pipelines for high pressure gas transmission
- IGEM/TD/1 Edition 5 Supplement 1 — Handling, transport and storage of steel pipe, bends and fittings
- IGEM/TD/2 — Application of pipeline risk assessment to proposed developments in the vicinity of high pressure Natural Gas pipelines
- IGE/TD/4 Edition 4 — PE and steel gas services and service pipework
- IGE/TD/12 Edition 2 — Pipework stress analysis for gas industry plant
- IGEM/TD/13 Edition 2 — Pressure regulating installations for transmission and distribution systems
- IGE/SR/18 Edition 2 — Safe working practices in the vicinity of gas pipelines and associated installations
- IGE/SR/22 — Purging of Natural Gas
- IGE/SR/23 — Venting of Natural Gas
- IGE/SR/24 — Risk assessment techniques
- IGEM/SR/25 Edition 2 — Hazardous area classification of Natural Gas installations
- IGEM/SR/28 Edition 2 — Trenchless Techniques
- IGEM/SR/29 — Dealing with gas escapes
- IGE/GL/1 — Planning of gas distribution systems operating at pressures not exceeding 7 bar
- IGE/GL/2 — Planning of transmission and storage systems operating at pressures exceeding 7 bar
- IGE/GL/5 Edition 2 — Plant modification procedures
- IGEM/GL/6 Edition 2 — Non-routine operations
- IGE/GL/8 Edition 2 — Reporting and investigation of gas related incidents
- IGEM/UP/2 Edition 2 — Installation pipework on industrial and commercial premises
- IGE/UP/3 Edition 2 — Gas fuelled spark ignition and dual fuel engines
- IGEM/UP/6 Edition 2 — Applications of positive displacement compressors to Natural Gas fuel systems
- IGE/UP/9 Edition 2 — Gas turbines
- IGEM/G/1 Edition 2 — Definitions for the end of a network, a meter installation and installation pipework
- IGEM/G/6 — Gas supplies to mobile dwellings
- IGEM/G/5 Edition 2 — Gas in multi-occupancy buildings
- IGEM/G/8 — Handling, transport and storage of PE pipe and fittings

A2.5 **BRITISH STANDARDS (abbreviated titles)**

- BS 1179-6 Glossary of terms used in the gas industry
- BS 2633 Class 1 arc welding of ferritic steel pipework
- BS 4250 Commercial butane and propane
- BS 5228 Noise and vibration control
- BS 5493 Protective coating of iron structures against corrosion
- BS 7361 Cathodic protection
- BS EN 837-1 Pressure gauges. Bourdon tube pressure gauges
- BS EN 1560-3 Circular flanges for pipes, valves and fittings
- BS EN 10253-2 Steel butt-welding pipe fittings
- BS EN 12732 Welding steel pipework
- BS EN 12007 Gas supply systems. MOP ≤ 16 bar
- BS EN IS0 3183 Steel pipe for pipelines
- BS EN ISO 9000 Quality management systems
- BS EN ISO 9001 Quality systems.
- BS EN ISO 9080 Plastics piping and ducting systems

A2.6 **OTHER STANDARDS AND PUBLICATIONS (abbreviated titles)**

- API 5L Linepipe
- ASME B16.9 Factory made wrought steel butt/welding fittings
- ANSI B16.28 Wrought steel butt/welding elbows and returns
- ASTM A105 Carbon steel forgings for piping applications
- ASTM A234 Piping fittings of wrought carbon steel and alloy steel. High and moderate temperature
- ASTM A420 Piping fittings of wrought carbon steel and alloy steel. High and low temperature
- ASTM A 860 Wrought high strength, low alloy steel butt welding fittings
- British Waterways Code of Practice
- HAUC. Reinstatement of openings in the highway
- HSE - IND(G) 163L - 5 steps to risk assessment ISBN 0 7176 0904 9
- LPGA CoP 17. Purging LPG
- LPGA CoP 22. LPG piping systems
- MSS SP-75. High test wrought butt welding fittings.
- NJUG Volume 4. Work in the vicinity of trees.
- Oil Industry Advisory Committee - Guidance on permit to work systems in the petroleum industry. HSE Books 1997 ISBN 0 7176 1281 3
- Oil Industry Advisory Committee - Guidance on the safe isolation of plant and equipment. HSE Books 1997 ISBN 0 7176 0871 9
- Successful health and safety management HSG65 HSE Books 1997 ISBN 0 7176.

A2.7 **GAS INDUSTRY STANDARDS**

- GIS/ECE1 Specification for electrofusion control boxes
- GIS/PL2-2 Pipes for use at pressures up to 5.5 bar
- GIS/PL2-3 Butt fusion machines and ancillary equipment
- GIS/PL2-4 Fusion fittings with integral heating element(s)

- GIS/PL2-6 Spigot end fittings for electrofusion and/or butt fusion purposes
- GIS/PL2-8 Pipes for use at pressured up to 7 bar
- GIS/PL3 Technical specification for self anchoring mechanical fittings for PE pipe for Natural Gas and suitable manufactured gas

APPENDIX 3 : PRESSURE TESTING

A3.1 INTRODUCTION

A3.1.1 This appendix covers the derivation of the equations used in determining the allowable leakage rates (and hence pressure change) during pneumatic testing. It also provides information on corrections to be made for temperature changes during testing. Appendix 4 provides maximum pressure criteria for the different tests and Sub-section 7.6 provides information on temperatures changes. This Appendix is included for background information only.

A3.2 DERIVATION

A3.2.1 Differentiating the equation of state for an ideal gas:

$pV = mRT$, in the general case, gives:

$$dp / dt = \frac{RTdm / dt}{V} + \frac{RmdT / dt}{V} - \frac{pdv / dt}{V}$$

where

p = gas pressure (bar absolute)
V = internal volume of the pipe (m^3)
m = mass of gas enclosed in the internal volume of the pipe (m^3)
R = specific gas constant, assumed constant
T = gas temperature (K absolute)
t = time (hour)
d = change of pressure, time, mass and volume.

A3.2.2 The pressure change with time depends upon any leak (dm/dt), temperature change with time (dT/dt) and volume change with time (dv/dt). Therefore, complete analysis of the pressure decay process requires a model for the leak flow path, measured temperature change profiles during the test, and measurements of, or a model for the creep (volume change) process when testing plastic pipe. Use of such techniques can significantly shorten the duration, and improve the quality, of the test, compared with the basic approach described below.

The following simple analysis ignores temperature and volume change.

The governing equation reduces to:

$$dp / dt = \frac{RTdm / dt}{V} \text{, noting that:}$$

$$dm / dt = -\rho\, q = -\rho_o\, Q = -\frac{p_o}{RT_o} Q$$

where

ρ = gas density
q = leakage rate ($m^3\ h^{-1}$), which varies with pressure, depending on the leak path, but is specified at MOP
Q = leakage rate ($m^3\ h^{-1}$)
$_o$ = value at the start of the test (suffix).

A3.3 PASS CRITERION AND THE LEAK PATH MODEL

In general, the installation is tested at a pressure higher than MOP. A pass criterion that any leakage of gas be less than Q at MOP is specified, typically defined at metric standard conditions. A standard figure used in the UK is 0.003 $m^3\,h^{-1}$ std (0.1 $ft^3\,h^{-1}$ std). Any smaller leak is not considered to be hazardous.

Convert the pass leak rate to that which will occur through the same leakage path at the test conditions. Assuming a laminar leak path, the revised flow rate will depend upon the absolute and gauge pressures, and the dynamic viscosity differences between air and gas. It can be shown that the allowable air leak rate is given by:

$$Q_{air} = Q \frac{\mu_{gas}}{\mu_{air}} \frac{p_g}{MOP_g} \frac{p_a}{MOP_a}$$

where
Q = leakage rate ($m^3\ h^{-1}$)
$_{air}$ = of air
μ = dynamic viscosity
$_{gas}$ = of the gas
p = gas pressure (bar)
MOP = maximum operating pressure (bar)
$_g$ = gauge reading (suffix)
$_a$ = absolute (suffix).

Note: Subscripts a and g refers to absolute and gauge pressure respectively and, for NG, the viscosity ratio μ_{gas}/μ_{air} can be taken as 1.1/1.8.

Rate of pressure drop

The preceding relationship reduces to:

$$\frac{dp}{dt} = -\frac{Q}{V} p_o \frac{T}{T_o}$$

where
dp/dt = change of pressure over time
Q = leakage rate ($m^3\ h^{-1}$)
V = gas volume (m^3)
P = gas pressure (bar)
T = gas temperature (K)
$_o$ = value at the start of the test (suffix).

Assuming $T=T_o$, and taking p_o as 1 bar absolute, with Q specified in $m^3\ h^{-1}$ (std) and V in m^3, the allowable pressure drop rate is given by:

$$\frac{dp}{dt} = \frac{Q}{V} \text{ bar per hour.}$$

This equation can be used to estimate the allowable pressure drop rates for small pressure drops only. As the pressure drops from the test pressure due to a leak, so does the leakage flow, Q, and the pressure decay is actually exponential. However, for small pressure drops (compared to the test pressure) the initial linear drop rate above can be used. For larger pressure drops, an analysis which incorporates the change in Q with pressure is required.

Temperature Effects

The relationship between temperature change of the air in the pipe and pressure change is, approximately:

Δp per °C = 3.333 (p+1) mbar where p is the gas pressure (bar gauge).

At 0.35 bar, a 1°C change will result in a pressure change of around 4.5 mbar, at 3 bar it is around 13.3 mbar and at 7 bar it is around 26.7 mbar.

APPENDIX 4 : TEST PRESSURES AND CREEP EFFECTS

A4.1 INTRODUCTION

This Appendix includes information to enable the calculation of test duration, conditioning period and allowable pressure drops for Strength, Tightness and combined testing of steel and PE pipelines (see A4.2, A4.3 and A4.4). The Appendix also provides guidance on allowances to be made for creep for PE pipelines.

A4.2 STRENGTH TESTING (HYDROSTATIC)

Clause 7.3.2 requires STP to be greater than MIP and at least 1.5 times MOP. Table 12 provides typical values.

MOP	TEST PRESSURE	TEST PERIOD	MAXIMUM PRESSURE LOSS
≤ 2 bar	3 bar	A minimum of 2 hours	5% of test pressure per hour
≤ 4 bar	6 bar		
≤ 5.5 bar	8.25 bar		
≤ 7 bar	10.5 bar		

Note 1: Suitable test instruments are electronic testers accurate to less than 3 mbar.

Note 2: For PE systems, creep will cause pressure drop.

Note 3: The test pressure is to be maintained at the highest point (lowest pressure) of the system under test.

TABLE 12 - HYDROSTATIC TESTS ON PE AND STEEL MAINS

A4.3 TIGHTNESS TESTING (PNEUMATIC)

Clause 7.4.2.1 requires TTP to be a value between OP and MIP. Table 13 provides typical test pressures and associated calculations for the test period. The calculated test period from Tables 13, 14 or 15 needs to be rounded up to the nearest minute. Where the calculated test period is less than 15 minutes (0.25 hours), a 15 minute test with no pressure loss allowed has to be applied.

MOP	TYPE	TEST PRESSURE	TEST PERIOD (See Notes 2, 4 and 5)	MAXIMUM PRESSURE LOSS
≤ 75 mbar	See Table 15			
≤ 2 bar	Tightness test	3 bar	t = 0.88 x V	3 mbar
≤ 4 bar	Tightness test	6 bar	t = 0.84 x V	3 mbar
≤ 5.5 bar	Tightness test	7 bar	t = 1.12 x V	3 mbar
≤ 7 bar	Tightness test	7 bar	t = 1.75 x V	3 mbar

Note 1: Suitable test instruments are electronic testers accurate to less than 3 mbar.

Note 2: Where a formula is given, e.g. t = 0.88 x V, the required test period t is in hours, and V (the pipe internal volume) is required in m^3. To calculate V, use $V = \pi d^2 L/4$, d is the internal diameter (m); L is the test length (m). For PE note that SDR = outer diameter/wall thickness. Cross sectional areas of different diameters of PE and Steel pipelines are given in Tables 15 and 16 (greyed out values).

Note 3: For all PE mains with MOP equal to or greater than 2 bar, there is an additional creep pressure drop allowance during the test period. This depends on the conditioning period before the test period, the pipe material and the test pressures.

Note 4: To calculate the test duration for PE and Steel pipes an alternative method is to multiply the Z-Factors for the appropriate pressure tier given in Tables 15 and/or 16 below by the length of main (L).

Note 5: Where the test period is calculated to be less than 15 minutes, a 15 minute test with no pressure loss allowed has to be applied.

TABLE 13 - TIGHTNESS TESTING (PNEUMATIC) ON PE AND STEEL MAINS

A4.4 COMBINED (STRENGTH AND TIGHTNESS) TESTING (PNEUMATIC)

A combined strength and tightness test can be carried out for pipelines up to 2 bar MOP. Table 14 provides typical test pressures and associated calculations for the test period. For pipelines above this pressure, separate strength and tightness tests have to be carried out. See clause 7.4.2 where the strength and tightness test are combined.

MOP	TYPE	TEST PRESSURE	TEST PERIOD (See Notes 2, 4 and 5)	MAXIMUM PRESSURE LOSS
≤ 75 mbar	Combined	350 mbar	t = 0.30 x V	3 mbar
≤ 2 bar	Combined	3 bar	t = 0.88 x V	3 mbar
≤ 4 bar	See Table 13			
≤ 5.5 bar				
≤ 7 bar				

Note 1: Suitable test instruments are electronic testers accurate to less than 3 mbar.

Note 2: Where a formula is given, e.g. t = 0.88 x V, the required test period t is in hours, and V (the pipe internal volume) is required in m^3. To calculate V, use $V = \pi d^2 L/4$, d is the internal diameter (m); L is the test length (m). For PE note that SDR = outer diameter/wall thickness. Cross sectional areas of different diameters of PE and Steel pipelines are given in Tables 15 and 16 (greyed out values).

Note 3: For all PE mains with MOP equal to or greater than 2 bar, there is an additional creep pressure drop allowance during the test period. This depends on the conditioning period before the test period, the pipe material and the test pressures.

Note 4: To calculate the test duration for PE and Steel pipes an alternative method is to multiply the Z-Factors for the appropriate pressure tier given in Tables 15 and/or 16 below by the length of main (L).

Note 5: Where the test period is calculated to be less than 15 minutes, a 15 minute test with no pressure loss allowed has to be applied.

TABLE 14 - COMBINED (STRENGTH AND TIGHTNESS) TESTING (PNEUMATIC) ON PE AND STEEL MAINS

MAIN (MOP)	➤ DIAMETER (mm)																					
	55	63	75	90	110	125	140	160	180	200	213	250	268	280	315	355	400	440	450	469	500	560	630
Sec. A	**Cross Sectional Area of PE Pipe (m^2)**																						
SDR11	0.0016	0.0021	0.0030	0.0043	0.0064	0.0082	0.0103	-	0.0170	0.0210	-	0.0329	-	0.0412	0.0522	0.0663	0.0841	-	0.1065	-	0.1314	-	0.2087
SDR13.6	-	0.0023	0.0032	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SDR17.6	0.0018	0.0024	0.0034	0.0050	0.0074	0.0096	0.0120	-	0.0200	0.0247	-	0.0386	-	0.0484	0.0612	0.0778	0.0987	-	0.1250	-	0.1543	-	0.2449
SDR21	-	-	-	-	-	-	-	-	-	-	-	0.0402	0.0461	0.0505	0.0638	0.0810	0.1029	-	0.1302	0.1414	0.1607	-	0.2552
SDR26	-	-	-	-	-	-	-	0.0171	-	-	0.0304	0.0418	0.0481	0.0525	0.0664	0.0843	0.1070	0.1295	0.1355	-	0.1673	0.2098	0.2657
Sec. B	**Z-Factor to Use to Calculate test period Pipelines with MOP ≤ 75 mbar (0.3 x Cross Sectional Area)**																						
SDR11	0.0005	0.0006	0.0009	0.0013	0.0019	0.0025	0.0031	-	0.0051	0.0063	-	0.0099	-	0.0124	0.0157	0.0199	0.0252	-	0.0319	-	0.0394	-	0.0626
SDR13.6	-	0.0006	0.0009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SDR17.6	0.0006	0.0007	0.0010	0.0015	0.0022	0.0029	0.0036	-	0.0060	0.0074	-	0.0116	-	0.0145	0.0184	0.0233	0.0296	-	0.0375	-	0.0463	-	0.0735
SDR21	-	-	-	-	-	-	-	-	-	-	-	0.0121	0.0139	0.0151	0.0191	0.0243	0.0309	-	0.0391	0.0424	0.0482	-	0.0766
SDR26	-	-	-	-	-	-	-	0.0051	-	-	0.0091	0.0125	0.0144	0.0157	0.0199	0.0253	0.0321	0.0389	0.0407	-	0.0502	0.0630	0.0797
Sec. C	**Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 2 bar (0.88 x Cross Sectional Area)**																						
SDR11	0.0014	0.0018	0.0026	0.0037	0.0056	0.0072	0.0091	0.0118	0.0150	0.0185	0.0210	0.0289	0.0332	0.0363	0.0459	0.0583	0.0740	-	0.0937	0.1018	0.1157	-	0.1836
SDR13.6	-	0.0020	0.0028	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SDR17.6	0.0016	0.0022	0.0031	0.0044	0.0066	0.0085	0.0106	0.0139	0.0176	0.0217	0.0246	0.0339	0.0390	0.0426	0.0539	0.0684	0.0869	-	0.1100	0.1194	0.1357	-	0.2155
SDR21	0.0017	0.0022	0.0032	0.0046	0.0068	0.0088	0.0111	0.0145	0.0183	0.0226	0.0257	0.0354	0.0406	0.0444	0.0561	0.0713	0.0905	-	0.1146	0.1244	0.1414	-	0.2246
SDR26	0.0018	0.0023	0.0033	0.0048	0.0071	0.0092	0.0115	0.0151	0.0191	0.0236	0.0267	0.0368	0.0423	0.0462	0.0584	0.0742	0.0942	0.1140	0.1193	0.1295	0.1472	0.1847	0.2337
Sec. D	**Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 4 bar (0.84 x Cross Sectional Area)**																						
SDR11	0.0013	0.0018	0.0025	0.0036	0.0053	0.0069	0.0087	0.0113	0.0143	0.0177	0.0200	0.0276	0.0317	0.0346	0.0438	0.0557	0.0707	-	0.0894	0.0971	0.1104	-	0.1753
Sec. E	**Z-Factor to Use to Calculate test period for pipelines with MOP ≤ 5.5 bar (1.12 x Cross Sectional Area)**																						
SDR11	0.0018	0.0023	0.0033	0.0048	0.0071	0.0092	0.0115	0.0151	0.0191	0.0236	0.0267	0.0368	0.0423	0.0462	0.0584	0.0742	0.0942	-	0.1192	0.1295	0.1472	-	0.2337
Sec. F	**Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 7 bar (1.75 x Cross Sectional Area)**																						
SDR11	0.0028	0.0037	0.0052	0.0075	0.0111	0.0144	0.0180	0.0236	0.0298	0.0368	0.0417	0.0575	0.0661	0.0721	0.0913	0.1160	0.1472	-	0.1863	0.2024	0.2300	-	0.3652

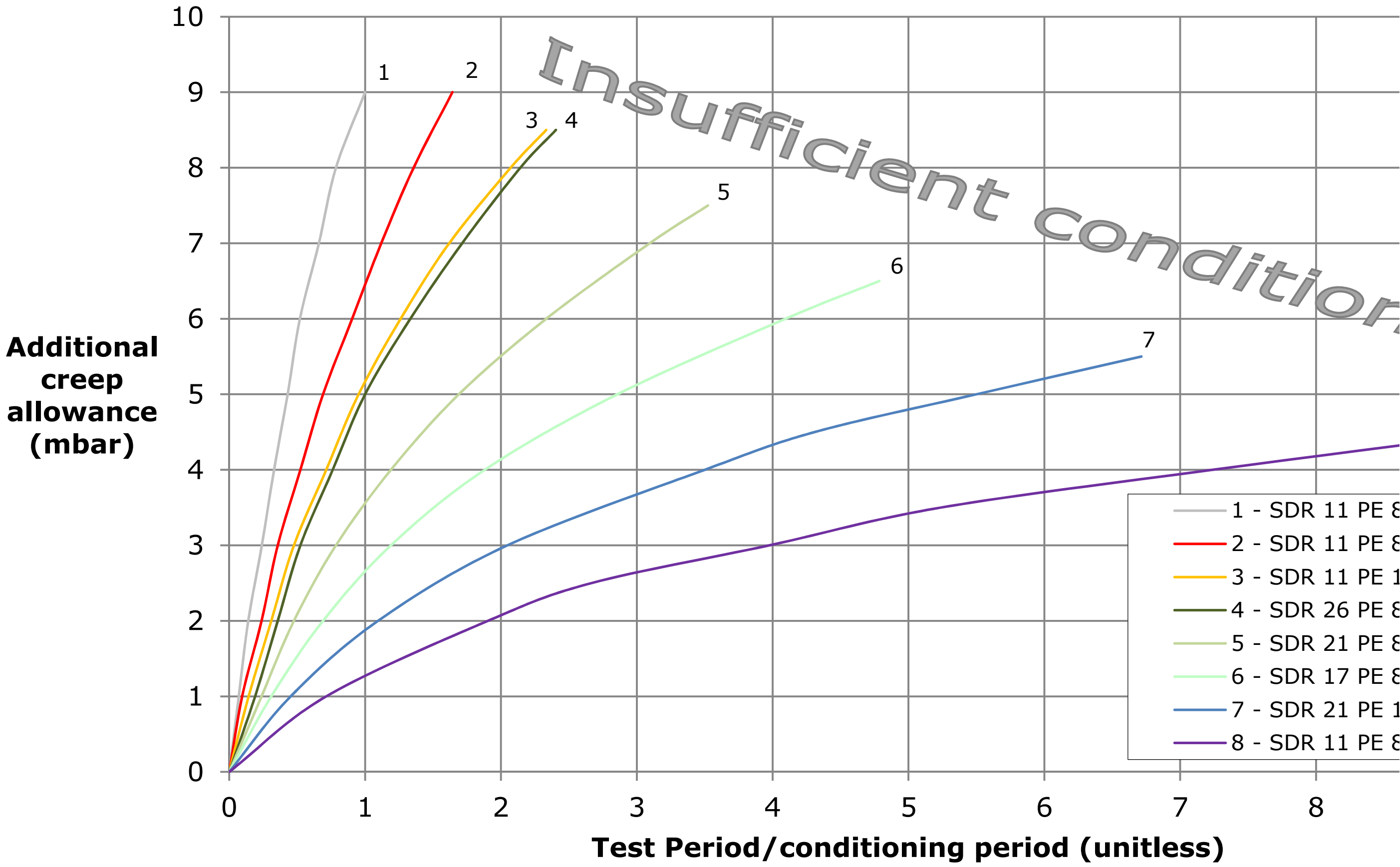
➤ TABLE 15 - CROSS SECTIONAL AREAS AND Z-FACTORS FOR PE PIPE ➤

	DIAMETER Diameter Nominal DN (mm) Nominal Pipe size NPS (in)																
	25	32	40	50	80	100	150	200	250	300	400	450	600	750	900	1050	1200
	1	1 1/4	1 1/2	2	3	4	6	8	10	12	16	18	24	30	36	42	48
Cross Sectional Area (m^2)	0.0005	0.0009	0.0013	0.0021	0.0049	0.0084	0.0195	0.0335	0.0533	0.0761	0.1197	0.1528	0.2772	0.4336	0.6225	0.8522	1.1131
Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 75 mbar (0.3 x Cross Sectional Area)	0.0002	0.0003	0.0004	0.0007	0.0016	0.0028	0.0064	0.0111	0.0176	0.0251	0.0395	0.0504	0.0915	0.1431	0.2054	0.2812	0.3673
Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 2 bar (0.88 x Cross Sectional Area)	0.0005	0.0008	0.0011	0.0018	0.0043	0.0074	0.0171	0.0295	0.0469	0.0670	0.1054	0.1344	0.2439	0.3816	0.5478	0.7499	0.9795
Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 4 bar (0.84 x Cross Sectional Area)	0.0004	0.0008	0.0011	0.0017	0.0041	0.0071	0.0164	0.0281	0.0447	0.0639	0.1006	0.1283	0.2328	0.3642	0.5229	0.7159	0.9350
Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 5.5 bar (1.12 x Cross Sectional Area)	0.0006	0.0010	0.0014	0.0023	0.0055	0.0094	0.0218	0.0375	0.0597	0.0853	0.1341	0.1711	0.3104	0.4856	0.6972	0.9545	1.2467
Z-Factor to Use to Calculate test period for Pipelines with MOP ≤ 7 bar (1.75 x Cross Sectional Area)	0.0009	0.0016	0.0022	0.0036	0.0086	0.0147	0.0341	0.0586	0.0932	0.1332	0.2095	0.2673	0.4850	0.7588	1.0893	1.4914	1.9479

TABLE 16 - CROSS SECTIONAL AREAS AND Z-FACTORS FOR STEEL PIPE

A4.5 CREEP

Pressure drop due to creep depends upon the pipe material, ambient temperature, the pipe SDR, previous stress history and degree of restraint offered from the backfill (or parent pipe for inserted PE). It does not vary with pipe volume. Figure 9 gives an indication only of the pressure drops due to creep for unrestrained PE pipe.



Note 1: The test pressure regime for each case is indicated in the legend. Example: Case 2 is SDR 11 PE 80 test 6/4 bar, with a test pressure of 6 bar, and an MOP of 4 bar.

Note 2: The conditioning period is the time from the start of pressurisation to the first test reading at the start of the test period. All exposed mechanical joints have to be tested for leakage upon initial pressurisation with an approved leakage detection fluid. Following the period of temperature stabilisation (indicated by a stable pressure reading) take an initial pressure reading. For PE mains operating at MOP 2 bar to 7 bar (where the effect of creep is being considered) the first test reading is taken at the end of the conditioning period. A further test pressure reading has to also be taken at the end of the test period. Where a long duration pressure test period (i.e. over 24 hours) is to be undertaken intermediate test pressure readings may be necessary so that the test may be assessed and aborted at an early stage if there is an indication that the test will ultimately fail.

Note 3: The minimum conditioning period (for the maximum additional creep allowance) can be calculated by taking the extremity of the appropriate curve. Example: SDR 21 PE 100 (Multi-layer pipe) 3/2 bar has a maximum additional creep allowance of 5.5 mbar when the conditioning period = test period/6.8. For a test period of 24 hours for this case the minimum conditioning period is 3.5 hours, i.e. 24/6.8.

Note 4: The additional creep pressure drop allowance for specific cases can be derived by calculating the ratio of the test period (hours)/conditioning period (hours), and then reading off the allowance from the appropriate curve.

Note 5: The additional allowance reduces to zero as the conditioning period is increased.

Note 6: Temperature stabilisation after pressurisation can take up to 2 hours for PE/Steel. Before the start of the test period the temperature of the air in the main has to be allowed to stabilise and this is indicated by a stable pressure reading.

Note 7: For SDR 13.5 use SDR 11 PE 80 3/2 bar.

Note 8: For systems having more than one pipe material/diameter the following is to be applied:

Where a 75 mbar to 7bar PE main contains significant amounts of pipe of different sizes and materials (>10%), including steel, the test period is established by the addition of the test periods appropriate to the length of each size/material using Tables 14 and 15 However, creep allowances can only be given for the volume of each contributing PE *section. The notional creep allowance for each section can be calculated from the total test period and the conditioning period, using Figure 9. The notional allowance calculated for each section can then be apportioned according to that section's contribution to the total volume, and each section's apportioned allowance then added together to give the total creep allowance for the test period.*

FIGURE 9 - ADDITIONAL CREEP PRESSURE DROP ALLOWANCES FOR PE MAINS UP TO 7 BAR

A4.6 **WORKED EXAMPLES**

A4.6.1 **PE Distribution Main, MOP ≤ 75 mbar, Single Pipe Diameter and SDR**

A4.6.1.1 *Installation details*

- MOP ≤ 75 mbar
- 92 m length
- 63 mm diameter
- SDR11
- PE distribution main
- Calibrated electronic pressure gauge being used.

A4.6.1.2 *Test type and test pressure*

As MOP ≤ 75 mbar, a combined strength and tightness will be carried out at 350 mbar (see Table 14).

A4.6.1.3 *Test period*

Using **Table 15 Sec. B** the Z-factor for a 63 mm, SDR11, PE distribution main MOP ≤ 75 mbar is **0.0006**.

To calculate the test period, multiply the Z-factor by the length i.e. 92 m:

0.0006 x 92 = 0.0552 hours

To convert the decimal points to minutes multiply the decimals by 60 and round up:

0.0552 x 60 = 3.312 = 4 mins

The total test period is therefore **4 mins.**

A4.6.1.4 *Maximum allowed pressure loss*

Where the calculated time is less than 15 minutes (0.25 hours), a 15 minute test with no pressure loss allowed has to be applied (see A4.3).

A4.6.1.5 *Pressure temperature stabilisation*

Before the start of the test period, the temperature of the air in the main needs to be allowed to stabilise before the test period is commenced. For PE and Steel distribution mains with a MOP ≤ 75 mbar, this will normally occur within 2 hours of pressurisation and will be indicated by a stable pressure reading.

A4.6.2 **Two PE Distribution Main of different diameters and SDRs**

A4.6.2.1 *Installation details*

- MOP ≤ 75 mbar
- 74 m length of 315 mm diameter SDR21 PE distribution main with a branch connection offtake
- The offtake is a 112 m length of 180 mm SDR17.6 PE distribution main
- Calibrated electronic pressure gauge being used.

A4.6.2.2 *Test type and test pressure*

As MOP ≤ 75 mbar, a combined strength and tightness will be carried out at 350 mbar (see Table 14).

A4.6.2.3 *Test duration*

For two PE Distribution Mains of different diameters and SDRs, the test period is calculated for each section and are then added together to give the total test period.

74 m x 315 mm SDR21	**112 m x 180 mm SDR17.6**
Using **Table 15 Sec. B** the Z-factor for a 315 mm, SDR21, PE distribution main MOP ≤ 75 mbar is **0.0191**. To calculate the test period, multiply the Z-factor by the length i.e. 74 m: **0.0191 x 74 = 1.4134 hours** To convert the decimal points to minutes multiply the decimals by 60 and round up: **0.4134 x 60 = 24.804 = 25 mins** For this section, the test period is therefore: **1 hour and 25 mins.**	Using **Table 15 Sec. B** the Z-factor for a 180 mm, SDR17.6, PE distribution main MOP ≤ 75 mbar is **0.0059**. To calculate the test period, multiply the Z-factor by the length i.e. 112 m: **0.0059 x 112 = 0.6608 hours** To convert the decimal points to minutes multiply the decimals by 60 and round up: **0.6608 x 60 = 39.648 = 40 mins** For this section, the test period is therefore: **40 mins.**

The total test period is therefore 2 hours and 5 mins.

A4.6.2.4 *Maximum allowed pressure loss*

Maximum permitted pressure loss allowed (see Table 14) for both pipes remains at 3 mbar.

A4.6.2.5 *Pressure temperature stabilisation*

Before the start of the test period, the temperature of the air in the main has to be allowed to stabilise before the test period is commenced. For PE and Steel distribution mains with a MOP ≤ 75 mbar, this will normally occur within 2 hours of pressurisation and will be indicated by a stable pressure reading.

A4.6.3 **PE Distribution Main, MOP ≤ 2 bar, Single Pipe Diameter and SDR**

A4.6.3.1 *Installation details*

- MOP ≤ 2 bar
- 97 m length
- 90 mm diameter
- SDR17.6
- PE distribution main
- Calibrated electronic pressure gauge being used.

A4.6..3.2 *Test type and test pressure*

As MOP ≤ 2 bar, a combined strength and tightness will be carried out at 3 bar (see Table 14).

A4.6.3.3 *Test period*

Using **Table 15 Sec. C** the Z-factor for a 90 mm, SDR17.6, PE distribution main MOP ≤ 2 bar is **0.0044**.

To calculate the test period, multiply the Z-factor by the length i.e. 97 m:

0.0044 x 97 = 0.4268 hours

To convert the decimal points to minutes multiply the decimals by 60 and round up:

0.4268 x 60 = 25.608 = 26 mins

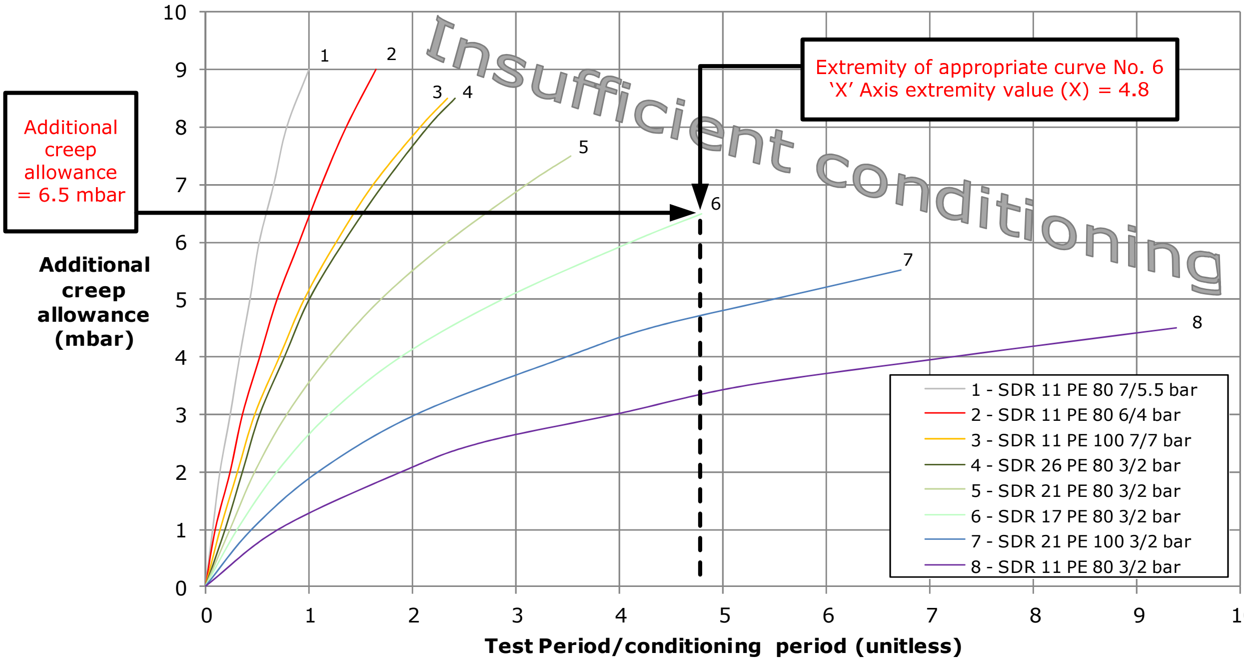
The total test period is therefore **26 mins.**

A4.6.3.4 *Pressure* t*emperature stabilisation*

Temperature stabilisation after pressurisation can take up to 2 hours. Therefore before the start of the test period, the temperature of the air in the main has to be allowed to stabilise before the test period is commenced (see Note 6 to Figure 9).

A4.6.3.5 *Conditioning Period*

Using Figure 9, (curve 6, SDR17.6 PE80 MP 3/2 bar) draw a vertical line from the end of **curve 6** until it reaches the bottom axis which reads **4.8**, see below.



This shows that the test period divided by the conditioning period = 4.8.

As the test period is known (in decimals = **0.4268**) transpose the equation as follows to determine the Conditioning Time:

$$\text{Conditioning period} = \frac{\text{Test period}}{4.8} = \frac{0.4268}{4.8} = 0.0889 \text{ hours}$$

To convert the decimal points to minutes multiply the decimals by 60 and round down:

0.0889 x 60 = 5.394 = 5 mins

Calculated conditioning period is therefore **5 mins (see Note below).**

*Note: Revision to Conditioning Period necessary due to the requirement for the Temperature Stabilisation Period to be taken into account. However, as you need to take account of the Temperature Stabilisation Period as well which can be up 2 hours duration you need to extend the Conditioning Period to that of the Temperature Stabilisation Period - up to 2 hours. (It is acceptable to run the Temperature Stabilisation Period and Conditioning Period at the same time.) This means that for this example the Condition Period is now **2 hours**.*

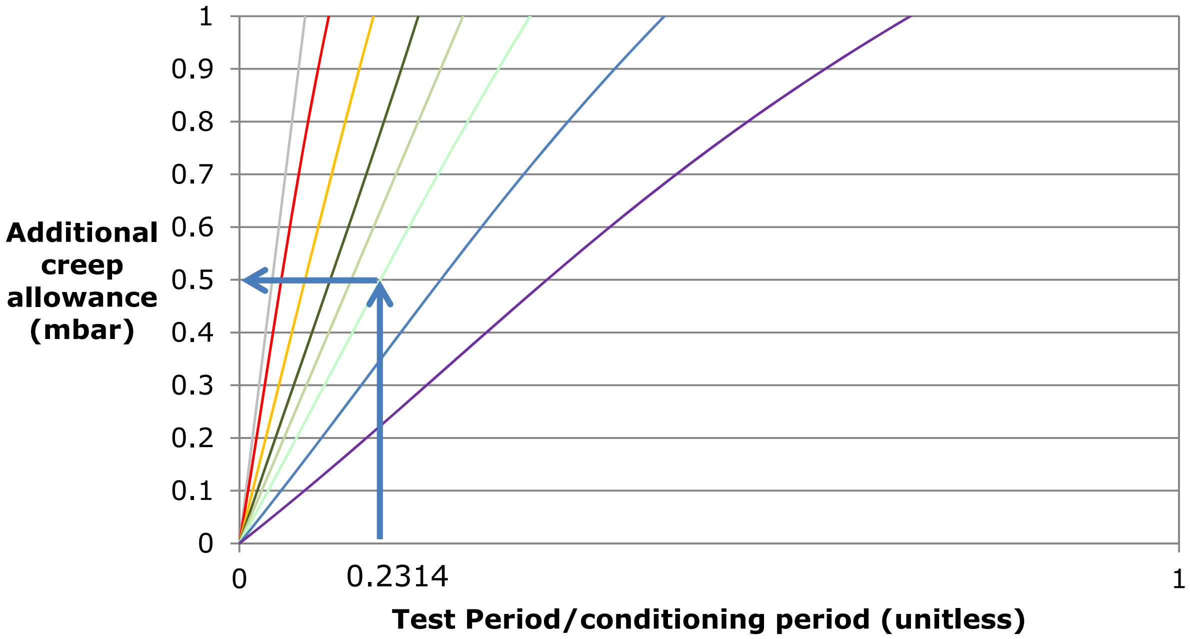
A4.6.1.4 *Maximum allowed pressure loss*

As the conditioning period has been extended from 5 minutes to 2 hours this will have an impact on the Additional Creep Allowance (which would have been 6.5 mbar - determined by using Figure 9 and drawing a horizontal line from the top of Curve 6 leftwards to the vertical axis)

Therefore the revised figure for the Test Period divided by the Conditioning Period equates to:

$$\frac{\text{Test period}}{2.0} = \frac{0.4268}{2.0} = 0.2134$$

Reverting back to Figure 9 locate 0.2134 along the bottom axis and draw a vertical line upwards until it crosses Curve 6, (exploded view of Figure 9 reproduced below). From that point draw a horizontal line leftwards to the vertical axis (additional creep allowance in mbar) and which confirms what the additional creep allowance for the PE pipe will be.



This shows that the additional creep allowance is **0.5 mbar**.

Add this **0.5 mbar** to the **3 mbar** maximum permitted pressure loss shown in Table 13 which gives a total pressure loss for this 97m x 90mm SDR17.6 PE80 Medium Pressure main of **3.5 mbar** based on a Test Period of 0.4268 hours rounded up to 26 minutes and a Conditioning Period of 2 hours (due to the requirement for Temperature Stabilisation of the air in the main).

APPENDIX 5 : TYPICAL PRESSURE TEST CERTIFICATES

SHEET 1 of 1

HYDROSTATIC PRESSURE TEST CERTIFICATE

Project Reference Number	Project Title	Hydrostatic Test Certificate Number

GENERAL DETAILS	
Drawing No.:	
Start location:	
End location:	
Pipework details (SMYS-Diameter-thickness-length):	
Design pressure:	bar
Test pressure:	bar
Maximum operating pressure (MOP):	bar
Test specification:	
Test period:	hours

TEST INFORMATION	TEST 'ON'	INTERMEDIATE READINGS						TEST 'OFF'
Date/time								
Recorded pressure (bar)								
Ground/skin temperature								

Gauge type:	
Serial number:	
Calibration date:	
Calibration expiry date	
Permissible loss:	mbar
Actual variance	mbar

REMARKS

TEST RESULT (Circle as appropriate)

Test accepted by:	
Designation:	
Date:	

PASS	FAIL

Test accepted by:	
Designation:	
Date:	

SHEET 1 of 2

PNEUMATIC PRESSURE TEST CERTIFICATE

Project Reference Number	Project Title	Pneumatic Test Certificate Number

GENERAL DETAILS

Test Procedure/Specification:

Test location (Node numbers or Plot/Postal addresses):

Maximum operating pressure (MOP):	bar
Tightness test pressure (TTP):	bar
Hydrostatic pressure certificate No. (if not a combined test):	

MINIMUM TEST PERIOD (FOR ALL MAINS UNDER TEST)

Minimum Test Period (t) from Table 13 or 14.

Note: Where there are mains of more than one diameter under test t is established by the addition of all individual values calculated using the above formula. These should be listed in the table below.

DIAMETER (mm)	SDR	L (m)	CROSS SECTIONAL AREA (Table 15 or 16)	FACTOR (F) (0.3/0.88/0.84/1.12/ 1.75) OR Z-FACTOR	t (LxAxF or LxZ) (Hours)
			N/A		
			N/A		
			N/A		
			N/A		
			N/A		
				t (Total)	

MINIMUM CONDITIONING PERIOD AND ADDITIONAL CREEP ALLOWANCE

The minimum conditioning period(s) can be found by factoring in the 'X' Axis extremity value (X) of the relevant curve in Figure 9.

Minimum test period (t (Total)):	
'X' Axis extremity value (X):	
Minimum conditioning (S = t(Total)/X):	hours

Note: S is the time from the start of pressurisation to the first test period reading. From Figure 9 it can be seen that the additional creep allowance (C), which is read off the 'Y' Axis, reduces to zero as S increases. If S and/or t (Total) are extended in time the formula above has to be re-calculated and a revised 'X' Axis value read off, and hence a revised C ('Y' Axis), derived below. This is only applicable for mains with MOP > 75 mbar.

Actual test period (t (Total)):	
Actual conditioning period (S):	
Revised 'X' Axis Extremity Value (X = t(Total)/S):	
Additional Creep Allowance (C (Figure 9)):	mbar

SHEET 2 OF 2

PNEUMATIC PRESSURE TEST CERTIFICATE

Project Reference Number	**Project Title**	**Pneumatic Test Certificate Number**

AUTHORISATION

	Initial pressurisation	**Test commenced**
Witnessed by:		
Designation:		
Date:		
Time:		

Note: *The difference between initial pressurisation and the first test reading have to equal S above. Total allowable pressure loss is the addition of the 3 mbar allowance for all tightness tests and C, if applicable, i.e. for mains with a MOP of ≤ 75 mbar as long as S is at least the minimum value shown above the maximum allowable pressure loss (MAPL) is 3 mbar.*

MAPL (3 mbar + C (for mains with MOP > 75 mbar)): ______ mbar

PNEUMATIC REPORT	TEST 'ON'	INTERMEDIATE READINGS		TEST 'OFF'
Date/time				
Absolute pressure				
Ground/skin temperature				
Pressure correction	//////	//////	//////	
Corrected pressure				

Gauge type:	
Serial number:	
Calibration date:	
Calibration expiry date	
Permissible loss:	mbar
Actual variance	mbar

TEST RESULT (Circle as appropriate)

PASS	**FAIL**

Test accepted by:	
Signature:	
Designation:	
Date:	

TEST DE-PRESSURISATION

Comments:

Witnessed by	
Designation:	
Date:	
Time:	

APPENDIX 6 : COMPRESSIBILITY OF NATURAL GAS

MAJOR CONSTITUENTS		RANGE (mol %)		TYPICAL COMPOSITIONS (mol %)		
		Minimum	Maximum	St Fergus Terminal	Bacton Terminal	Lupton Blending Point
Carbon dioxide	CO_2	0.81	2.2	2.2	0.81	2.45
Nitrogen	N_2	0.96	2.45	0.96	1.92	1.69
Methane	CH_4	86.75	93.03	86.75	93.12	87.21
Ethane	C_2H_6	3.11	7.1	7.1	3.11	6.18
Propane	C_3H_8	0.65	2.25	2.25	0.65	1.74
Iso Butane	C_4H_{10}	0.11	0.36	0.36	0.11	0.19
Pentane	C_5H_{12}	0.14	0.33	0.25	0.14	0.33
Hexane	C_6	0.1	0.14	0.01	0.1	0.14
Heptane	C_7	0.03	0.05	0.03	0.05	0.05
Octane	C_8	0	0.03	0	0.03	0.01
Nonane	C_9	0	0.01	0	0.01	0.003
Benzene	C_6H_6	0.001	0.03	0.003	0.03	0.001
Toluene	C_7H_8	0.001	0.01	0.001	0.01	0.003

MINOR CONSTITUENTS	RANGE (ppm v/v)		TYPICAL COMPOSITION (ppm v/v) (including odorant)
	Minimum	Maximum	
Hydrogen sulphide	0	3.3	1.0
Methyl ethyl sulphide	0	1.0	0
Diethyl sulphide	0	0.5	0
Ethyl mercaptan(DMS)	0	0.5	0
Tertiary butyl mercaptan(TBM)	0.5	2	1.2
Water vapour	10	550	100
Methanol vapour	0	200	100
Dimethyl Sulphide	0.2	0.8	0.5

Note 1: For odorised gas, the GT adds an odorant blend of TBM and DMS. Other sulphides and mercaptans will be present only in trace quantities of naturally occurring sulphur. However, the total sulphur concentration within the gas will always be lower than 35 ppm as specified in GS(M)R.

Note 2: Gas distributed at a pressure exceeding 7 bar may not, in all cases, be odorised by the GT.

Note 3: Gas distributed at a pressure not exceeding 7 bar may contain very small quantities of additives, for example MEG or other conditioning agents.

Note 4: Water content figures are those typically found in the distribution networks. There may be isolated instances where gas is saturated with water vapour at ground temperature.

TABLE 17 - TYPICAL NATURAL GAS COMPOSITIONS (JANUARY 1998) (COURTESY OF TRANSCO)

PRESSURE	TEMPERATURE °C							
(bar abs)	-20	-10	0	10	20	30	40	50
1.021	0.9965	0.9970	0.9973	0.9976	0.9979	0.9981	0.9983	0.9985
1.075	0.9964	0.9968	0.9972	0.9975	0.9978	0.9980	0.9983	0.9985
1.100	0.9963	0.9967	0.9971	0.9974	0.9977	0.9980	0.9982	0.9984
1.500	0.9949	0.9955	0.9961	0.9965	0.9969	0.9973	0.9976	0.9978
2.000	0.9932	0.9940	0.9947	0.9953	0.9959	0.9963	0.9968	0.9971
4.000	0.9864	0.9880	0.9895	0.9907	0.9918	0.9927	0.9935	0.9943
7.000	0.9761	0.9790	0.9815	0.9837	0.9856	0.9873	0.9887	0.9900
10.000	0.9658	0.9700	0.9736	0.9767	0.9794	0.9818	0.9839	0.9858
20.000	0.9309	0.9396	0.9471	0.9535	0.9591	0.9639	0.9681	0.9718
30.000	0.8953	0.9090	0.9206	0.9304	0.9389	0.9463	0.9527	0.9583
40.000	0.8592	0.8783	0.8942	0.9077	0.9192	0.9291	0.9377	0.9453
50.000	0.8230	0.8477	0.8682	0.8854	0.9000	0.9125	0.9234	0.9328
60.000	0.7869	0.8177	0.8429	0.8638	0.8815	0.8966	0.9096	0.9209
70.000	0.7518	0.7887	0.8186	0.8432	0.8640	0.8816	0.8967	0.9098
80.000	0.7187	0.7613	0.7957	0.8239	0.8475	0.8675	0.8846	0.8994
9 0.000	0.6890	0.7364	0.7747	0.8061	0.8323	0.8546	0.8736	0.8900
100.000	0.6641	0.7147	0.7561	0.7902	0.8188	0.8430	0.8637	0.8816

Calculations based on AGA 8 - 1994/ISO 12213 -1:1997 Gas Density
(Gas composition figures for Mean Bacton Gas courtesy of Transco)

Note 1: This table is for illustration purposes only with the calculated results being dependent on the gas composition used. Reference needs to be made to the GT for the gas composition appropriate to the installation.

Note 2: For the purposes of this document, at 1 bar absolute the compressibility of Natural Gas in the temperature ranges shown is taken as unity.

TABLE 18 - COMPRESSIBILITY (Z) FOR "MEAN BACTON GAS"

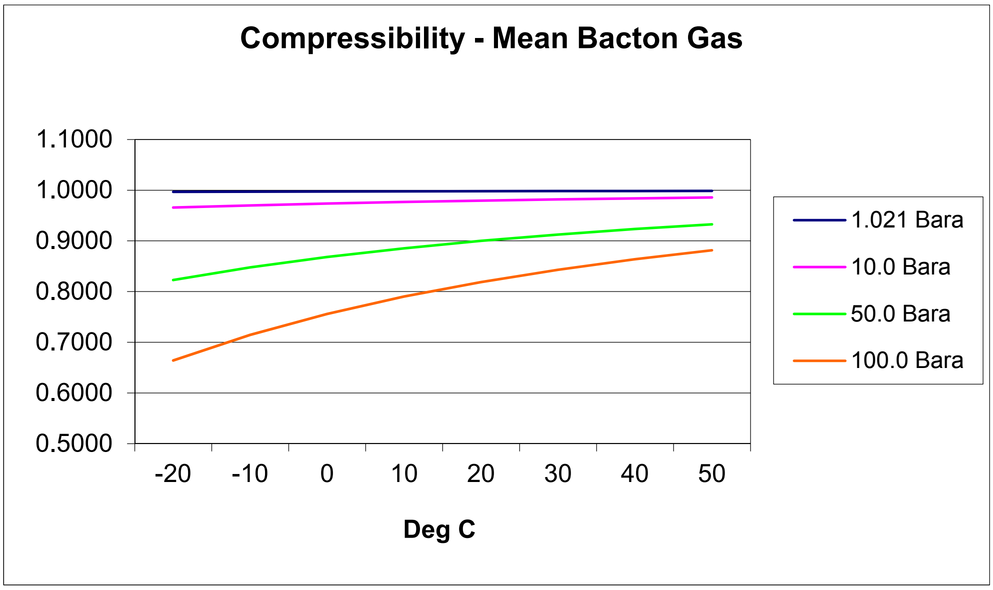


FIGURE 10 - COMPRESSIBILITY (Z) FOR "MEAN BACTON GAS"

PRESSURE	TEMPERATURE °C							
(bar abs)	-20	-10	0	10	20	30	40	50
1.021	1.0012	1.0008	1.0005	1.0002	0.9999	0.9996	0.9994	0.9992
1.075	1.0014	1.0010	1.0006	1.0003	1.0000	0.9997	0.9995	0.9993
1.100	1.0015	1.0011	1.0007	1.0003	1.0000	0.9998	0.9996	0.9994
1.500	1.0029	1.0023	1.0017	1.0013	1.0009	1.0005	1.0002	0.9999
2.000	1.0046	1.0038	1.0031	1.0024	1.0019	1.0014	1.0010	1.0007
4.000	1.0115	1.0099	1.0084	1.0072	1.0061	1.0051	1.0043	1.0035
7.000	1.0222	1.0192	1.0166	1.0143	1.0124	1.0107	1.0092	1.0079
10.000	1.0331	1.0287	1.0248	1.0216	1.0187	1.0163	1.0141	1.0122
20.000	1.0719	1.0619	1.0535	1.0464	1.0404	1.0352	1.0306	1.0267
30.000	1.1145	1.0977	1.0839	1.0724	1.0627	1.0544	1.0473	1.0412
40.000	1.1612	1.1361	1.1158	1.0993	1.0855	1.0739	1.0640	1.0556
50.000	1.2124	1.1770	1.1492	1.1269	1.1086	1.0934	1.0806	1.0697
60.000	1.2680	1.2202	1.1838	1.1551	1.1319	1.1128	1.0969	1.0835
70.000	1.3272	1.2651	1.2190	1.1833	1.1549	1.1318	1.1128	1.0968
80.000	1.3883	1.3106	1.2540	1.2111	1.1773	1.1502	1.1279	1.1094
90.000	1.4482	1.3549	1.2880	1.2378	1.1988	1.1675	1.1421	1.1211
100.000	1.5025	1.3960	1.3197	1.2626	1.2185	1.1836	1.1552	1.1318

Where zb = 0.997781
Calculations based on AGA 8-1994/ISO12213 –1:1997 Gas Density
(Gas composition figures for Mean Bacton Gas courtesy of Transco.)

Note: This table is for illustration purposes only with the calculated results being dependent on the gas composition used. Reference needs to be made to the GT for the gas composition appropriate to the installation.

TABLE 19 - Z_{FACTOR} FOR "MEAN BACTON GAS"

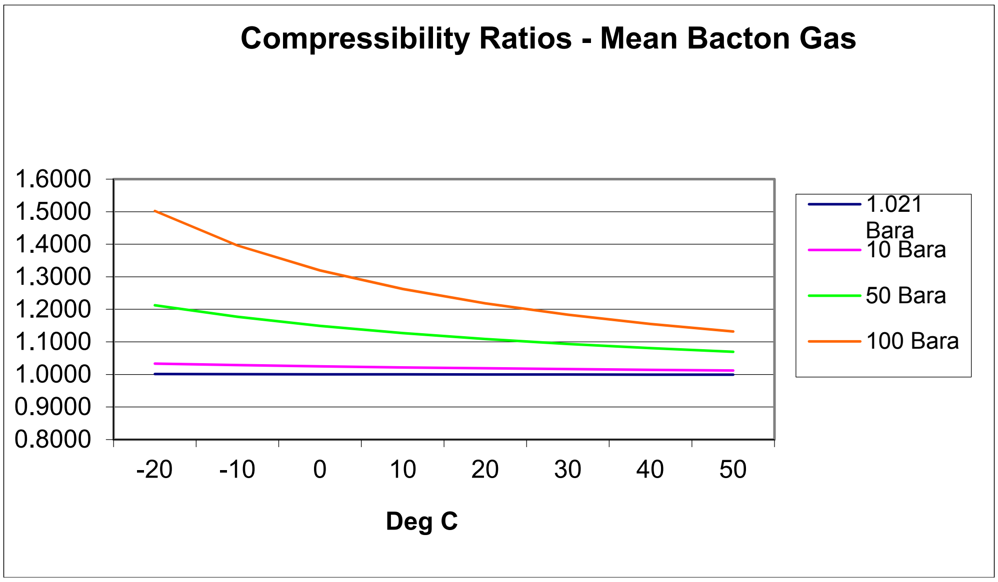
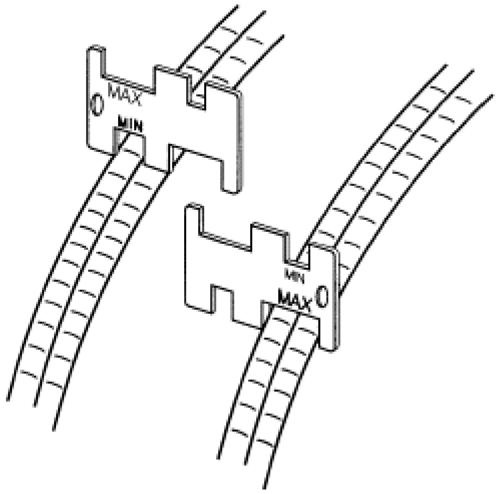


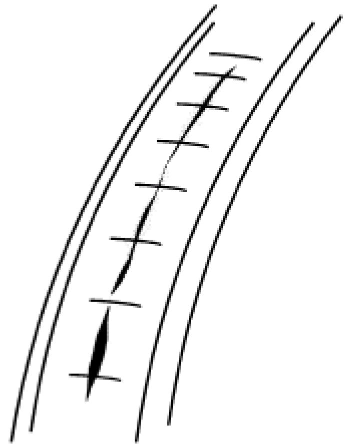
FIGURE 11 - COMPRESSIBILITY RATIO (ZB/Z) FOR "MEAN BACTON GAS"

APPENDIX 7 : PE WELDING DEFECTS



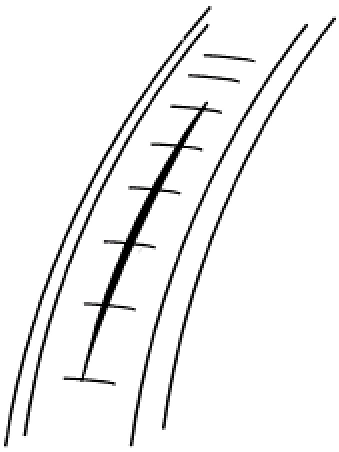
1. Bead width

Run the max/min bead gauge along the bead to check that it is within the specified limit. At the same time check for areas of distortion in the bead.



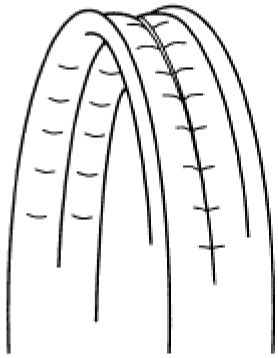
2. Contamination

Examine the underside of the bead over its complete length for contamination at the interface and, if found, confirm on the joint.



3. Slit defects

Examine the underside of the bead over its complete length for any separation caused by lack of fusion. This will be seen as a slit at the interface.



4. Lack of fusion

Confirm lack of fusion in the bead by bending it backwards on itself along its complete length. If faulty a clear separation will be seen. Locate the lack of fusion in the joint.

FIGURE 12 - WELDING DEFECTS

APPENDIX 8 : EFFICENCY FACTOR (e) FOR BUTT WELDED PE WHEN INTERNAL JOINT BEADS ARE NOT REMOVED

NOMINAL PIPE DIAMETER (mm)	SDR	MAXIMUM INTERNAL BEAD HEIGHT (mm)	EFFICIENCY FACTOR (e) BUTT FUSED PE INTERNAL JOINT BEADS NOT REMOVED			
			Velocity = 1.5 m s^{-1}		Velocity = 4.7 m s^{-1}	
			e_6	e_{12}	e_6	e_{12}
90	11	5.0	0.91	0.95	0.87	0.93
125	11	5.0	0.92	0.96	0.89	0.94
180	17	5.0	0.94	0.97	0.92	0.96
250	17	6.3	0.92	0.96	0.89	0.94
315	17	7.9	0.90	0.95	0.87	0.93
355	17	8.9	0.89	0.94	0.86	0.92
400	17	10.0	0.87	0.93	0.83	0.90
500	17	12.5	0.84	0.91	0.80	0.88

Note 1: e_6 represents 6 m between butt welds.
e_{12} represents 12 m between butt welds.

Note 2: Linear interpolation or extrapolation can be assumed for velocities other than those above.

Note 3: Values for SDR 17 for pipe of diameter 90 and 125 mm are not available at the time of publication.

TABLE 20 - EFFICENCY FACTOR (e) FOR BUTT WELDED PE WHEN INTERNAL JOINT BEADS ARE NOT REMOVED

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