IGEM/UP/6 Edition 3
Communication 1813

Founded 1863
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Application of compressors to Natural Gas fuel systems

DRAFT FOR COMMENT

1 This draft Standard IGEM/UP/6 Edition 3 has been prepared by a Panel under the chairmanship of Iain Ward.

2 This Draft for Comment is presented to Industry for comments which are required by 20th November 2017, and in accordance with the attached Reply Form.

3 This is a draft document and should not be regarded or used as a fully approved and published Standard. It is anticipated that amendments will be made prior to publication.

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Thomas Donnelly
IGEM
IGEM House
26-28 High Street
Kegworth
Derbyshire, DE74 2DA
Tel: 0844 375 4436
Fax: 01509 678198
Email:tomd@igem.org.uk

IGEM
Institution of
Gas Engineers & Managers

Attached is the Draft for Comment of IGEM/UP/6 Edition 3 – "Application of compressors to Natural Gas fuel systems" and the associated comment form.

We wish to make it as easy as possible for those of you representing industry bodies to issue the draft to your Members. You can either forward this email with attachment complete or forward it without the attachment and invite them to visit our website via where the Draft and http://www.igem.org.uk/technical-standards/standards-development/drafts-for-comment.aspx Comment Form are posted.

Organisations to which this Draft has been circulated:

Organisation	Representative
AIGT	JOHN BARRATT
Association of Register Gas Installers	TONY BRUNTON
BSI/GSE/30	GAVIN JONES
BPEC	Awaiting contact
BRITISH GAS	RICHARD HARPER
CAPITA	DAVID J SMITH
CIBSE	HYWEL DAVIES
CIPHE	TONI-LOUISE MATTHEWS
CORGI DIRECT	Awaiting contact
DNO COLLAB FORUM	CHRIS CLARKE
EI	MARK SCANLON
ENA	MATTHEW HINDLE
EUA (was SBGI)	STEVEN SUTTON
EUSKILLS	IAN MOSS
GISG	MIKE LEPPARD
GAS SAFE REGISTER	JOHN STIRLING
HSE	ANDREW COX
HSE	MARGARET GREGSON
HSENI	DALE SHIRLOW
B&ES (was HVCA)	JACK VERBER
ICOM	ROSS ANDERSON
*Large Business Forum	TREVOR SMALLPEICE
MAMCoP Board	STEPHANIE CATWALL
NATIONAL GRID	HILARY BUXTON
NGN	MARTIN ALDERSON
	LAUREN GRAHAM
NICEIC	CHRIS LONG
OFGEM	STEVE BROWN
Organisation of professional gas operatives	WIM RUTJES
SGN	PAUL DENNIFF
UKLPG	RICHARD HAKEEM
WALES & WEST	CHRIS CLARKE
YPN	Peter Amos

Organisation	**Representative**
<u>IGEM</u>	
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LNGC	

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IGEM House
26-28 High Street
Kegworth
Derbyshire, DE74 2DA
Tel: 0844 375 4436
Fax: 01509 678198
Email: general@igem.org.uk

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CONTENTS

SECTION 1 : INTRODUCTION

1.1 This Standard supersedes IGEM/UP/6 Edition 2 Communication 1741, which is obsolete.

1.2 This Standard has been drafted by an Institution of Gas Engineers and Managers (IGEM) Panel, appointed by IGEM's Utilisation Committee, subsequently approved by that Committee and has been approved by IGEM's Technical Coordinating Committee on behalf of the Council of IGEM.

1.3 This Standard covers the application of compressors to Natural Gas (NG) fuel systems, including industrial/commercial premises and NG filling stations.

1.4 It does not cover gas compressors used for gas transportation systems.

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.

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

1.6 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:

- have done everything to ensure, so far as it is reasonably practicable, that "responsible engineers" have the skills, training, experience and personal qualities necessary for the proper exercise of professional judgement
- have systems and procedures in place to ensure that the exercise of professional judgement by "responsible engineers" is subject to appropriate monitoring and review
- not require "responsible engineers" to undertake tasks which would necessitate the exercise of professional judgement that is 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.

1.7 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 in the sense that actions by people initiated or contributed to the accidents, or people might have acted better to avert them.

It is therefore necessary to give proper consideration to the management of these human factors and the control of risk. To assist in this it is recommended that due cognisance should be taken of HSG48.

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 to this Standard. Amendments to this Standard will be issued when necessary, and their publication will be announced in the Journal of IGEM and other publications as appropriate.

1.9 Requests for interpretation of this Standard in relation to matters within its scope, but not precisely covered by the current text, should be addressed in writing to Technical Services, IGEM, IGEM House, 26-28 High Street, Kegworth, Derbyshire, DE74 2DA and will be submitted to the relevant Committee for consideration and advice, but in the context that the final responsibility is that of the engineer concerned. If any advice is given by or on behalf of IGEM, this does not relieve the responsible engineer of any of his or her obligations.

1.10 This Standard was published in XXX XXXX.

SECTION 2 : SCOPE

2.1 This Standard covers the installation and operation of compressors, with outlet pressures in the range exceeding 0.5 barg but not exceeding 400 barg.

Note 1: Requirement for the installation of boosters and compressors with outlet pressures not exceeding 0.5 barg are given in IGEM/UP/2.

Note 2: For the purposes of this Standard and IGEM/UP/2, a booster is a centrifugal machine with an outlet pressure not exceeding 0.5 barg.

2.2 This Standard applies to compressors pressurising NG (or an equivalent 2nd family gas as defined in BS EN 437). This Standard may not be appropriate for other gases such as 1st family, other 2nd family and 3rd family gases, including "landfill gas", "mines gas", "digester gas" etc; (see Sub-Section 4.3).

Note: *Some principles in this Standard could be applied to other gases however further specialist requirements will need to be specified by the relevant compressor manufacturer.*

This Standard applies only to gas compressors that are installed downstream of a primary meter installation.

This Standard does not specify the design and manufacturing requirements of compressors such as those contained in BS EN 1012.

2.3 This Standard applies to new construction and replacement of, or extension to, servicing, maintenance of existing installations using compressors. It is not retrospective, but it is recommended that existing installations be modified to meet this Standard, when appropriate.

Note: Standards rarely cover the retrospective issue of existing installations. They can, however, set a basis for consideration of performance upon which a risk assessment can be developed.

2.4 Unless otherwise specified, metric standard conditions are assumed by this Standard.

2.5 This Standard applies to new compressor installations only.

2.6 All pressures are gauge pressures unless otherwise stated.

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

2.8 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 : LEGAL AND ALLIED CONSIDERATIONS

This Standard is set out against a background of legislation in force in GB (UK to include Northern Ireland) at the time of publication. Similar considerations are likely to apply in other countries and reference to the appropriate national legislation will be necessary. The following legal and allied considerations outlined are particularly relevant to compressors.

Appendix 2 lists legislation, guidance notes, Standards etc. which are identified within this Standard as well as further items of legislation that may be applicable. Where Standards are quoted, equivalent national or international Standards etc. equally may be appropriate. Unless otherwise stated, the latest version of the referenced document should be used.

3.1 HEALTH AND SAFETY AT WORK ETC. ACT (HSWA)

HSWA applies to all persons involved with work activities, including employers, the self-employed, employees, designers, manufacturers, suppliers etc. as well as the owners of premises. It places general duties on such people to ensure, so far as is reasonably practicable, the health, safety and welfare of employees and the health and safety of other persons such as members of the public who may be affected by the work activity.

All persons engaged in the design, construction, commissioning, operation, maintenance and alteration of pipework must be competent to carry out such work. Competency is achieved by an appropriate combination of education, training and practical experience.

3.2 THE GAS ACT

3.2.1 In particular, the Gas Act stipulates requirements for:

- notification to the gas supplier and the gas transporter (GT) of the intention to install a compressor
- the fitting and maintenance of a supply protection device
- the avoidance of affecting the supply system.

3.2.2 The user of a gas compressor must provide written notification to the gas supplier and the GT of the intention to connect a compressor to the gas supply network.

The user must provide adequate protection for the gas supply pipework against high pressure being fed back into the supply so exceeding the maximum operating pressure (MOP) of that pipework or of any component contained within it. For this reason, the gas supplier and the GT must be provided with evidence that all appropriate safeguards have been taken.

3.2.3 Before a compressor that is to be fitted to an installation connected to the public gas supply network, is considered acceptable for operation, it is required (as permitted by the Gas Act) by the gas supplier and the GT that suitable protective devices be fitted and maintained by the compressor operator. The gas supplier and the GT must also be satisfied that no undue compressor induced perturbations are imposed on the metering system or into the gas supply. Usually, this will mean demonstrable compliance with relevant published Standards.

3.3 COMPETENCY

Any person engaged in the design, installation or testing of a compressor system must be competent to carry out such work. Competency is achieved by an appropriate combination of education, training and practical experience.

Installations in GB falling within the scope of the GS(I&U)R also require persons working on gas systems to be registered as a Class of Persons recognised by HSE.

3.4 CONFINED SPACES REGULATIONS

These Regulations apply to a large range of confined spaces. The supplier or designer of an enclosure and equipment within it is required to perform a risk assessment of the enclosure with respect to safe access and egress and to give clear instructions to operators on access/egress as well as to what actions to take in the event of a gas alarm occurring.

Employers and the self-employed should prevent entry into confined spaces unless avoidance is not reasonably practicable and unless there is a system of work which renders the work safe. They are also required to have specific emergency arrangements in place.

3.5 CONSTRUCTION (DESIGN AND MANAGEMENT) REGULATIONS (CDM)

These Regulations impose duties on designers, clients (and their agents), developers, principal designer and principal contractors.

Further information is given in L153, which sets out the principles duty holders are required to use in their approach to identifying the measures they need to take to control the risks to health and safety in a particular project.

The general principles of prevention are to:

- avoid risks where possible
- evaluate those risks that cannot be avoided and
- put in place proportionate measures that control them at source.

Construction includes the alterations, repair, redecoration, maintenance, decommissioning or demolition of a structure. It also covers installation, commissioning, maintenance or removal of gas services.

3.6 DANGEROUS SUBSTANCES AND EXPLOSIVE ATMOSPHERES REGULATIONS (DSEAR)

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

The following publications contain details of DSEAR and their application:

- INDG 370
- L138.

All gas systems except those in domestic parts of buildings fall within the scope of DSEAR. This requires that a risk assessment be completed for each premise to determine if any hazardous area exists and its extent. Normally, systems of MOP not exceeding 0.5 bar do not require the use of certified electrical components if correctly installed, tested and maintained.

3.7 ELECTRICITY AT WORK REGULATIONS

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

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

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

Note: HSR25 provides guidance on the Regulations.

3.8 GAS SAFETY (INSTALLATION AND USE) REGULATIONS (GS(I&U)R)

GS(I&U)R are relevant statutory provisions of HSWA setting out general and detailed requirements dealing with the safe installation, maintenance and use of gas systems, including gas fittings, appliances and flues.

Note: GS(I&U)R do not apply to certain premises (see L56 Guidance Notes 28 and 29). However, where they do not apply, the principles of GS(I&U)R need to be applied.

GS(I&U)R place responsibilities on those installing, servicing, maintaining or repairing gas appliances, pipework etc. as well as suppliers and users of gas.

GS(I&U)R define the type of work that requires persons carrying out such work, or their employers, to be an “approved class of person”, for example Gas Safe registered.

The installer must check the safety of any appliance or pipework they install or work on and take appropriate action where they find faults. Where the premises are let or hired out, the landlord or hirer has special responsibilities to ensure that any installer they use for the gas fitting, service or maintenance or safety is a member of an approved class of persons and is competent to carry out such work. If any serious fault is found, the installer must inform both the landlord/hirer, as well as the user, so that such faults can be rectified before further use.

3.9 GAS SAFETY (MANAGEMENT) REGULATIONS (GS(M)R)

3.9.1 GS(M)R place specific duties on GTs, or their emergency service providers (ESPs), for dealing with gas escapes from pipes on their networks. Their primary duty is to make the situation safe. They are responsible not only for dealing with escapes from their own pipes, but also for dealing with escapes from gas fittings supplied with gas from pipes on their network. In GS(M)R, the term “gas escapes” includes escapes or emissions of carbon monoxide (CO) from gas fittings.

3.9.2 The ESP has specific duties to:

- provide a continuously staffed and free telephone service to enable persons to report gas escapes and
- pass such reports on to the person who has the responsibility for dealing with the escape.

3.9.3 In addition, there are duties imposed on gas suppliers and GTs to notify the ESP should they, rather than the ESP, receive a report of an escape from the consumer.

3.9.4 GS(M)R require GTs to investigate fire and explosion incidents upstream of the emergency control valve (ECV) and to send a report of the investigation to HSE. GTs are also required to investigate fire and explosion incidents downstream of the ECV but this is limited to establishing whether the seat of the fire or explosion was in an appliance and if so which one, or in the meter installation or installation pipework.

3.9.5 Responsibility for investigating RIDDOR reportable incidents as a result of an escape of CO from incomplete combustion of gas from a gas appliance, is placed on gas suppliers. HSE must be notified before such investigations commence.

Note: Advice on dealing with gas escapes is contained in.

3.10 MANAGEMENT OF HEALTH AND SAFETY AT WORK REGULATIONS (MHSWR)

Linked closely with specific duties under GS(I&U)R (see Sub-Section 3.4) MHSWR impose a duty on employers and the self-employed to make assessments of risks to the health and safety of employees, and non-employees affected by their work. They also require effective planning and review of protective measures.

3.11 NOISE AT WORK REGULATIONS

Under these Regulations, the employer is required to identify any potential injurious noise sources and carry out an assessment when an employee is exposed to a level of noise in excess of the first action level of a daily personal exposure of 85 dB(A). Action is then required to reduce noise at source so far as is reasonably practicable. Only then can consideration be given to hearing protection. A duty is also placed on manufacturers and suppliers to provide information on the noise likely to be generated by their product.

3.12 PRESSURE EQUIPMENT DIRECTIVE (PED)

3.12.1 PED applies to the design of pipework of MOP exceeding 0.5 bar which is designed and installed for a site user, for example a factory occupier. PED is implemented in the United Kingdom (UK) by the Pressure Equipment Regulations (PER) and the Pressure Systems Safety Regulations (PSSR). Compliance with PED can be demonstrated by the use of a harmonised standard. BS EN 15001-1 and -2 have been specially prepared for the gas industry and include a wide range of materials. Systems falling within the scope of PED must display a CE mark and this must be affixed by an approved person or body.

3.13 PRESSURE EQUIPMENT REGULATIONS (PER)

PER are intended to allow the free trade of pressure equipment throughout the European Union (EU). PER deal with the manufacture, design and supply of pressure equipment. They impose duties on the responsible person

Note 1: A "responsible person" is defined as "the manufacturer or his authorised representative established within the Community; or where neither the manufacturer nor his authorised representative is established within the Community, the person who places the pressure equipment or assembly on the market or puts it into service as the case may be."

Note 2: "Pressure equipment" is defined as "vessels, piping, safety accessories and pressure accessories; where applicable, pressure equipment includes elements attached to pressurised parts, such as flanges, nozzles, couplings, supports lifting lugs and similar."

Note 3: The duties on the "responsible person" are to ensure that pressure equipment:

- *satisfies the relevant essential requirements*
- *has undergone the relevant conformity assessment procedure, if applicable*
- *has had the CE mark affixed by the manufacturer, if applicable*
- *has had the declaration of conformity drawn up by the manufacturer is in fact safe.*

Note 4: Not all pressure equipment is covered by PER. There are 21 categories of exceptions, detailed in Schedule 1 of PER.

Note 5: The relevant conformity assessment procedure is determined by the classification of the pressure equipment according to criteria laid down in PER. The classification system results in equipment being placed in one of 5 categories depending on the inherent level of hazard within the system.

The category then determines the range of conformity assessment modules relevant to that equipment. The modules are designed to allow the manufacturer to choose between a quality assurance route or type testing.

3.14 PRESSURE SYSTEMS SAFETY REGULATIONS (PSSR)

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

3.14.2 Relevant fluids include NG at a pressure greater than 0.5 bar i.e. above atmospheric pressure. A pressure system would include bulk storage tanks, pipelines and protective devices. Once the pressure in the pipework drops below 0.5 bar, and the user/owner can show clear evidence that the system does not contain, and is not liable to contain, a relevant fluid under foreseeable operating conditions, then that part of the system is no longer covered by PSSR. This is likely to be the case after the pressure relief valve associated with a pressure reducing valve which takes the pressure to below 0.5 bar, for example at the entry to a building but note the special requirements placed on protective devices in such systems (see para 110b of L122). PSSR also apply to pipelines and their protective devices in which the pressure exceeds 2 bar (see Sch 1 part 1 item 5 of L122).

3.14.3 More information is available in L122 and some information is presented in INDG 261 and IND G178.

3.15 PROVISION AND USE OF WORK EQUIPMENT REGULATIONS (PUWER)

3.15.1 Work equipment has a wide meaning and includes tools such as hammers, laboratory apparatus, for example Bunsen burners, ladders, lifting equipments and machinery for use at work.

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

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

3.15.4 Other pipework systems “designed and specified” by the consumer and which are thereafter installed and tested by a contractor will not normally fall within the scope of PED.

Sections of pipework designed and manufactured “off-site” will, generally, always fall within the scope of PED if designed and specified by the contractor, as is the normal procedure within the UK.

Systems in which the pressure (bar) times the volume (litres) is less than 250 are partially exempt from PED on the basis that they have a low contained energy. Pipework of diameter not greater than 25 mm nominal size is also partially exempt.

3.15.5 There is also a duty on the user of an installed system within the scope of PED not to allow the system to be used until they have a written scheme of examination covering protection devices, pressure vessels and parts, which if they fail, give rise to danger.

The written scheme of examination (WSoE) must be drawn up by a "competent person" and the system must be examined in accordance with the WSoE by a "competent person". The more complex a system is, the more qualifications, experience and training are needed to ensure competence.

Guidance on the selection of competent persons is given in L122. Users (or owners) of pressure systems are free to select any competent person they wish, but they have to take all reasonable steps to ensure that the competent person selected can actually demonstrate competence i.e. the necessary breadth of knowledge, experience and independence. In judging levels of competence, users or owners may wish to know that a national accreditation scheme has been developed by the United Kingdom Accreditation Service (UKAS) for bodies that provide services of this nature.

3.16 REPORTING OF INJURIES, DISEASES AND DANGEROUS OCCURRENCES REGULATIONS (RIDDOR)

3.16.1 RIDDOR require employers, self-employed people or those in control of work premises to report certain work related accidents, diseases and dangerous occurrences.

3.16.2 Other people have duties to report certain gas incidents which may not appear to be work related:

- death or major injury arising out of the distribution, filling, import or supply of NG or Liquid Petroleum Gas (LPG) should be reported by the conveyor for NG and the filler, importer or supplier for LPG
- dangerous gas fittings (as defined in RIDDOR) should be reported by a ''member of a class of persons''.

3.16.3 Major injuries, death and dangerous occurrences must be notified immediately, for example by telephone, to the enforcing authority by the ''responsible person'' as defined by RIDDOR. Reports can be made to the Incident Contact Centre by:

- telephone on 0845 300 9923
- fax on 0845 300 9924
- email to riddor@connaught.plc.uk
- internet at www.riddor.gov.uk or
- via a link from HSE website at www.hse.gov.uk.

It is also possible to report to the local HSE office by telephone and then follow up with a written report on the correct F2508 form within the required timescale (10 days, or 14 days for dangerous gas fittings). Other reports should be made as soon as practicable and within 10 days of the incident.

3.16.4 L73 contains detailed guidance on RIDDOR, including a full list of injuries etc. that need reporting. HSE61 (rev 1) and MISC310 give some information on RIDDOR and how to report.

3.16.5 IGEM/GL/8 provides guidance on the reporting and investigation of gas related incidents.

3.17 SUPPLY OF MACHINERY (SAFETY) REGULATIONS

These Regulations set out "essential requirements" written in general terms, which must be met by manufacturers/suppliers before a product may be supplied within the European Community. European standards provide the detail on the essential requirements. Machinery as defined, once having been verified against the relevant standards, can then be affixed with the CE mark. The manufacturer or importer will have to be able to assemble a technical file detailing information on the health and safety considerations that went into the design of the product.

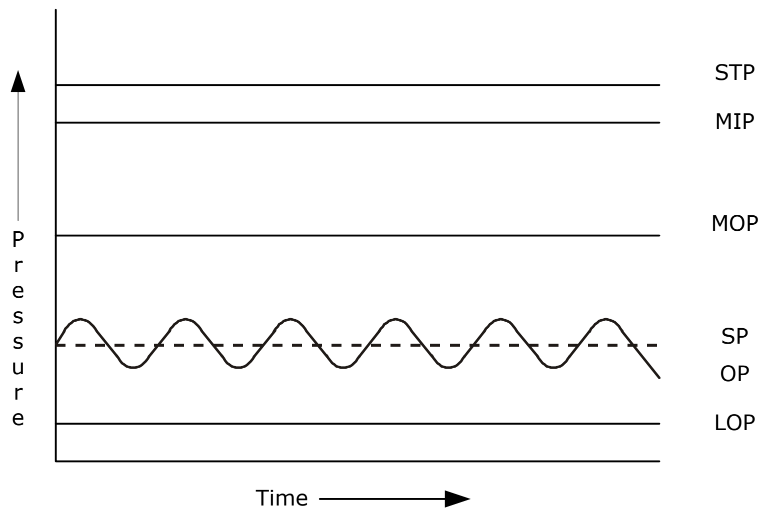
SECTION 4 : GAS SUPPLY

4.1 PRESSURE AT THE OUTLET OF THE ECV

4.1.1 The characteristics of the gas pressure at the outlet connection from the ECV shall be fully specified including any normal or abnormal variations (see Figure 1).

In some cases, it may be permissible to obtain a gas supply direct from the distribution network or national transmission system (NTS) without the application of pressure control regulators at the meter installation. Such a supply requires special permission from the GT and will, if the site is covered by GS(I&U)R require a relaxation from GS(I&U)R. Reference should be made to IGEM/GM/8 Part 1 in such cases.

4.1.2 IGEM has adopted the terms and definitions used in European standards for pressure i.e. maximum operation pressure (MOP), operating pressure (OP), maximum incidental pressure (MIP), lowest operating pressure (LOP) and strength test pressure (STP). Figure 1 explains these terms. Further guidance is given in IGEM/GM/8 Part 1.



STP strength test pressure
MIP maximum incidental pressure (fault pressure)
MOP maximum operating pressure
SP set pressure
OP operating pressure
LOP lowest operating pressure

FIGURE 1 - RELATIVE PRESSURE LEVELS

4.1.3 The following factors shall be taken into account:

- MOP and LOP under normal operating conditions
- maximum and minimum operating pressure that may result under fault conditions of supply to the ECV, especially where it is an unregulated supply.

Details of these pressures may be available from the GT based on historic pressures, network pressure setting, or (if available) instrumentation. Note that there may be seasonal and/or diurnal pressure variations.

Where the difference in the maximum and minimum pressures under normal operating conditions is significant, a "best endeavours" estimate of the anticipated variation of pressure with time should be made. For example a pressure/time profile should be formed (see Figure 2), the time being annual, monthly and/or daily as required.

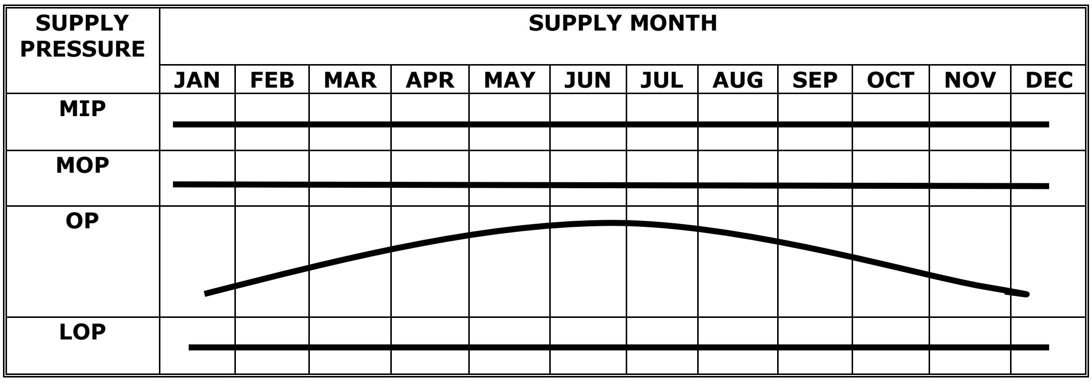


FIGURE 2 - EXAMPLE PRESSURE/TIME PROFILES

4.1.4 Considering the information required under clauses 4.1.1, 4.1.2 and 4.1.3 and the load to be supplied, it should be decided whether the compressor is to operate:

- over the whole range of gas supply pressures or
- over part of the range of gas supply pressure or
- over the whole range of gas supply pressure but with the inlet pressure to the compressor regulated.

Note: Other factors that may influence the choice include:

- *the estimated annual power absorption of the compressor*
- *the capability of the compressor type to accept variable inlet pressure*
- *the capital cost of overcoming inlet pressure swings*
- *the anticipated frequency of occurrence of the maximum and minimum supply pressures (see clause 4.1.3)*
- *load variations during operation of the compressor*
- *any constraints which may have been applied to the operation of the compressor system by the gas supplier and any upstream GT.*

4.2 EFFECT OF OPERATING A COMPRESSOR ON THE GAS SUPPLY SYSTEM

4.2.1 The operation of a gas compressor may cause an abnormally large and rapid change of flow in the gas supply system upstream of the primary meter installation or within the consumer's installation pipework. These changes must not create pressure fluctuations that compromise the proper operation of the gas supply for other consumers (see clause 3.1.1) or, of other plant/appliances connected to the installation pipework.

4.2.2 The GT must be notified at the earliest possible time of the intention to connect any gas compressor to the gas supply network.

Note: Failure to notify the GT within 14 days of the intended commissioning date is a contravention of the Gas Act.

4.2.3 The following technical details of the proposed compressor system shall be provided to the GT (a typical form is shown in Appendix 13):

- outlet receiver volume
- over and under pressure protection devices that may be installed on the inlet of the compressor
- compressor type and operating mode
- Mechanical vibration suppression
- Arrangements for pulsation damping, including inlet pipework materials, pipework/vessel storage volumes
- a process and instrumentation diagram (P&ID) illustrating the safety devices and their logic of operation

- annual and diurnal load profiles to enable the assessment of the impact of the load on the gas supply system.

Note: If adequate information is not provided the gas supply may be disconnected (see also clause 3.1.1).

Note 2: The possible range of compressor types, installation configuration and operating mode is extensive. Therefore not every item listed above may be applicable to all installations to demonstrate mitigation of potential risks to operation of the compressor and/or the supply network.

4.2.4 As a result of receiving the information provided as required by clause 4.2.3, the GT may need to carry out analysis to investigate possible effect of the compressor load on the supply network, paying attention to steady state and dynamic situations. This may be more significant on lower pressure networks; in particular the effect of short term dynamic pressure fluctuations in supply networks operating below 0.5 bar. If the GT analysis indicates that pressure fluctuations are expected to exceed acceptable values, the GT will specify the calculated limit and the installation shall be made to comply with this limit.

Note: Modification to the installation may include:

- *safeguards to prevent simultaneous start up of any compressors that operate in parallel*
- *specification of particular ramp up/ramp down rates for the compressor, as expressed by the resultant impact on network pressures*
- *the specification of a number of low and high pressure safeguards on the inlet to the compressor as well as their settings.*

4.3 GAS COMPOSITION AND CONDITIONING

4.3.1 In the UK, the quality of normally distributed NG must comply with the statutory requirements of GS(M)R.

4.3.2 Any additional specification relating to the quality of gas required by the manufacturer of any particular item of equipment shall be considered in the design of the plant and pipework. This may include additional driers and/or liquid interceptors upstream or downstream of the compressor.

4.3.3 During design, consideration shall be given to periodic fluctuations in supply composition including water dew point from the gas transportation system. Confirmation of possible fluctuations should be sought from and approved by the GT.

Note: The GT must provide details affecting a specific location that may be expected to incur gas quality variations, in particular historic events involving liquids and/or particulate contamination.

4.3.4 Gas passing from a compressor or its associated downstream drying system if fitted, shall have a moisture content which shall not cause hydrate/water formation in any downstream equipment or vehicle fuel system under the expected operating conditions.

It may be necessary to install a gas drying system to achieve the required moisture content. Where appropriate NG supplied from any drying system shall be treated to comply with GS(M)R if it is to be resold, for example at a NG vehicle filling station.

4.3.5 Where the composition of the gas to be compressed is required to be within limits specified by the equipment manufacturer, details of the composition of gas and any known variations should be obtained from the gas supplier/GT.

4.4 FILTRATION

4.4.1 A filter or strainer shall be considered on the inlet to any compressor, providing filtration to the level specified by the compressor manufacturer. It shall not be assumed the gas supplier/GT provides adequate filtration.

4.4.2 Consideration shall be given to the fitting of twin stream filters with appropriate valving, to enable routine changing or cleaning of filter elements without interfering with the operation of the compressor.

4.4.3 A system or mechanism shall be employed to ensure that it is not possible to access any high pressure filter for removal before venting the associated pipework.

4.4.4 Consideration shall be given to:

- the provision of filter differential pressure indication and/or alarms
- protection against filter element failure.

4.5 PROTECTION OF THE GAS SUPPLY SYSTEM

There are specific legal duties on persons installing and operating compressors to prevent nuisance to others and to protect the gas supply system which must be complied with (see Sub-Section 3.1 and 4.2).

4.5.1 Protection against reverse pressurisation

4.5.1.1 *General*

4.5.1.1.1 The consumer must provide adequate protection against reverse pressures being fed back into the upstream network.

4.5.1.1.2 Any system assessment shall identify the probability and consequences of failure, as well as any specific precautionary measures that shall be taken to either prevent or reduce the effects of any such failure.

Note: Guidance on calculating potential over and under pressures is given below and in Appendix 10. Appendices 5 and 6 summarise the design of safety devices.

4.5.1.2 *Overpressure protection of the supply system*

4.5.1.2.1 If the maximum settle out pressure (see clause 4.5.1.4) is less than the maximum gas supply pressure, a minimum of one non-return valve (NRV) shall be installed.

Note 1: In the context of this Standard a NRV is one that closes in the event of reverse gas flow and will generally not require manual resetting. This NRV has to be acceptable to the GT and not be affected by the pulsing flows when used in conjunction with a reciprocating compressor, as may be the case with the simple swinging flap type valve.

Note 2: Piston type NRVs may be acceptable for screw, centrifugal and sliding vane compressors that can accept higher inlet pressure drops across such valves. In such cases the inlet low pressure protection device may need locating upstream of the NRV.

Note 3: Further information for NRVs can be found in IGEM/G/10.

4.5.1.2.2 If the estimated maximum settle out pressure does not exceed 2 bar but exceeds the maximum gas supply pressure (MOP_u), a minimum of two safety devices shall be installed. These shall include a NRV (on the outlet of the compressor) and one of the following:

- a relief valve on the suction side of the compressor
- a NRV on the inlet of the compressor

- an actuated slam-shut valve (SSV) installed on either the inlet or outlet of the compressor, with its signal taken from the inlet of the compressor. Any such valve shall close on unacceptably high pressure on the upstream side of the compressor and shall not be capable of being reset until the pressure has been restored to normal.

  Note: This valve may be pneumatically (gas or air) driven or electrically powered.

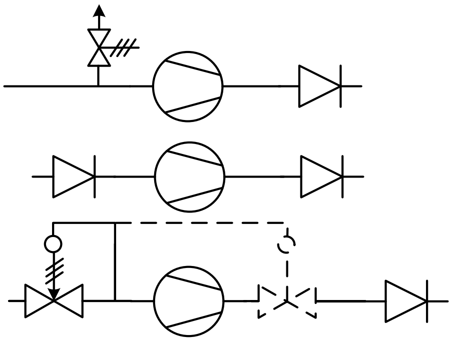
4.5.1.2.3 If the estimated maximum settle out pressure exceeds 2 bar and exceeds the maximum gas supply pressure (MOP_u), a minimum of three safety devices shall be installed. These shall include a NRV on the outlet of the compressor and upstream of any receiver (it need not be upstream of the filter coalescer) and at least two of the following:

- a relief valve on the inlet of the compressor
- a NRV on the inlet of the compressor
- an actuated SSV which closes on sensing unacceptably high pressure on the upstream side of the compressor which shall be fitted upstream of the compressor (and upstream of any inlet pulsation/snubber vessel).

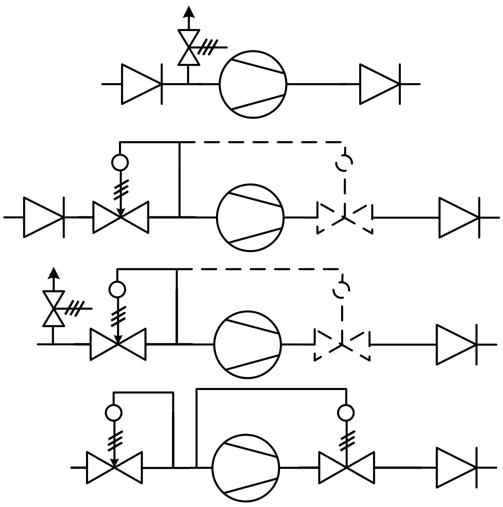
Note 1: Figure 3 shows arrangements described above.

Note 2: Other protection methods, for example a double block and bleed valve system, are acceptable provided they give at least an equivalent level of protection to that obtained in clause 4.5.1.2.2 and 4.5.1.2.3 as appropriate. A reciprocating compressor without any form of spillback or cylinder unloading may be considered as equivalent to a second NRV.

Note 3: In certain cases particularly large or complex installations, it may be necessary to fit an additional NRV on the outlet of the meter installation.



(a) System protection systems for maximum settle out pressure not exceeding 2 bar (clause 4.5.1.2.2)



(b) System protection systems for maximum settle out exceeding 2 bar (clause 4.5.1.2.3)

KEY

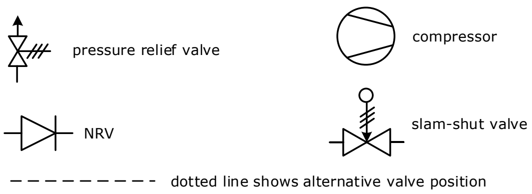


FIGURE 3 - TYPICAL CONSUMER INSTALLATIONS

4.5.1.3 *Under pressure protection of the supply system*

In the event of an inlet low gas pressure condition occurring, the control system shall respond to a sensor in the inlet pipework of the compressor and shut down the compressor if the gas supply pressure falls to an unacceptable level (also see clause 4.5.2 and 6.19.2).

4.5.1.4 *Determination of the estimated maximum settle out pressure*

The maximum settle out pressure at the ECV shall be determined by calculating the worst case condition that can occur when the compressor discharge volume expands back into the supply installation.

$$\text{Estimated PSO} = [(P_{in} V_{in}/ Z_{in}) + (P_{out} V_{out}/ Z_{out})] / (V_{in} + V_{out})$$

P_{so} final equilibrium pressure at the ECV (bar absolute)
P_{in} maximum pressure at the ECV when the compressor is operating (bar absolute)
V_{in} volume of pipework (including any snubber volumes) between the compressor inlet and the ECV (m^3)
Z_{in} compressibility factor at P_{in}
P_{out} maximum outlet pressure of the compressor (bar absolute)
V_{out} total volume of the compressor outlet pipework including any receiver (m^3)
Z_{out} compressibility factor at P_{out}

Note: Appendix 9 includes compressibility factor information for a typical UK NG. Appendix 10 gives an example of the calculation.

It may also be worth mentioning in an additional note that this calculation differs from the precise calculation in that it assumes ZSO = 1. If a more precise PSO is required then it can be calculated by multiplying the estimated value by ZSO for that value and then iterating to a precise value.

Note: This calculation assumes ZSO = 1.0 and is adequate for most applications. In cases where a more precise calculated value of PSO is required this can be achieved by multiplying the initial value obtained by the correct ZSO and repeating to iterate to a precise value.

4.5.1.5 *Potential high reverse pressures applied to the inlet system*

The compressor manufacturer/system designer shall ensure that any inlet pulsation/snubber vessel is of sufficient size to limit pressure increases during any bypass flow condition to a level of at least 20% below the relief valve setting of either the inlet cylinder of the compressor or any other relief valve within the upstream pipework or meter installation system.

4.5.2 **Protection against under pressure**

The gas supply network upstream of the primary meter installation must be protected from unacceptably low pressure conditions resulting from compressor operation.

4.5.2.1 An independently hardwired low gas pressure cut off switch shall be installed, which shall operate when the pressure falls below that acceptable to the GT. Automatic restart shall be prevented after the compressor has been stopped by the low pressure cut off.

Note: The set pressure of the pressure cut off switch will reflect the minimum pressure acceptable to the GT as measured at the ECV.

4.5.2.2 If necessary an additional safety device shall be installed to prevent the compressor from causing unacceptably low pressure in the gas supply to other plant i.e. boilers etc. supplied from the pipework common to the compressor suction.

Note: For example, the safety device could include a specific start up control system, to ensure that specified rates of change of flows (ramp rates) would not be exceeded, or a "low suction pressure" SSV could be installed.

4.5.2.3 There shall be no built in mechanical or electrical by pass of the pressure switch.

4.5.2.4 Latching pressure switches shall not be used unless the design is such that failure of or tampering with the mechanism cannot lead to unsafe conditions.

4.5.2.5 The pressure switch:

- should be capable of onsite adjustment of the cut off pressure
- shall be capable of being sealed to prevent unauthorised adjustment
- setting should be reproducible within +/- 5% of the set point
- setting shall be at a level so as not to adversely affect any other appliance on site or to affect the gas supply. The GT should be consulted to determine its requirements.

Note: The minimum acceptable cut off pressure for normal low pressure supplies is 10 mbar.

4.5.3 Creep relief valves

4.5.3.1 Consideration shall be given to providing additional small capacity creep relief valves to give protection for upstream pipework against the possibility of creep from the discharge side during prolonged shut down conditions.

4.5.3.2 The capacity of any such relief valve shall be such as will safely handle foreseeable reverse flows under fault conditions.

Note 1: Typically this will be less than 5% of design flow.

Note 2: Pressure settings are determined by reference to the lower limit of the SSV taking into account accuracy and repeatability of the set point of both devices.

4.5.4 Vent pipes from relief valves

4.5.4.1 Vent pipes from relief valves should be designed to prevent undue back pressure significantly restricting the valve capacity.

4.5.4.2 The pressure loss across the vent line at the maximum relief valve capacity should be estimated, for example using a flow calculator and making due allowance for any bends.

For sub critical flow, the back pressure at maximum flow should be small when compared with the relief operating pressure. For example a back pressure of 5% of the operating relief pressure would reduce the relief capacity by about 2.5%. If necessary the capacity should be recalculated allowing for the back pressure.

4.5.4.3 For choked flow it shall be confirmed that the back pressure is not such that the flow at the valve will no longer be choked.

SECTION 5 : METERING/COMPRESSOR EFFECTS

The operation of a gas compressor in particular a reciprocating compressor, can substantially interfere with the proper operation of gas metering equipment. The effects produced depend upon the type of meter involved and are summarised in Appendix 3.

5.1 The design of any gas metering system, associated with a compressor load, shall take account of the possible effects outlined in Appendix 3, by selection of an appropriate type of meter together with the specification of compressor generated pulsation and load changes.

Note: IGEM/GM/8 provides further information.

5.2 Any constraints on pulsations or compressor operation, imposed by the gas supplier, that are essential to the metering method to be used, shall be taken into account.

5.3 The design and operation of any compressor system and the type and installation of the meter shall be such that the meter accuracy and life are not adversely affected by any of the following:

- flow pulsations generated by the compressor during steady state operation
- any rapid or frequent flow changes caused by the operation of the compressor load control system, for example step unloading at regular intervals
- any venting or other transient situation which may cause excessive ''over speeding'' of the meter.

Unless other considerations apply, these influences shall be restricted in their design to limit effect on the meter within the following limits:

- Reference should be made where necessary to ME1 and/or ME2 for meter system accuracy
- no meter to be exposed to rates of change of flow or pressure outside the limits specified by its manufacturer.

SECTION 6 : INSTALLATION OF A COMPRESSOR

6.1 LOCATION

6.1.1 Any compressor shall be installed in a well ventilated location, after completion of a risk assessment on the suitability of that location.

Note: Where this may result in unacceptable effects on safety, security, noise levels, weather protection etc., the use of a room or an enclosure with a suitably designed ventilation system is acceptable (see clause 6.5).

6.1.2 Adequate access shall be available for maintenance. Clearance should be provided on all sides and above the compressor, in accordance with manufacturer's instructions.

Note: This may require provision for lifting equipment.

6.1.3 Due consideration shall be given to the expected ambient temperatures to ensure that the compressor cannot operate outside the manufacturer's specified operating temperature. If necessary, a supply of cooling air shall be provided, for example by means of additional natural ventilation.

Ambient temperatures within the enclosure shall be limited to a maximum of 45°C or as specified by the manufacturer.

6.1.4 A gas compressor shall not be located in a room specifically intended to house an air compressor, unless the air inlet of each compressor is independently ducted from outside the room.

Note: This is intended for example to prevent leaks of gas being drawn into the inlet of the air compressor and being distributed around the compressed air system.

6.1.5 The chosen location shall take account of the potential failure of any high speed rotating parts leading to injury to persons or significant damage to other gas pipework or controls. Appropriate safety measures shall be implemented for example spacing, guarding, etc.

6.1.6 Gas compressors shall not be located in engine enclosures.

Note: It is not possible to make gas engines suitable for Zone 2 environments (see Sub-Section 6.2). However gas compressors may be located in plant rooms subject to risk assessment and hazardous area classification (see Sub-Sections 6.2 and 6.3).

6.2 HAZARDOUS AREA CLASSIFICATION

6.2.1 Hazardous areas may have to be approximated at an early stage in a project to allow electrical equipment to be specified and other potential sources of ignition to be located. However a definitive drawing shall be produced prior to operation of the compressor, based on PD CLC/TR 60079.

6.2.2 Where doors are open during plant operation or when there is high pressure gas within an enclosure, it shall be assumed that the zoned area extends the full distance through the door opening as given above.

6.2.3 A hazardous area classification shall be undertaken to determine the safe selection and location of electrical equipment and location of other potential sources of ignition.

Note 1: It may be necessary to seek specialist advice for such a classification.

Note 2: For existing installations not complying with IGEM/UP/6, it may be acceptable to use pro-rata zoning distances between each pressure break point.

The classification shall be in accordance with a recognised hazardous area assessment procedure e.g. IGEM/SR/25, IGEM/UP/16 or PD CLC/TR 60079 as appropriate.

Note: When performing hazardous area assessments consideration needs to be given to primary and secondary releases.

6.3 COMPRESSORS IN BUILDINGS

6.3.1 General

6.3.1.1 Adequate ventilation shall be provided for any compressor location. All spaces shall include a suitable ventilation system (see Sub-Section 6.5), gas venting system, safety system and certificated electrical and instrumentation equipment.

The build up of a gas concentration shall be limited such that, in the event of an explosion there will not be injury to persons or structural damage to buildings that might lead to their collapse. The rate of ventilation should be such as to limit the size of the cloud of gas envelope such that, if ignited it would not cause a hazard.

Note 1: In many cases this will require limiting the pressure rise on ignition to the strength of the enclosing space that could be as low as 10 mbar. The application of sensitive gas detection and resulting rapid gas shut off can reduce the size of the problem. See BS ISO 21789 and ASME 2005-GT-68725.

Note 2: For a simple enclosed space where a high proportion of the walls are open to atmosphere or louvered, natural ventilation could be considered sufficient. Because of the potential high level of noise emitted by the machinery, the design of an enclosure is usually of a robust, fully sealed, thick walled type of special design requiring interlocked mechanical ventilation. Further investigations on this topic were performed during 2007 at the Health and Safety Laboratories. The results are available on the HSE website.

6.3.1.2 All spaces around compressors and their ancillaries shall be analysed for the limits and zoning requirements with respect to hazardous areas (see clause 6.2.3).

6.3.1.3 As far as is practicable the spaces around compressor plant shall be kept clear of other plant and systems to permit servicing and maintenance to take place safely. The storage of extraneous and combustible materials adjacent to compressors shall be prohibited.

6.3.1.4 Acoustic panels around plant or forming part of an enclosure (see Sub-Section 6.4) shall be restrained and/or be of light weight such that they do not lead to danger in the event of explosion.

6.3.1.5 The storage of flammable products e.g. lubricating oils within a compressor housing shall be discouraged as it constitutes a fire and spillage hazard.

6.3.1.6 The effects of a gas leak, and the implications of subsequent ignition, shall be assessed when considering installing a compressor within a building.

Note: For example, the use of enclosed basements is not considered a suitable location without the use of mechanically ventilated enclosures.

6.4 ENCLOSURES

6.4.1 Enclosures, for example purpose built acoustic enclosures in which ignition sources may exist shall in general be considered as a complete hazardous area and zoned as in Sub-Section 6.2.

6.4.2 Enclosures may require suitable means for explosion relief, sufficient to ensure structural integrity in the event of an explosion within it. Guidance on explosion relief should be taken from IGEM/TD/13 or another standard that is applicable to the design conditions.

6.4.3 Unless the risk assessment indicates otherwise any enclosure shall be fitted with a gas detection system.

6.5 VENTILATION

6.5.1 The ventilation air rate (see clause 6.3.1.1) should be such that a gas leak, if ignited would not lead to an explosion of such magnitude as would lead to injury to persons or unacceptable damage to property. This should be balanced by the potential for an ignition source to exist and the likelihood of persons to be at work within the enclosure during its operation. The magnitude of the problem can be reduced by early gas detection (5 to 10% Lower Flammability Limit (LFL)) and rapid reduction (within 30 seconds) of the gas pressure to a low level (typically below 0.5 bar).

Note: This approach may be more relevant to systems operating at very high pressures.

6.5.2 A ‘‘potential gas release’’ shall be quantified in accordance with IGEM/SR/25. Calculations to determine the potential release rate shall be based on the maximum and minimum inlet and outlet pressures.

6.5.3 A ventilation system shall be provided which under normal operating conditions shall:

- ensure continuous dilution of the ambient air such that a potential gas release shall not produce a concentration of flammable gas of greater than 25% LFL.

  Note: Typically this is about 88 times the gas leakage release rate and 40 to 50 air changes per hour would not be unusual. See IGEM/SR/25.
- ensure that there are no ‘‘dead’’ spaces where flammable gas could accumulate
- provide sufficient ventilation to cater for any air cooling requirement of the enclosed equipment. Where external cooling radiators are applied, the ventilation rate should be adequate for cooling under summer design conditions.

The ventilation system in a space where ignition sources may exist shall remain in operation or on standby whenever pressurised gas remains in the pipework in any enclosure/room. The standby mode option shall only be used in conjunction with a gas detection system with heads appropriately located to detect foreseeable local points of gas leakage, for example shaft seals, crankcase vents. Where gas detection is not fitted, failure of the ventilation system (including any standby system) shall cause depressurisation of the high pressure system to below 0.5 bar, preferably within 30 seconds.

6.5.4 The internal pressure of the enclosure should not deviate appreciably from outside atmospheric pressure.

Note: If this is not achieved, difficulty might be experienced in opening or closing access doors and panels.

6.5.5 Ventilation air shall be uncontaminated and taken from a non-hazardous area, such that a flammable atmosphere cannot be induced into the ventilation system or the enclosure.

6.5.6 Any purpose provided ventilation opening shall not be liable to inadvertent obstruction.

6.5.7 Acoustic treatment shall not reduce the effectiveness of ventilation openings.

6.5.8 Any mechanical ventilation shall be considered a failure risk. Consequently the ventilation system design in a space where ignition sources may exist, shall include an emergency procedure that ensures that upon failure of the ventilation system and thereafter upon gas detection, the hazard is controlled by reduction of the contained gas pressure within the enclosure to below 0.5 bar (see Appendix 7).

Note: Compressor locations may have any combination to any degree of natural and mechanical ventilation.

An example of combined ventilation type would be sufficient natural ventilation to accommodate a ''potential gas release'' at the maximum compressor inlet pressure with additional mechanical ventilation to accommodate a ''potential gas release'' at the maximum compressor outlet pressure.

6.6 CERTIFIED ELECTRICAL, POWER AND INSTRUMENTATION EQUIPMENT

All electrical, power and instrumentation equipment within an enclosure shall be in accordance with the clause 6.2.3.

6.7 GAS DETECTION SYSTEM (WHERE FITTED)

6.7.1 Detection heads shall be strategically placed to monitor two alarm levels, for example 5 to 10 and 25% LFL.

Note 1: To reduce the possibility of spurious trips, a three head voting system may be incorporated. For example any one head indicating 25% LFL causes alarm activation. Whereas any two heads indicating 25% LFL will result in compressor trip and enclosure venting.

Note 2: The use of low trip alarm levels for example 5 and 10% LFL, will increase the levels of safety.

6.7.2 Any gas detector indicating above a specified level for example 10% LFL, on start up shall prevent operation of the compressor.

6.7.3 Consideration shall be given to the need to incorporate fire, smoke and rate of temperature rise detection equipment in addition to an automatic fire extinguishing system. Where gaseous fire extinguishant is used the ventilating system ducting shall contain automatic shutters to prevent the loss of extinguishant.

6.7.4 Special attention shall be given to the need to maintain ventilation of the enclosure after shut down of the compressor when a gas detection system has activated.

6.7.5 Personnel escape doors shall be provided at strategic positions in the enclosure walls. Operational procedures shall not permit personnel to enter an enclosure until it has been safely ventilated to a low level.

6.7.6 Emergency manual shut off buttons shall be located at/nearby all personnel doors.

6.8 VENTING SYSTEMS

6.8.1 Compressors should have an emergency depressurisation and venting system.

Note: For compressors with a normal outlet pressure not exceeding 2 bar, an emergency depressurisation and venting system may not need to be fitted.

In the event of any emergency for example gas leakage, fire, or ventilation system failure; the system shall also isolate gas supplies to and from the compressor plant and equipment in the protected enclosure/building/room.

6.8.2 The compressor installation emergency depressurisation system shall be capable of reducing gas pressure in all pipework, plant and equipment, to a safe level over a period of time both of which shall be determined by risk assessment.

Note: The location of large pressure vessels within the compressor space is not recommended due to the resulting large volumes of gas that will need to be vented due to an emergency caused by gas leakage, fire, or ventilation system failure.

6.8.3 Venting shall be to atmosphere via a vent stack of suitable height exhausting to a safe location and taking into consideration the following;

- should terminate preferably 3 m above ground level and preferably 1 m above roof level
- vent pipes should terminate vertically upwards where practicable or vertically downwards
- vents should not pass through electrical intake rooms, transformer rooms, lift shafts, refrigeration chambers
- vents shall be of permanent construction
- vents should be straight and short as practicable and shall be designed to prevent undue back pressure upon the relief valve
- consideration shall be taken in the design of vent terminals to minimise the risk of blockage from foreign matter and ingress of water
- vent system shall have adequate support to reduce stresses caused by the venting process
- when deciding on the location, consideration shall be given to the preservation of the environment, the impact on planned alterations, routing and termination of vents
- the hazardous area zone should not pass the outside of the customers boundary onto publicly accessible areas
- Ventilator shall not be located by or near any air intake duct.

Note: Further guidance on zoning considerations is provided in IGEM/SR/25 or IGEM/UP/16 as appropriate and for venting see IGE/SR/23.

6.8.4 Relief valves and vent sizing/length are dependent on the particular relief valve characteristics and advice should be sought from the manufacturer/supplier.

Certain items of equipment would require a permanent facility via local vents terminating above enclosure roof height i.e. lube oil reservoir vents, control valves, compressor distance pieces, etc. These shall also be zoned according to IGEM/SR/25.

6.8.5 Provision shall be made for ancillary vents from parts of the compressor design, for example crankcase vents etc.

6.8.6 Where necessary the termination heights of vents shall be increased if the roof area is also used for normal access to ancillary equipment for maintenance purposes or if there are other nearby structures (see IGEM/SR/25).

6.8.7 Emergency and pressure relief valve vents shall terminate vertically upwards with an appropriate device to minimise the ingress of rain etc. (see Figure 4).

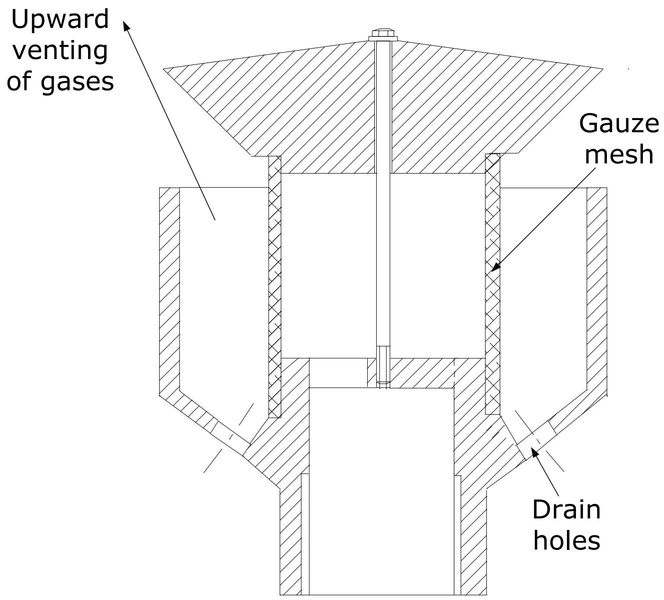


FIGURE 4 - TYPICAL "IDEAL" VENT TERMINAL

6.8.8 Overpressure relief valve protection shall be applied to gas/liquid cooling systems where failure of the heat exchanger could lead to an overpressure condition within the liquid side of the cooling system.

Consideration shall be given to the application of pressure sensors within the liquid side of the cooling system to give an early warning of impending heat exchanger failure. Vents from such systems shall take account of the fact that they may discharge fluids as well as gases.

6.8.9 The use of a flame arrestor is not recommended with natural gas compressors.

Note: Flame arrestors may be required with air/gas mixing machines.

If a flame arrestor is fitted, the required flow capacity for the vent shall be maintained under all conditions and it shall be designed to encourage the safe dispersion of the releasing gas, and prevent the ingress of water, rain, snow, etc. (see also Sub-Section 6.8).

Any flame arrestor shall comply with BS EN 12874.

6.8.10 The siting of any vent termination may result in a hazardous area classification at the point of discharge (depending on the nature of the vent), for example continuous; expected during normal operation, etc. The fitting of a flame arrestor may enlarge the hazardous area from that of an ideal vent (see IGEM/SR/25).

6.8.11 Vent manifolding shall be permitted only where it can be shown that excess pressures, or adverse back pressure effects on other equipment, will not occur.

Note 1: Vent manifolding across parallel compressors is not recommended.

Note 2: Vents may also be required on lubrication oil reservoirs, vented distance pieces, gas/water cooling systems etc.

Note 3: Advice on hazardous area classification is contained in BS EN 60079-10 and IGEM/SR/25.

6.8.12 Vent pipework shall be designed for exhausting gas at high pressure and high velocity, by catering for the affects of erosion, excessive noise and reduction in temperature due to expansion of the gas.

6.9 MOUNTING A COMPRESSOR

6.9.1 The mounting design/selection shall take into account the vibration characteristics of the compressor. Appendix 4 describes the causes of vibration and methodology for limiting effects.

Note 1: Reciprocating compressors generate free forces which can be minimised by careful design. Consequently reciprocating compressors generally require a mass concrete and/or anti-vibration mounts (AVMs) on which to stand.

Note 2: A compressor installed on a concrete base has a natural frequency determined by the structure and loading of the ground, which is considerably higher than the vibration frequency of the compressor itself (normally twice its rotational speed). Knowledge of the soil mechanics and concrete structures is essential when designing a concrete foundation.

Note 3: Screw, centrifugal and rotating vane compressors, being high speed rotary machines, develop lower levels of mechanical vibration than reciprocating compressors during normal operation. Therefore they can be mounted with or without AVMs.

6.9.2 A compressor installed on AVMs usually has a natural frequency considerably lower than the vibration frequency of the compressor alone. With this type of installation the forces transmitted to the foundations are normally less than 10% of the free forces of the compressor. This type of installation is only suitable for high speed compressors (700 rpm and over). Where large out-of-balance forces exist, consideration has to be given to mounting the compressor on an inertia block prior to mounting on the AVMs.

6.9.3 Inlet and outlet pipework shall not be subjected to a vibration level exceeding 10 mm/s RMS. Where the compressor would cause this level to be exceeded, a flexible connection shall be used (see clause 6.11.1).

Any compressor vibration shall not exceed 15 mm/s RMS. Where this level is foreseeable, the upper end of the compressor crankcase on a reciprocating compressor, should be fitted with a vibration switch designed to signal a visual alarm on the control panel if the compressor vibration was to exceed 15 mm/s RMS.

6.10 COMPRESSOR DRIVE

Electric motor drives shall be zoned as per the compressor package when located within the same space as the compressor.

Note: Where an electric motor or engine prime mover is used and located in a separate enclosure, it need not be zoned provided that there is:

- *guaranteed sealing of the drive shafts between the enclosures or*
- *there is a physical break and externally ventilated air gap between the enclosures or*
- *there is a guaranteed difference in compartment ventilated air pressures such that high pressure gas cannot enter the "safe" enclosure.*

For engine drives, reference should be made to IGEM/UP/3.

6.11 COMPRESSOR PIPEWORK

6.11.1 Flexible connections shall be of rigid or flexible construction with factory fitted end fittings and in accordance with the paragraphs below.

6.11.2 Corrugated stainless steel flexible connections shall be to BS EN ISO 10380 or an equivalent standard and in accordance with IGEM/UP/2.

6.11.3 Suitability of a flexible connection for a specified vibration level should be confirmed with the manufacturer of the compressor and the connection.

6.11.4 Non-metallic hoses shall comply with BS EN 1762.

6.11.5 Any flexible connection shall be suitable for any combination of the extremes of service conditions.

6.11.6 Flexible hoses should be inspected by a competent person according to manufacturers' recommendations and conditions of use. Replacement should be carried out at pre-determined intervals, for example every five years or as recommended by the manufacturer.

6.11.7 Where it is necessary to isolate the gas pipework from compressor generated vibration, this shall be specified by the compressor manufacturer in association with the system design engineer.

6.11.8 Operating methodologies should be prepared during the design stage, covering the procedures for commissioning the plant or separate parts of the plant to gas and to air. The methodologies should be such as to enable the designer to determine the location of isolation, tightness test, purge and gas sampling valves.

6.11.9 A readily accessible manual isolation valve shall be installed immediately upstream and downstream of the compressor system; including any flexible connections and pressure vessels located within the compressor enclosure/room.

Note: Valves may also be needed either side of pressure vessels or other components to enable simple maintenance to be applied without total depressurisation of the whole system.

Consideration shall be given to the use of valves providing a double block and vent configuration on high pressure systems to enable safe working practices during plant maintenance.

Note: Such valves may be ball valves with inter venting between the seats (three port).

6.11.10 A by-pass shall not be fitted around any item of safety equipment. In the extremely rare case where it is not practicable to shut down plant for maintenance, etc., duplicate safety equipment shall be provided.

6.11.11 Suitably sized and located valved connections shall be fitted within the compressor pipework to enable safe pressure testing, decommissioning to air and recommissioning to gas of the compressor package.

Note 1: Typically valves will need to be 25% of the main pipe size with valved test points for gas analysis provided.

Note 2: The preparation of operating methodologies at an early stage in the design will help ensure correctly sized and located valves.

6.12 PIPEWORK

For pipework of MOP at or below 0.5 bar, reference shall be made to IGEM/UP/2.

The following applies to pipework of MOP in excess of 0.5 bar and is additional to the requirements of IGEM/UP/2.

6.12.1 Pipework shall be located in a duct or void only if the duct or void is ventilated adequately (further guidance is provided in IGEM/UP/2).

6.12.2 Pipework of MOP exceeding 2 bar and exceeding 25 mm diameter shall not be located in a buried common service duct unless adequate ventilation and safety shall be assured by risk assessment.

6.12.3 Any compression fitting which shall not exceed 40 mm diameter shall if used for MOP exceeding 5 bar, be of the twin ferrule type made of stainless steel and shall provide positive retention of the pipe in the fitting while maintaining the integrity of the pipework.

6.12.4 The number of flange, screwed and compression joints shall be kept to a minimum.

Note: The use of other jointing methods, for example mechanically pressed fit joints on pipework of diameter not exceeding 25 mm, may be acceptable where the manufacturer of the fitting(s) makes a declaration of suitability for the duty.

As far as is reasonably practical welded flanges should only be used at the ends of pipework, for example at the building ECV/additional emergency control valve (AECV), at valve positions and at the compressor inlet/outlet connections.

6.12.5 Valves and fittings shall be of carbon steel and shall conform to, as appropriate:

- BS 1560
- BS 1640
- BS EN 10253-1
- BS 3799
- BS EN 1092-1
- BS EN 1515 1 and 2.

6.12.6 Steel pipe shall conform to, as appropriate:

- BS EN 10216-1
- BS EN 10216-5
- BS EN 10217-1
- BS EN 10217-3
- BS EN 10217-5
- API 5L Grade B
- ASTM A269 Grades 304L, 316, 316L or 321.

6.12.7 Wall thickness of steel pipes shall be selected consistent with the working pressure, operating conditions and relevant design standards.

6.12.8 Pipework shall normally be of steel construction and jointed using welding or other method as required by the applicable standard. This must include appropriate testing as specified for the design application.

Note: For welding requirements reference can be made to other appropriate standards such as BS 2633.

6.12.9 **Welders competence**

Welders shall be qualified and approved in accordance with the welder approval standards listed in Table 1.

CONSTRUCTION STANDARD/CODE	WELDING PROCEDURE APPROVAL	WELDER APPROVAL
BS 2633	BS EN ISO 15614	BS EN 287
BS 4677	BS EN ISO 15614	BS EN ISO 9606
ANSI/ASME B31.1	ASME B&PV Section 1	ASME IX
ANSI/ASME B31.3	ASME B&PV Section 1	ASME IX
BS 2971	BS EN ISO 15614	BS EN 287
BS 4515-1	BS 4515-1	BS 4515-1

TABLE 1 - WELDING STANDARDS

Note: Further welding requirements can be found in IGEM/UP/2.

6.12.10 A manual isolation valve for emergency use shall be installed outside each building or enclosure housing a compressor. This valve shall enable isolation of that building from the gas supply. Consequently it shall be mounted in a safe and accessible position and shall be operated at least once annually, preferably more frequently. The valve shall be labelled "Gas Emergency Control".

6.12.11 The gas pipework to and from any compressor shall be securely supported and protected against corrosion or mechanical damage.

6.12.12 Pipework and supports shall be designed to accommodate any pipe movement and increased forces and weight encountered during a test procedure.

6.12.13 Pipework shall be subject to regular visual inspection by a competent person. The inspection intervals depend on operating conditions and pressures, however inspection intervals shall be 12 months or less.

6.12.14 Carbon steel pipe may be acceptable at pressures above 100 bar. However for such pressures consideration shall be given to the use of seamless stainless steel to ASTM A269 grades 304L, 316, 316L or 321.

6.13 BURIED PIPEWORK

6.13.1 Buried pipework shall be:

- fabricated from steel pipe in accordance with the specifications in clause 6.7.6 for MOP not exceeding 100 bar or of stainless steel to ASTM A269 Grade 316L for all pressures or
- welded and inspected in accordance with BS 2633 and BS 4677.

6.13.2 NDT shall be applied as per Table 2 below.

MOP	TYPE/POSITION OF WELD	VISUAL EXAMINATION	RADIOGRAPHIC AND/OR ULTRASONIC EXAMINATION	SURFACE CRACK TEST
500 mbar < MOP ≤ 5 bar	Circumferential welds on pipes and pipe fittings	10%	10%	
	Branches, fillet welds	10%		10%
	Longitudinal welds	100%	10%	
5 bar < MOP ≤ 16 bar	Circumferential welds on pipework and pipe fittings	20%	10%	
	Pipework in occupied areas	20%	10%	
	Branches, fillet welds	100%		10%
	Longitudinal welds	100%	100%	
	Welds which cannot be tested hydrostatically	100%	100%	
MOP > 16 bar	Circumferential welds on pipes and pipe fittings	100%	20%	
	Branches, fillet welds	100%		20%
	Longitudinal welds Sweepolets	100%	100%	
	Welds which cannot be tested hydrostatically	100%	100%	
	Pipework (appliances) installed in occupied areas	100%	100%	

Note: This Table is based upon Table 22 in BS EN 15001.

TABLE 2 – MINIMUM INSPECTION AND TESTING OF STEEL WELDS FOR INSTALLATIONS WITH MOP EXCEEDING 500 MBAR (replicated from IGEM/UP/2 Edition 3)

6.13.3 Carbon steel pipework shall be coated and have cathodic protection to BS 7361.

6.13.4 The number of joints shall be minimised.

6.14 TESTING

Following installation pipework of MOP not exceeding 16 bar shall be tested generally to IGE/UP/1.

For higher MOP and for hydrostatic testing procedures pipework shall be tested as described in (a) or (b) below:

(a) Pneumatically pressure tested for sizes not exceeding 50 mm nominal bore and MOP not exceeding 40 bar. Appendix 11 describes a detailed procedure.

Where pipework is pneumatically tested, special attention shall be given to material selection, connection methods and NDT, to ensure safety and to limit damage in the event of failure. Hydrostatic testing is preferred.

(b) Hydrostatically pressure tested (see also IGEM/TD/1) pipework shall be designed and installed to facilitate drainage and drying following test completion. Pipe supports, and thrust supports at bends, etc., shall be designed for additional loads resulting from weight of water, induced thrusts etc. when tested in situ. Prior to the application of the hydrostatic test, a pneumatic tightness test shall be applied as detailed in (a) above or IGE/UP/1, at a pressure not exceeding 5 bar or the design working pressure, whichever is the lower.

After the application of the hydrostatic test, a pneumatic tightness test shall be applied as detailed in (a) above or IGE/UP/1, at a pressure not exceeding 5 bar or the design working pressure, whichever is the lower.

No water shall remain within the pipework following testing, as water ingress into a running compressor could be catastrophic. After testing, the pipework system shall be dried. This may be achieved by vacuum drying or other equally effective means.

6.15 VENTS

6.16 PULSATION, FLOW CHANGE AND PROTECTION OF THE METERING SYSTEM

6.16.1 Reciprocating compressors

6.16.1.1 *General*

6.16.1.1.1 A reciprocating compressor will generate flow/pressure pulsations during operation. The compressor manufacturer shall be consulted and to confirm that the levels specified in clause 6.16.2 will not be exceeded.

6.16.1.1.2 The compressor manufacturer/packager shall ensure that suitably designed pulsation vessels or their equivalent and pressure relief systems are fitted in the compressor package on the inlet, interstage or outlet as necessary.

6.16.1.2 *Pulsation limitation*

6.16.1.2.1 Where continuous flow and pressure pulsations are produced at the compressor plant inlet, they shall be damped adequately at source by means of suitably sized pulsation/snubber vessels.

6.16.1.2.2 The maximum allowable pulsation levels depend on the type of fiscal gas meter employed by the gas supplier or meter asset manager (MAM) and the upstream pipe volume/configuration and is governed by the following criteria.

(a) Where a turbine meter is installed upstream of a compressor, the amplitude of the flow oscillation at the meter position shall be less than +/- 5% of the mean flow for all flows in excess of 10% of the compressor capacity. In addition, (c) below shall be specified.

(b) Where an RD meter is to be installed upstream of the compressor, the pressure oscillation at the meter outlet shall be such that the maximum rate of change of pressure is less than 0.34 bar/s.

(c) Where either a turbine meter or no meter is installed upstream of the compressor, the maximum amplitude of the pressure oscillation at the compressor inlet shall be less than:

- ± 5 mbar at MOP_u not exceeding 75 mbar
- ± 10 mbar at MOP_u exceeding 75 mbar but not exceeding 2 bar
- ± 25 mbar at MOP_u exceeding 2 bar.

6.16.1.2.3 If a pressure regulator or similar device is considered to be an integral part of the pulsation damping system, the above pressure oscillations shall not be exceeded in the event of failure in the open position of the regulator if such failure would not initiate an alarm or trip out the compressor.

Note: The background to the levels of pulsation quoted above is:

- *when a turbine meter is fitted, the level specified has to be sufficient to reduce any effect on meter registration to < 0.1%*
- *when a rotary displacement meter is fitted, the level specified is to minimise the load on the bearings*
- *when no meter is installed on the immediate inlet, the level specified has to be sufficient to avoid possible interaction or interference with other plant. These values correspond to between ± 0.5% and ± 1% of the absolute pressure, which is the manner in which pulsation compressor manufacturers often quote damper performance. It is also more stringent than would often be quoted.*

6.16.1.3 *Compressor flow changes during "normal operating" conditions*

The compressor outlet pressure control system shall be such that during "normal operation", there is no possibility of changes in flow demand at the compressor inlet greater than ± 25% of the nominal compressor capacity occurring, at intervals more frequent than once every 15 minutes.

Note 1: "Normal operation" is defined as the flow and inlet pressure conditions at which the compressor will operate for significant periods. For example on a typical gas turbine combined heat and power (CHP) installation, normal operation might be at 30% to 90% of the maximum compressor load. Such conditions as black start and turbine crash stop are excluded from this requirement (but see clause 6.16.1.4 below).

Note 2: This is intended to exclude the use of a reciprocating compressor controlled solely by simple single step unloading and also requires that a compressor controlled by for example, a combination of step unloading and spillback operates stably at all normal conditions.

6.16.1.4 *Compressor flow changes during "abnormal operating" conditions*

6.16.1.4.1 The compressor control system shall be designed such as to minimise, as far as is reasonably practicable the magnitude and rate of load changes imposed on the compressor supply during abnormal operating conditions.

Note: "Abnormal operating conditions" means those that will only occur on rare occasions during operation of the compressor. Examples may be black start of the compressor, gas/oil changeover of a gas turbine or fault conditions such as a turbine crash stop or compressor trip.

6.16.1.4.2 The consumer shall provide information describing the compressor control action and flow time profiles anticipated during black start, crash stop and similar situations to the GT if requested.

Note: Gas suppliers or GTs usually reserve the right to require changes if subsequent operational analysis shows the anticipated demands to be unacceptable to its metering or supply system. The accuracy of supplied information at the design stage is therefore of paramount importance.

6.16.1.5 *Reciprocating compressor staging pulsation control*

6.16.1.5.1 Pulsations which exist at the discharge port of each staging cylinder can cause reduced valve life, high stress levels in interstage and discharge pipework and higher levels of power consumption. Consequently to avoid these undesirable effects, pulsation suppression devices should be incorporated in the design of the compressor.

These pulsation suppression devices shall be designed to limit the peak to peak pulsation levels to 7% or less of mean absolute pressure when measured at the compressor cylinder flanges.

Note: The resonance of a gas system can be eliminated by introducing friction losses or by changing the mass spring system. Friction is introduced by reducing port or line sizes. Mass spring systems in the gas are changed by changing manifold volume, port sizes or port lengths.

6.16.2 **Screw, centrifugal and sliding vane type compressors**

These compressors generate pulsating flows that are a function of speed and design for example the number of lobes on the male rotor screw. Normally these pulsating flows are small provided the capacity control system operates stably.

Performance can be significantly affected if care is not taken in the design of the discharge pipework. For optimum performance the discharge port and downstream pipe system should be designed to take account of any recommendations from the manufacturer.

6.17 COMPRESSOR CONTROL

Guidance on the control of compressors is provided in Appendix 8.

6.17.1 Where flow control is achieved by cylinder unloading valves, fail safe type valves should be installed that require external pressure to load and are normally unloaded in the absence of this pressure.

6.17.2 Where high gas pressure is used to load, an independent pressure source for initial start up (black start condition) shall be provided. Nitrogen from cylinders is a convenient method when automatic isolation is provided when adequate line pressure becomes available. The pressure supply shall be interlocked to prevent the compressor starting under full load.

Note: Starting flows may be further reduced by the use of a slow opening valve for example oil damped on the outlet of the compressor, by a slow closing valve on the compressor bypass, by a manual bypass valve (especially for black start conditions), unloading of screw compressor rotors or motor speed control.

6.18 PRESSURE VESSELS

6.18.1 Any high pressure storage vessel shall be designed to enable easy and safe removal of any condensate or lubricating oils where appropriate, recognising that such liquids may be flammable. Drain points shall be fitted with two lockable valves in series or a lockable valve and with a blind flange or plugged valve.

6.18.2 A valved connection normally not less than 25 mm diameter shall be fitted at high and low level to enable displacement purging.

Suitably located test points normally 15 mm diameter shall be located for vent gas testing.

The safe means of venting the gas shall be considered.

6.18.3 A safety relief valve shall be fitted on each system to protect the vessel from excessive outlet pressures, unless other approved means have been provided and approved by the competent person.

Where the safety valve is isolated from the vessel during shutdown conditions (as may be the case where an automatic shut off valve is fitted on the outlet of the compressor) a limited bore valve shall be fitted on the vessel for pressure protection in the event of fire.

6.19 ELECTRICAL EQUIPMENT

The following clauses describe control instrumentation, alarm and shutdown systems for use with compressors.

Note: All electrical installations shall be compliant with relevant BS and or GT or other applicable standards and specifications.

6.19.1 Control and instrumentation

The electrical control system shall, in addition to motive power, provide appropriate safety features for the compressor, as follows:

- safety of personnel during normal operation and during maintenance activities
- safety of the public
- safe operation of all plant under normal and abnormal conditions
- correct/safe sequence of operation of the plant during start up, operation and shutdown
- safety of the environment
- security of the upstream system.

6.19.2 Protection system

6.19.2.1 Control system(s) shall be provided to monitor operating parameters to ensure safe limits are not exceeded, and to shut down the compressor to a safe state on the occurrence of an unsafe condition or any event upon which the safety of the plant may be contingent, ensuring protection of personnel and plant. This may include automatically venting pressure from the compressor.

Protective systems may comprise mechanical or electronic systems, or combination of both. For example, overpressure may be mitigated by provision of Pressure Relief Valves in conjunction with instrumentation.

6.19.2.2 The overall philosophy of the protection system shall be such that all systems shall be failsafe, such that the installation presents no hazards whilst dormant after an unplanned shutdown. Upon restoration the system shall recover to a safe state automatically and all monitoring and related arrangements restore to the design requirements.

Consideration must be given to allowing or preventing automatic restart after an unplanned shutdown.

Design of the protective systems should take account of risks of failure, the installation complexity and scale, and the possible consequences of different modes of failure. Design must identify all credible causes of failure, quantify risks and consequences, and lower risks to staff and the public in accordance with the principles ALARP.

In regard to electronic systems, identify Safety Related systems as defined in BS61508 and or BS61511.

6.19.3 **Interlocks**

6.19.3.1 Equipment interlocks shall be provided to ensure safety of operational staff and the operation of the compressor. This shall take account of the process interfaces with connected plant and equipment.

The compressor shall have appropriate measurement of operating parameters to enable automatic application of stop functions, relief of excess pressures, and communication to connected processes.

Consideration shall be given to interlocks that prevent operation of the compressor if values are exceeded. These are intended to preserve the integrity of the compressor and thereby prevent or at least mitigate hazards.

The design shall identify a Cause and Effect Matrix to relate possible causes of faults and the resultant automatic consequence. All possible causes of fault should be identified and included.

In simple installations, design risk assessment methodology may allow mechanical devices such as high and low pressure slam shut valves, pressure relief valves etc. to be considered instead of electronic devices.

6.19.3.2 Protective interlocks shall utilise suitably rated instrumentation and logic control as required by related standards, and facilitate the logic sequence required to mitigate hazards.

6.19.3.3 Alarms shall be displayed in a suitable HMI and be presented in a way that meets standards and recommendations for example EEMUA guidelines. All alarms that require the compressor to automatically stop shall require manual acknowledgement and reset before restart. This may be possible from a remote location where appropriate electronic communication access is provided.

6.19.4 **General**

6.19.4.1 All condition detecting devices shall be identified and classified with respect to functional or safety importance. All detecting elements for alarms and automatic trips shall be fail safe transmitters or switches.

6.19.4.2 In the event of a continuity failure the control logic shall recognise this as an abnormal condition and cause a consequent action as per the Cause and Effect Matrix.

6.19.4.3 Where a transmitter is utilised for control purposes it shall be independent and separate from any safety related application circuit.

6.19.4.4 Separate initiating devices should be provided for alarm, shut down, control and monitoring.

Note: Reference should be made as appropriate to BS 61508, BS 61511 and relevant manufacturer recommendations.

6.19.4.5 Any transmitter element shall fail to a defined zero signal level that shall be detected and the control logic shall instigate the correct action as per the Cause and Effect Matrix.

6.19.4.6 The predetermined condition for which an alarm is generated shall initiate a visual and optional audible warning.

6.19.4.7 An alarm indicating conditions injurious to personnel, for example internal gas in air detected inside the compressor kiosk, shall initiate an external visual and audible warning.

6.19.4.8 Measuring and detecting elements or integral transmitter assemblies mounted in the vicinity of the process tapping or connection point, shall as a minimum have electronic/electrical transducer and transmitter parts housed enclosures complying with BS EN 60529 and the requirements of DSEAR where necessary.

6.19.4.14 An Emergency Stop button shall be provided in an accessible location to facilitate manual stop function.

6.20 ELECTRICAL SUPPLIES

6.20.1 General

6.20.1.1 Unless otherwise specified for a particular plant, electrical equipment shall be capable of providing a rated output continuously at 94% to 106% of system voltage, coincident with -5% to +2% of system frequency.

6.20.1.2 Voltage depressions to 80% of system voltage shall have no detrimental effect on equipment operation.

6.20.2 Hazardous areas

6.20.2.1 Where equipment is to be installed in a hazardous area, this shall be indicated on the applicable data sheet. Equipment intended for hazardous areas shall conform to BS EN 60079-25 and/or BS EN 60079-15 and be installed in accordance with BS EN 60079-14.

6.20.2.2 All equipment for use in a hazardous area shall be of a type certified by a National Certifying Authority for example BASEEFA or equivalent.

6.20.3 Electrical documentation

6.20.3.1 A legible diagram, chart or table or equivalent form of information shall be provided indicating in particular:

- the type and composition of each circuit
- points of utilisation served
- number and size of conductors
- type of wiring
- information necessary for the identification of each device performing functions of protection, isolation and switching.

The location of each device shall be referenced.

6.20.3.2 Diagrams shall indicate the electrical arrangement of all component parts. The format shall be such that an understanding of the function shall be readily gained with accompanying notes if needed.

Relays shall be shown in de-energised state, with their contacts open or closed according to ‘‘circuit fail conditions/process fail condition’’.

Interface terminals shall be uniquely identified by both symbol type and number.

6.20.3.3 Any symbol utilised shall comply with BS EN 60617-2.

SECTION 7 : OPERATION AND MAINTENANCE

7.1 Operation and maintenance procedures for the equipment shall be obtained from the compressor manufacturer/packager and suppliers of other items such as pressure vessels and relief valves.

7.2 The procedures shall give guidance on the testing and purging of the equipment prior to and after maintenance.

Note: The use of flammable gas for pressure testing at high pressures is not acceptable.

The procedures shall give detailed information on the method of purging separate parts of the system to gas and to air using nitrogen together with detailed positions of test points and gas concentration end points.

7.3 The service intervals of pressure parts shall be as determined by a competent person.

7.4 A supply of nitrogen should be available during maintenance operations and venting procedures should be displayed on site in case emergency depressurisation becomes necessary.

7.5 Consideration shall be given to the use of methods of depressurising high pressure gas systems to nearby lower pressure systems to minimise environmental damage caused by gas emissions.

7.6 Gas detection and ventilation equipment shall be checked regularly for correct operation. Calibration of gas detectors (both fixed and portable) shall be performed to traceable standards as specified by the manufacturer.

7.7 Any condensate or waste lubricating oils shall be disposed of taking due account of relevant local and national environmental regulations.

Note: Such oils/condensates may be flammable and flammable gases may be emitted after release of pressure. In some cases it will be impossible to purge vessels containing oils due to the continuing release of flammable gas in which case draining is essential.

SECTION 8 : COMMISSIONING

8.1 During design and construction the method of commissioning shall be considered.

8.2 A full written commissioning procedure shall be prepared and agreed by the parties concerned in the supply and installation of the whole system and with the GT.

Note: It is essential that the interaction between items of plant be considered and that the commissioning of the compressor and metering systems be coordinated to avoid the possibility of excessive loading or pressure fluctuations on the gas meter or the gas supply system.

8.3 Plant shall be commissioned by competent engineers and in accordance with the manufacturer's instructions. Due account shall be taken of IGEM/UP/4.

Note: The manufacturers will need to make available written commissioning instructions.

8.4 Where specified, Acceptance Tests shall be performed in accordance with BS ISO 1217.

APPENDIX 1 : GLOSSARY, ACRONYMS, ABBREVIATIONS, SUBSCRIPTS, UNITS AND SYMBOLS

GLOSSARY

All definitions, other than those given below are given in IGEM/G/4 which is freely available by downloading a printable version from IGEM's website, www.igem.org.uk.

Recommended and legacy gas metering arrangements are given in IGEM/G/1 which is freely available by downloading a printable version from IGEM's website, www.igem.org.uk.

ACRONYMS AND ABBREVIATIONS

ACoP	Approved Code of Practice
AECV	additional emergency control valve
AVM	anti-vibration mounting
BASEEFA	British Approval Service for Electrical Equipment in Flammable Atmospheres
CO	carbon monoxide
CDM	Construction (Design and Management) Regulations
CE	CE mark(ing)
CHP	combined heat and power
CoP	Code of Practice
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
ECV	emergency control valve
ESP	emergency service provider
EU	European Union
GB	Great Britain
GS(I&U)R	Gas Safety (Installation and Use) Regulations
GS(M)R	Gas Safety (Management) Regulations
GT	gas transporter
HSE	Health and Safety Executive
HSWA	Health and Safety at Work etc. Act
IGEM	Institution of Gas Engineers and Managers
LFL	lower flammability limit
LOP	lowest operating pressure
LPG	liquefied petroleum gas
MAM	meter asset manager
MAX	maximum
MHSWR	Management of Health and Safety at Work Regulations
MIN	minimum
MIP	maximum incidental pressure
MOP	maximum operating pressure
NDE	non-destructive examination
NDT	non-destructive testing
NRV	non-return valve
NTS	national transmission system
OP	operating pressure
P & ID	process and instrumentation diagram
PED	Pressure Equipment Directive
PER	Pressure Equipment Regulations
PSSR	Pressure Systems Safety Regulations
PUWER	Provision and Use of Work Equipment Regulations
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
RMS	root means square
SMYS	specified minimum yield stress
SP	set point
SSV	slam-shut valve
STP	strength test pressure
TIG	tungsten inert gas (welding)
UK	United Kingdom

UKAS	United Kingdom Accreditation Service.

SUBSCRIPTS

u	upstream
so	settle out
in	inlet
out	outlet
v	volume
st	standard.

UNITS

bar abs	bar absolute
barg	bar gauge
dB(A)	decibel (A weighted)
kW	kiloWatt
mA	milliampere
min	minute
mm	millimetre
mm/s	millimetre per second
m	metre
m^3	cubic metre
$m^3\ h^{-1}$	cubic metre per hour
mbar	millibar
mbarg	millibar gauge
mol %	percentage of molecules
ppm	parts per million
rpm	revolutions per minute
sec	second
°C	degree Celsius
v/v	volume per volume.

APPENDIX 2 : REFERENCES

This Appendix lists Legislation, official Guidance and Standards that are referred to in this Standard. In addition, Legislation and official Guidance are listed which are not referenced but which may be of use to the reader.

A2.1 LEGISLATION

- Health and Safety at Work Act 1974
- Gas Act 1986 and 1995, as amended
- Pressure Equipment Directive
- Gas Safety (Management) Regulations 1996
- Gas Safety (Installation and Use) Regulations 1998
- Construction (Design and Management) Regulations 2015
- Electricity at Work Regulations 1989
- Management of Health and Safety at Work Regulations 1999
- Confined Spaces Regulations 1997
- Noise at Work Regulations 1989
- Provision and Use of Work Equipment Regulations 1998
- Supply of Machinery (Safety) Regulations 1992
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
- Dangerous Substances and Explosive Atmospheres Regulations 2002
- Pressure Systems Safety Regulations 2000
- Pressure Equipment Regulations 1999.

A2.2 HSE ACoPs AND GUIDANCE

- HSE CoP 20 Standards of Training in Safe Gas Installation
- HSE61 (rev 1) RIDDOR Explained
- HSG48 Reducing error and influencing behaviour. Guidance
- HSG85 Electricity at Work. Guidance
- L22 Safe use of work equipment. ACoP and Guidance
- L56 Safety in the Installation and Use of Gas Systems and Appliances. ACoP and Guidance
- L73 Reporting of Injuries, Diseases and Dangerous Occurrences Regulations. Guidance
- L80 A guide to the Gas Safety (Management) Regulations. Guidance
- L81 Design, Construction and Installation of Gas Service Pipes. ACoP and Guidance
- L82 A guide to the Pipelines Safety Regulations. Guidance
- L108 Controlling Noise at Work
- L122 Safety of Pressure Systems
- L138 Dangerous Substances and Explosive Atmospheres Regulations 2002. ACoP and Guidance
- L153 Construction (Design and Management) Regulations 2015. ACoP
- HSR25 Electricity at Work Regulations. Guidance
- INDG 178(rev 1) Written schemes of examination
- INDG 229 Using work equipment safely

- INDG 261 (rev 1) Pressure systems – safety and you
- INDG 291 Simple guide to the Provision and Use of Work Equipment Regulations
- INDG 370 Fire and explosion; How safe is your workplace? A short guide to the Dangerous Substances and Explosive Atmospheres Regulations 2002.
- MISC310 RIDDOR reporting: Information about the new reporting centre
- PM84 Control of Safety Risks at Gas Turbines used for Power Generation
- "Programmable Electronic Systems in Safety Related Applications".

A2.3 **BRITISH STANDARDS (ABBREVIATED TITLES)**

- BS 1560 Circular flanges for pipes, valve and fittings
- BS 1640 Steel butt-welded pipe fittings
- BS 2633 Class 1 arc welding of ferritic steel pipework
- BS 3799 Steel pipe fittings, screwed and socket welding
- BS 4675-2 Mechanical vibration in rotating machinery
- BS 4677 Arc welding of austenitic stainless steel pipework
- BS 7361 Cathodic protection
- BS 7671 IEE wiring regulations
- BS 7854-1 Mechanical vibration
- BS EN 437 Test gases
- BS EN 13480 Metallic industrial piping. Inspection and testing
- BS EN 15001 Quality assessments
- BS EN 60079 Electrical apparatus for explosive gas atmospheres
- BS EN 60617-2 Graphical symbols for diagrams (Obsolete) (see IEC online symbol library)
- BS EN 837-1 Bourdon tube pressure gauges
- BS EN 1011-3 Fusion welding of austenitic stainless steels
- BS EN 1515 Flanges and their joints
- BS EN 1762 Rubber hoses and hose assemblies for LPG and natural gas
- BS EN 1092-1 Flanges and their joints. Circular flanges
- BS EN 10216-1 Seamless steel tubes for pressure purposes
- BS EN 10217-1 Welded steel tubes for pressure purposes. Non-alloy steel tubes
- BS EN 10217-3 Welded steel tubes for pressure purposes. Alloy fine grain steel tubes
- BS EN 10217-5 Welded steel tubes for pressure purposes. Submerged arc welded non-alloy and alloy steel tubes
- BS EN 10253-1 Butt-welding pipe fittings. Wrought carbon steel for general use
- BS EN 12874 Flame arresters.
- BS EN ISO 10380 Corrugated metal hose and hose assemblies
- BS EN 60529 Degress of protection provided by enclosures (IP code)
- BS ISO 1217 Displacement compressors
- BS ISO 21789 Gas turbine applications - safety.

A2.4 IGEM STANDARDS

• IGEM/G/1	Defining the end of a Network, a meter installation and installation pipework
• IGEM/G/4	Definitions for the gas industry
• IGE/GM/8	Non-domestic gas meter installations
• IGEM/SR/29	Dealing with gas escapes
• IGEM/G/7	Risk assessment techniques
• IGEM/SR/25 Edition 2	Hazardous area classification of Natural Gas installations
• IGEM/TD/1 Edition 5	Steel pipelines for high pressure gas transmission
• IGEM/TD/13 Edition 2	Pressure regulating installations for transmission and distribution systems
• IGE/UP/1 Edition 2 RWA	Strength testing, tightness testing and direct purging of industrial and commercial gas installations
• IGEM/UP/2 Edition 3	Installation pipework on industrial and commercial premises
• IGEM/UP/3 Edition 3	Gas fuelled spark ignition and dual fuelled engines
• IGEM/UP/9 Edition 2	Application of Natural Gas and fuel system to gas turbines and supplementary and auxiliary fired burners
• IGEM/GL/8 Edition 3	Reporting and investigating incidents.

A2.5 RELATED PROCEDURES GUIDANCE, REGULATIONS AND CODES OF PRACTICE

• VDI 2063	Measurement and Evaluation of Mechanical Vibrations of Reciprocating Engines and Reciprocating Compressors
• ASME 2005-GT-215	A new gas turbine enclosure ventilation design criterion. R Santon, M Ivings and D Pritchard
• API 5L	Specification for Welded and Seamless pipe gas, water, and oil in both the oil and natural gas industries
• ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
• HSE	Explosion Hazards at Gas Driven Power Plants. R.C.Santon.

APPENDIX 3 : METERING OF COMPRESSOR FLOWS

Most metering systems can be adversely affected by the continuous pulsations and frequent load changes which the operation of some compressors may impose upon the gas flow. However the significance of this depends greatly upon the type of meter involved and upon the type of compressor and its method of control.

A3.1 COMPRESSOR TYPE

A3.1.1 Screw and sliding vane type compressors generally introduce a minimal level of pulsation onto the inlet flow. Normally they also operate with a continuously varying rather than step loaded control method. Therefore in general compressor considerations do not restrict meter selection associated with a screw or sliding vane type compressor.

A3.1.2 Reciprocating compressors are far more likely to create problems because of the continuous flow pulsations which are inherent to their principle of operation. There is also the possibility of rapid, frequent, load changes associated with step loading techniques. Thus care is needed to ensure that the pulsation damping and load control employed are compatible with metering requirements. In many cases especially where a turbine meter is included, the pulsation requirements to allow accurate metering are more rigorous than those to ensure mechanical integrity.

A3.2 EFFECT ON METER TYPES

The effect of pulsations and load changes varies considerably with meter type as summarised below. Pulsation effects on some newer metering principles are not well documented. In such instances assurances will need to be sought from the equipment manufacturer.

A3.2.1 Turbine meters will over register when exposed to pulsating flow. The error involved depends both on frequency and amplitude of pulsation, but can be very significant. A turbine meter will also over register due to the ‘‘spin-down’’ time required on a rapid stopped load. Again errors can be very significant especially if the flow is reducing to zero. Such effects are well documented and the requirements to minimise errors reasonably well defined. In general ensuring a flow pulsation level at the meter of less than +/- 5% of the mean flow reduces the consequent over registration to negligible proportions.

A3.2.2 Rotary displacement meter accuracy is accepted as being affected very little by pulsations (although this does not appear to be well documented). However exposure to continuous large compressor generated pulsations may create excessive bearing wear and therefore pulsation levels do need to be restricted. Normally step loads do not affect accuracy significantly but can create large pressure changes that are generated while the meter speed responds to the load change. These may be particularly important on low pressure systems.

A3.2.3 Orifice plate metering can be affected substantially by pulsations due to ‘‘square root law’’ effects and also possible effects on the associated instrumentation. However these are well documented in standards and the steps needed to ensure accurate operation are well defined. Step loading effects depend largely upon the instrumentation response.

A3.2.4 Vortex shedding meters can be very sensitive to pulsations if the output ‘‘locks on’’ to the pulsation frequency rather than the correct vortex shedding frequency. Documentation is limited but does suggest that it is possible for very modest pulsation levels to create substantial errors.

A3.2.5 Ultrasonic meters are in principle reasonably insensitive to pulsating flow but this appears to be very little documented and may be very dependent upon the particular ‘‘measurement and computational’’ strategy employed.

A3.2.6 Diaphragm meters are unlikely to be relevant to any but the smallest compressor loads. They may be significantly affected by flow pulsations.

APPENDIX 4 : VIBRATION

A4.1 GENERAL

Any compressor installation is likely to give rise to pulsations and transient pressure rises that will affect the installation pipework by causing vibrations in the supply. The vibration levels will need to be taken into account when designing the pipework.

Note: Vibration limits for compressors are provided in appropriate codes for example in machinery standards VDI 2063, BS 7854-1 and BS 4675.

Pipework vibration standards are not as comprehensive as machinery standards because of the range of pipework dimensions, configurations, supports, fittings and the type of excitation causing the vibrations.

A4.2 CAUSES

Pipework vibrations can be caused by either of two types of excitation:

- periodic (pulsating) where the force is repeated at equal intervals of time.

  Pulsating gas flows principally are caused by reciprocating compressors and are more complex than simple harmonic motion. The action of each cylinder, the number of operating cylinders, the speed of the compressor and the characteristics of the discharge valve all have to be considered.

  If any one excitation force frequency from the many is coincident with the natural frequency of the pipework, then resonance occurs and the vibration is amplified.

- transient excitation may occur from any rapid change in flow of gas through pipework. If the pipework has a natural frequency in the band of the transient frequency, it will vibrate freely - similar to "twanging" a steel rule.

A4.3 LIMITING VIBRATION LEVELS

Vibration levels may be limited as follows:

- the ideal solution to decrease vibrations is the complete removal of pressure pulsations and transients from the gas stream. However realistically the solution will be a cost effective compromise, for example by the installation of large volume snubbers at the compressor inlet and outlet that act as pulsation dampers.

  Snubber volumes may be predicted using published data.

- other design factors that may reduce vibration problems include;
  - avoidance of over sizing pipework supplying compressors
  - avoidance of changes in pipe diameter; or at least minimising the length over which the change occurs
  - minimising the length of "stabs" that may be installed to supply other equipment.

APPENDIX 5 : ESSENTIAL FEATURES OF NON-RETURN AND SLAM-SHUT VALVES TO COMPLY WITH THE GAS ACT

A5.1 NON-RETURN VALVE (NRV)

Any NRV has to:

- be capable of withstanding the maximum reverse pressure as calculated in clause 4.5.1.4 (maximum settle out pressure) or the limited reverse pressure that may occur despite the existence of system relief valve
- have an acceptable forward pressure drop and stable performance under specified flow rates
- have an acceptable reverse leakage rate.

Where the compressor is of the reciprocating type, the NRV has to be of a type capable of accepting a pulsating flow.

The suitability of any NRV can be confirmed by its manufacturer in this respect and if necessary further advice may be sought from the compressor manufacturer or a specialist compressor equipment supplier.

A5.2 **SLAM-SHUT VALVE (SSV)** (sometimes also referred to as an actuated slam-shut block valve).

Any SSV has to:

- be capable of withstanding the maximum reverse pressure as calculated in clause 4.5.1.4 (maximum settle out pressure) or the limited reverse pressure that may occur despite the existence of system relief valves.
- be fitted in the correct orientation to the direction of flow.

  Impulse lines need to be connected upstream of a reverse facing SSV to avoid possible overpressure of the sensing element after the valve has tripped. In cases of doubt advice may be sought from the manufacturer of the SSV.

- be unaffected by flow and/or pressure pulsations. Dependent on valve design, these will not be problematic as the trip set point will be significantly in excess of the operating pressure
- have a fast closing time in response to a fault pressure associated with a reverse gas flow; normally this will be less than 1 second.

A detailed fault condition analysis has to be carried out to establish the slam shut response time required particularly where:

- pipework volume is small
- suction/inlet pressure is low
- the compressor has large spill back capacity
- the compressor interstage/outlet relief is returned to suction side

It is important that the SSV does not trip under any normal i.e. safe operating condition for example when the compressor load changes. This may involve allowing a considerable margin between the setting and the normal operating pressure and using a large capacity relief valve, particularly on a low pressure supply. The trip setting may be determined for network and control analyses and/or for the rating of the installation pipework.

APPENDIX 6 : ESSENTIAL FEATURES OF A RELIEF VALVE INSTALLED ON THE INLET TO A COMPRESSOR

A6.1 FULL CAPACITY RELIEF VALVE

A6.1.1 A relief valve may be used as one of the safety devices to protect the supply system against excessive reverse pressure as required by clause 4.5.1.

A6.1.2 Where there is the possibility of a direct connection between compressor outlet and inlet for example via a spillback, the flow capacity of the relief valve has to be greater than the total capacity of all spillback connections at maximum compressor outlet pressure.

Note: The capacity of any interstage relief valves which are connected back to the compressor inlet need to be included when determining the required inlet relief capacity.

A6.1.3 Consideration has to be given to the response time of the relief valve to ensure that excessive pressure rise will not occur while it is opening.

A6.2 CREEP RELIEF VALVE

A6.2.1 A small capacity relief valve is used to protect inlet pipework and equipment from overpressure, due to creep, during shut down conditions. This potential overpressure could also activate a trip device and prevent start up when required.

A6.2.2 The capacity of any creep relief valve needs to be kept to a minimum and when fully effective not normally exceed 5% of the compressor design capacity.

A6.2.3 Normally the response time of a creep relief valve is not critical.

APPENDIX 7 : ENCLOSURES - EMERGENCY PROCEDURES FOR MECHANICAL VENTILATION

To comply with Sub-Section 6.5 an enclosure with a mechanical ventilation system has to be subject to an emergency procedure to cover for system failure. The factors governing a ventilation system design include:

- gas inlet pressure
- the compressor gas outlet pressure
- the ‘‘potential gas release’’ (see Sub-Section 6.5)
- the volume of gas within the enclosure, etc.
- a full analysis of the procedures needed to ensure compliance with clause 6.3.1 will reveal the design requirements
- additional features such as a gas detection system also have to be considered.

A typical procedure would upon failure of the ventilation system, on plant where gas detection is not fitted cause:

- shut down of the compressor and any ancillaries within the enclosure
- shut down of the gas supply to and from the pipework in the enclosure
- depressurisation of the high pressure system within 30 seconds by the use of an emergency dump valve
- prevention of start up of the compressor and any ancillaries within the enclosure until the fault is rectified
- initiation of an alarm to alert responsible personnel.

Where gas detection is also fitted a typical procedure would cause:

- shut down of the gas supply to and from the pipework in the enclosure
- depressurisation of the high pressure system within 30 seconds by the use of an emergency dump valve
- isolation of electrical equipment within the compressor enclosure, other than emergency lighting and gas detection and ventilation fans if running (noting that electrical components of safety systems required to remain operable shall be outside the enclosure or suitably zoned)
- prevention of start up of the compressor and any ancillaries within the enclosure until the fault is rectified
- initiation of an alarm to alert responsible personnel.

APPENDIX 8 : COMPRESSOR CONTROL

A8.1 OPERATIONAL CONTROL

Compressors of all types can be applied to deliver pre-set outlet pressure, inlet pressure, or flow within design ranges. Unless the parameters are fixed it is therefore necessary to provide controls to match the compressor operating conditions to meet design values during operation. Normally, this is achieved by control using measured inlet or outlet pressure or metered flow rate.

In some situations, it is possible to sense the rate of change of the output parameter and to provide an advance signal to the compressor, so that it starts to change before it is sensed by the control pressure switches or flow meter.

Some compressors, dependent on design and operating parameters may also require a high pressure storage reservoir to supply the maximum gas flow rate for up to 10 seconds, to allow time to react to transient changes of parameters.

Compressors should be designed to meet the required duty to ensure operation is possible within the desired ranges of pressure, flow and temperature, and to do this within the range that meets economic and reliability conditions.

Consideration must also be given at design stage to the ambient operating conditions including temperature, noise and vibration to ensure that changes in ambient conditions do not adversely affect satisfactory operations.

Consideration must also be given to the specific requirements at start up and shut down in terms of pressure and flow surges, operating sequence and effect on adjacent plant. Of particular importance is ambient temperature, which can cause significant changes to operating range and/or efficiency.

There are several methods of flow control that can be used on compressors. Usually, the choice is made by undertaking an analysis of cost and performance. Some methods give excellent savings on power consumption, while others are ideal where low levels of pulsations are required. The cost of the flow control devices also varies but the dominant factor usually is power consumption.

A8.2 VARIABLE INLET PRESSURE

A wide variation in the inlet pressure can lead to control problems. As the inlet pressure rises, the compression requirements fall requiring the compressor to do less work and thus reducing the absorbed power, this may make the compressor more efficient, but in the extreme it could mean the compressor cannot operate. Low inlet pressure can cause overloading and result in similar inefficient or non-operation.

It is possible to regulate the inlet pressure within a design range using external devices. Alternatively, it may be possible to modulate the gas flow around a by-pass, a recycle loop, or to adjust the compressor speed.

Note that the inlet pressure may be the chosen control value for operation.

A8.3 VARIABLE OUTLET PRESSURE

Changes to outlet pressure conditions may render a compressor unstable or inefficient as with inlet changes. Consideration must be given to design conditions consistent with pressure rating and capacities of connected components and materials.

Note that the outlet pressure may be the chosen control value for operation.

A8.4 **VARIABLE FLOW RATE**

In situations where this is the required control value the output flow may cause variations in inlet pressure, outlet pressure or both. Inlet or outlet pressure changes imposed by external factors may render the compressor unable to achieve a flow set point.

A8.5 **METHODS OF COMPRESSOR CONTROL**

A8.5.1 Careful consideration should be given to the most appropriate form of control to achieve the correct operating parameters, given the operating load and duty, and manufacturer’s recommendations. This is likely to be taken from one or more of the following:

- speed control
- throttle control
- step control
- by-pass flow control
- reliability.

APPENDIX 9 : NATURAL GAS COMPOSITION AND PROPERTIES

MAJOR CONSTITUENTS		SUPPLY SYSTEM RANGE (mol %)		TYPICAL COMPOSITIONS (mol %) (ex-terminal)		
		Minimum	Maximum	St Fergus Terminal	Bacton Terminal	Lupton Terminal
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	iC_4	0.11	0.36	0.36	0.11	0.19
Pentane	nC_5	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	SUPPLY SYSTEM 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	0	0.5	0
Tertiary butyl mercaptan	0.5	2	1.2
Water vapour	10	550	100
Methanol vapour	0	200	100
Dimethyl sulphide	0.2	0.8	0.5

Notes:

- *For odorised gas, Network Owners add an odorant blend of TBM and DMS. Other sulphides and mercaptans will be present only in trace quantities of indigenous sulphur. However the total sulphur concentration within the gas will always be lower than 35 ppm as specified in GS(M)R.*
- *Gas distributed above 7 bar may not in all cases be odorised by the Network Owner.*
- *Gas distributed below 7 bar may contain very small quantities of additives for example monoethylene glycol or other conditioning agents.*
- *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 3 - TYPICAL NATURAL GAS COMPOSITIONS (JANUARY 1998) (COURTESY OF NG TRANSCO)

Pressure Bar absolute	**TEMPERATURE °C**		
	15	**50**	**75**
2	0.9957	0.9972	0.9979
10	0.9783	0.9859	0.9896
20	0.9568	0.9721	0.9796
30	0.9355	0.9588	0.9700
40	0.9145	0.9458	0.9608
50	0.8940	0.9335	0.9521
60	0.8742	0.9217	0.9440
70	0.8554	0.9107	0.9364
80	0.8377	0.9005	0.9295
90	0.8214	0.8911	0.9233
100	0.8068	0.8828	0.9178
110	0.7942	0.8755	0.9130
120	0.7837	0.8693	0.9091
130	0.7755	0.8643	0.9060
140	0.7697	0.8605	0.9037
150	0.7662	0.8580	0.9023
160	0.7651	0.8566	0.9017
170	0.7660	0.8565	0.9020
180	0.7689	0.8575	0.9031
190	0.7735	0.8597	0.9050
200	0.7796	0.8629	0.9077
210	0.7871	0.8671	0.9111
220	0.7958	0.8722	0.9153
230	0.8054	0.8781	0.9201
240	0.8160	0.8848	0.9255
250	0.8273	0.8923	0.9315
260	0.8392	0.9003	0.9380
270	0.8516	0.9089	0.9451
280	0.8646	0.9180	0.9526
290	0.8779	0.9276	0.9605
300	0.8916	0.9377	0.9688
310	0.9055	0.9481	0.9775
320	0.9198	0.9588	0.9865
330	0.9342	0.9699	0.9958
340	0.9488	0.9812	1.0054
350	0.9636	0.9928	1.0152
360	0.9785	1.0046	1.0253
370	0.9935	1.0166	1.0356
380	1.0086	1.0287	1.0461
390	1.0238	1.0411	1.0567
400	1.0391	1.0535	1.0676

TABLE 4 - COMPRESSIBILITY FACTORS FOR TYPICAL NATURAL GAS (CALCULATIONS ARE BASED ON AGA8 USING TYPICAL NATURAL GAS) (COURTESY OF BRITISH GAS PLC)

APPENDIX 10 : EXAMPLE - MAXIMUM SETTLE OUT PRESSURE

A gas compressor supplied at 20 mbar gauge with a maximum outlet pressure of 20 bar gauge. The total inlet volume (from ECV to compressor inlet) is 1.5 m^3 and the outlet volume including a receiver is 6.1 m^3. The maximum gas supply pressure is 75 mbar.

Applying equation from clause 4.5.1.4 with:

P_{in} = 1.033 bar abs
V_{in} = 1.5 m^3
P_{out} = 21 bar abs
V_{out} = 6.1 m^3.

From Appendix 9, Table 3, Z_{in} = 1, Z_{out} = 0.95.

Z_{so} cannot be determined until P_{so} is known but, as a first approximation, assume $Z_{so} = Z_{in}$.

First estimate for P_{so} = [(1.033 x 1.5 / 1) + (21 x 6.1 / 0.95)] x [1 / (1.5 + 6.1)]

= 17.95 bar abs.

A revised estimate for Z_{so} can be made, based on this pressure, from Appendix 9, Table 3:

Z_{so} = 0.96

and a new estimate for P_{so} calculated from;

P_{so} = 17.95 x 0.96 = 17.22 bar abs.

Note 1: Further iterations could be made but will not normally be necessary.

Note 2: The compressibility factors are based on a temperature of 15°C.

Number of safety devices required

In this case, clause 4.5.1.2 applies as:

$P_{so} > MOP_u > 2$ bar.

A minimum of three safety devices have to be installed to include a NRV on the outlet of the compressor and at least two of the following:

- a relief valve on the suction side of the compressor
- a NRV on the suction side of the compressor
- an actuated SSV which closes on sensing unacceptably high pressure on the suction side of the compressor which has to be fitted on the discharge side of the compressor.

APPENDIX 11 : PNEUMATIC PRESSURE TESTING OF PIPEWORK UP TO 50 mm NOMINAL BORE AT PRESSURES ABOVE 2 BAR BUT NOT EXCEEDING 40 BAR

A11.1 SCOPE

A11.1.1 This Appendix describes a procedure that may be adopted for the pneumatic testing of pipework systems up to and including 50 mm nominal bore after completion of construction, to prove their strength and leak tightness at test pressures not exceeding 40 bar. Hydrostatic testing is safer and is to be used whenever possible at high pressures.

A11.1.2 The duties and responsibilities of the Contractor are specified and the potential dangers associated with pneumatic testing are emphasised.

A11.2 DEFINITIONS

For the purpose of this Appendix the following definitions apply:

A11.2.1 **Contractor:** the person, firm or company with whom the client enters into a contract to which this Appendix applies including the Contractor's personal representatives, successors and permitted assigns.

A11.2.2 **Engineer:** the Engineer appointed from time to time by the client and notified in writing to the Contractor to act as Engineer for the purpose of the contract.

A11.2.3 **Specialist Test Engineer:** the Test Engineer appointed by and specifically named by the Contractor to be in full charge of all tests to be performed.

A11.3 GENERAL

A11.3.1 The Contractor ensures that only fully trained personnel are allowed to carry out the tests.

The Specialist Test Engineer draws up a schedule of all operations for the test, clearly stating the responsibilities of his subordinates during all phases of the work. The schedule includes details of the following:

- safety precautions as outlined in A11.4
- the supply of any test fittings
- pneumatic test procedure
- full programme giving proposed dates of tests.

A11.3.2 Agree the pipework sections to be tested and indicate on relevant drawings. Include all items of equipment to be tested. More than one section may be combined and tested if agreed by the Engineer.

A11.3.3 Ensure all test equipment for example fittings, components and connections used in the test are to specifications approved by the Engineer and designed for a working pressure not less than the test pressure.

A11.3.4 Disconnect the pipework from the meter installation and any compressors, engines or boilers.

A11.3.5 Blow through the section of the pipework system to be tested through, preferably with inert gas and check to ensure freedom from blockage and that any foreign matter has been removed.

A11.3.6 Remove any equipment and instrumentation specified by the Engineer which may be damaged during the test procedure and seal the pipework safely.

A11.3.7 Connect the pipework to the test medium supply using suitable control valves, relief valves and a calibrated test gauge so arranged that the maximum test pressure will not be exceeded. A typical test set up procedure given in A11.5.6.

A11.3.8 Use only standard test gauges (1/4%) in accordance with BS EN 837-1 of at least 150 mm dial diameter. Check the calibration prior to use. Also check the calibration whenever a gauge may have been damaged. Ensure the Calibration Certificate supplied by the gauge manufacturer for the actual gauge to be used is available at the time of any calibration check.

A11.3.9 Pipework shall be inspected by the Engineer and declared ready for test before any testing takes place.

A11.3.10 Use a testing medium that is dry, oil free air or nitrogen. Ensure the test procedure is approved by the Engineer.

A11.3.11 Do not commence the test without the presence of the Engineer and the Specialist Test Engineer.

A11.4 SAFETY

A11.4.1 The safety of all persons whether or not involved in the testing is of paramount importance. Do not allow any procedure that would violate this concept.

A11.4.2 Pneumatic testing is potentially a more hazardous operation than hydrostatic testing at the same pressure, in that any failure during testing is likely to result in more serious consequences arising from the energy release of a compressible fluid.

Consult at the pipework design stage with the Engineer on the adequacy of the safety precautions proposed by the Contractor. Check that the safety precautions ensure that no person would be injured if any part of the piping system failed during the test operation. Subject the safety precautions to the written approval of the Engineer with particular reference to the following:

- adequacy of protection for all persons whether or not involved in the tests
- adequacy of protection of adjacent pipework and equipment (see A11.4.4)
- adequacy of any applicable NDT carried out before the test including testing previously carried out by others
- extent of area cleared for test safety purposes (see A11.4.5)
- resistance of the materials to fast fracture
- procedure to prevent local chilling during filling and emptying
- extent of remote monitoring provided during test.

A11.4.3 Ensure all personnel engaged on the test are fully instructed regarding the possible hazards involved in pneumatic testing. Pay particular attention to supporting and securing pipes by the use of proper pipe supports.

A11.4.4 Take suitable precautions to protect any adjacent services or equipment from the effects of failure of the pipework that might lead to unacceptable damage or dangerous failure. In such cases make safe the services before the test and ensure vulnerable equipment is moved or protected.

A11.4.5 Define a test area and agree it with the Engineer. Include all enclosed areas through which the pipework runs and local access ways. Define the boundaries of the test area by marker tapes and display proper warning notices reading

"WARNING - PIPEWORK UNDER TEST" at all points where access may be gained to the test area. Extend the test area for at least 5 m from the pipe.

A11.4.6 Attention is drawn to the fact that if the test medium (usually compressed nitrogen) is let down to the test pressure from high pressure storage, its temperature will fall. Ensure the test arrangements are such that the temperature of the medium entering the pipework under test is not lower than the agreed test temperature. Do not allow the medium to fall below the dew point at the corresponding test pressure to prevent condensation within the pipework.

A11.4.7 Prior to the pneumatic test subject all welds to NDT.

A11.5 TEST PROCEDURE

A11.5.1 Carry out an initial proving test at a pressure not exceeding 2 bar to check the soundness of flanged joints, etc., and to check for leaks using a leak detection fluid before carrying out the pressure test.

A11.5.2 Gas pipework of MOP not exceeding 16 bar

Test pipework in accordance with applicable national regulations using appropriate standards, such as IGE/UP/1 (for gas).

A11.5.3 Gas pipework of MOP exceeding 16 bar

A11.5.3.1 *General*

(a) Strength test all components for example valves and filters individually and ensure they are certificated for use at not less than the design pressure conditions.

Note: A pneumatic tightness test may be applied at 0.5 bar before proceeding on to higher pressure tests.

(b) Hydrostatically strength test any individual section of new or replacement fuel pipe before assembly but where this is not possible, hydrostatically strength test in situ. If the application of a hydrostatic test is not practicable a pneumatic strength test may be applied subject to a suitable risk assessment (see A11.4.2). Do not carry out a pneumatic strength testing of large volume components such as vessels and filter bodies.

On completion of a hydrostatic test, drain the pipework and dry it adequately for example with foam pigs and vacuum drying. Seal individual pipework sections to ensure dryness until installation.

Note: Normally, vacuum drying to ***at least*** *100 mbar and maintaining for a stabilisation period is considered adequate.*

(c) Following a successful strength test carry out a tightness test on the complete assembly.

Note: Further information on testing is given in IGE/UP/1, IGEM/TD/1, IGEM/TD/13 and BS EN 13480.

A11.5.3.2 *Test pressures*

TEST TYPE	MINIMUM TEST PRESSURE *1	RECOMMENDED TEST TIME (min) *2	RECOMMENDED STABILIZATION TIME (min)
Hydrostatic strength *5	Greater of 1.5 MOP and 1.1 MIP	60	30
Pneumatic tightness following hydrostatic strength and re-assembly	OP	15	15*4
Pneumatic strength*4	Greater of 1.5 MOP and 1.1 MIP*3	30	15*4

Components have to be selected to be able to withstand the test pressures.

*1 *These test pressures are a minimum.*
*2 *For longer duration tests an absolute pressure gauge may be necessary to overcome any changes in atmospheric pressure. Alternatively, correction methods as given in IGE/UP/1 may be used. Stabilisation time will be affected by length/volume of system under test and source of high pressure.*
*3 *This type of test can only be applied if it is impracticable to apply a hydrostatic strength test and a suitable risk assessment has taken place.*
*4 *The stabilisation period may be ended when the pressure has settled.*
*5 *When hydrostatic testing austenitic steels, the halogen content of the water needs to be less than 30 ppm.*

TABLE 5 - TEST PROCEDURES

A11.5.3.3 Do not exceed 90% of the design specified minimum yield stress (SMYS).

A11.5.4 **Hydrostatic strength testing**

A11.5.4.1 Pneumatically test pipework including components in accordance with IGE/UP/1 at a pressure not exceeding 350 mbarg, to ensure tightness prior to applying a hydrostatic strength test.

Apply suitable safety distances during pneumatic testing.

A11.5.4.2 Hydrostatically strength test the pipework system using the principles of IGE/UP/1 but raising STP to that given in Table 5.

A11.5.5 **Pneumatic strength testing**

Only carry out pneumatic strength testing of a system (with air or inert gas) in the special case where a hydrostatic strength test is not practicable. This may include cases where the ingress of liquid into the turbine cannot be prevented. Only consider a pneumatic strength test subject to a risk assessment and 100% non-destructive examination (NDE).

Form a procedure which may be applied as a pneumatic test taking into account the design of the whole installation and risks on the site.

Note 1: IGEM/G/7 provides guidance on risk assessment techniques.

Note 2: High pressure pneumatic testing is not the normal accepted practice in the UK.

Where a pneumatic test is performed on a system, pay stringent attention to material selection, connection methods, NDE, etc. to ensure safety and to limit damage in the event of failure of the system under test or the test equipment.

A11.5.6 Following the successful completion of the initial proving test, test pipework to Table 4.

Apply the pressure gradually for example in stages of not more than 10% of the final test pressure with sufficient time between stages to allow pressure conditions to stabilise. During pressurisation limit the maximum pressure with personnel present to a maximum of 5 bar.

A11.5.7 After reaching the final test pressure isolate the pipework system from the pressure source and allow the pressure to stabilise. Monitor the pressure for a minimum of 10 minutes during which time do not allow loss of pressure. Monitor the ambient temperature during the test to ensure that any changes are not affecting the validity of the test. After this period gradually reduce the pressure to MOP of the system then leak test utilising a minimum number of personnel and using leak detection fluid. If any leakage is found reject the pipework system and after remedial work repeat the complete test procedure.

A11.5.8 Reduce the pressure to less than 2 bar or to a safe level to be decided by the Engineer before approaching the pipework in the event of any failure, and before carrying out any remedial work on the pipework system.

A11.5.9 After refitting any equipment removed as required by A11.3.5, subject the pipework to a proving test according to A11.5.1 at the discretion of the Engineer.

A11.5.10 **Typical test set up procedure (see Figure 5)**

A11.5.10.1 Assemble and test the high pressure gas storage and pressure reduction unit in accordance with the manufacturers' instructions.

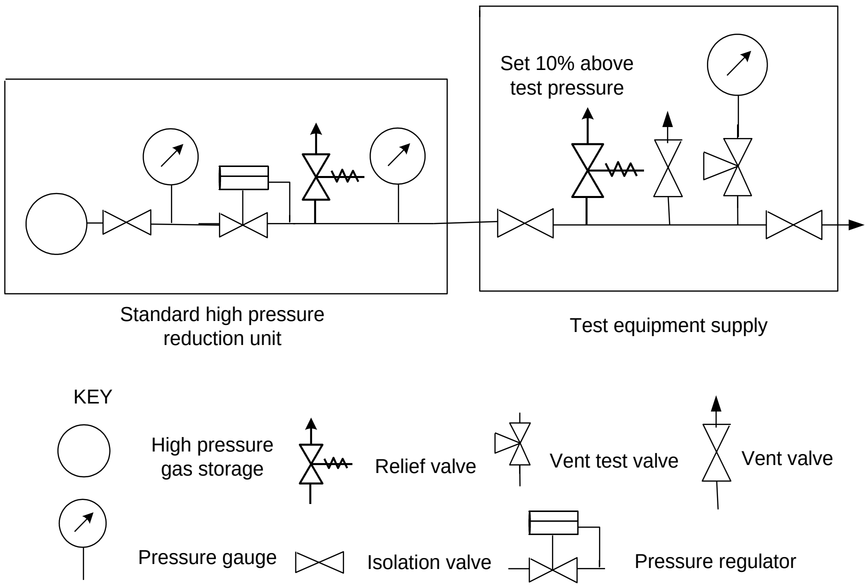


FIGURE 5 – TYPICAL TEST SET UP PROCEDURE

A11.5.10.2 Carry out a visual inspection for damage of all parts of the test rig.

A11.5.10.3 Calibrate the test gauge and fit the gauge to the test rig.

A11.5.10.4 Close the shut off valve at the outlet to the test unit and open the inlet valve.

A11.5.10.5 Lower the setting of the test unit relief valve until it is proved to be working. Raise the setting in small stages until the test pressure plus 10% is reached.

A11.5.10.6 Open the shut off valve at the outlet of the test unit to pressurise the pipework system.

A11.5.10.7 Close the shut off valve at the inlet to the test frame when test pressure is reached in order to isolate the system under test.

A11.5.10.8 Upon completion of the test relieve the pressure using the vent.

A11.6 DEPRESSURISING

Release pressure in a controlled manner by the use of a suitable pressure let-down valve provided with vent pipework led away to a safe location.

A11.7 RECORDS

Issue a test certificate upon satisfactory completion of the tests. Complete all test records and pass them to the client.

APPENDIX 12 : SIZING OF VENTS

A vent may be required to permit controlled emergency depressurisation of vessels or sections of pipework. The following estimates the vent valve or restricting orifice size needed to reduce the pressure within the volume to below 1 bar within a specified venting time, typically to below 0.5 bar in less than 60 seconds.

The approximate size of vent may be calculated from:

$Q_{st} = 0.415\ P_1\ d^2\ Z^{-0.5}\ (m^3\ h^{-1}\ (st))$

d nominal diameter (port diameter) of vent valve, or limiting orifice (mm)
V volume to be depressurized (m^3)
P_1 absolute pressure before venting (bar abs)
t_v time to vent volume to a pressure of 1 bar (sec)
Z compressibility factor - an average value taken over the whole of the venting period (see Table 3) for pressures up to 6 bar abs, Z can be taken as 1.
Q_{st} flow rate through the vent when absolute pressure within the volume is P1 bar (m^3h^{-1}) (st))
L_n Naperian logarithms (Log_e)

$d\ = 93\ [V\ L_n\ (2.0137^{-1}\ P_1)\ (Z^{0.5}\ t_v\ )^{-1}\ ]^{0.5}\ (mm)$

Note 1: The equation for d is derived from the equations of state and mass flow rate. The value 93 takes account of the inconsistency in units between d, V, P_1 and t_v.

Note 2: The equation for Q_{st} is derived from equations of state and mass flow rate equations. The value 0.415 takes account of the inconsistency in units between Q_{st}, P_1 and d.

Note 3: If a meter is included within the pipework to be vented, consideration needs to be given to the possibility of over speeding the meter. A discharge coefficient of 0.6 is assumed.

For a given 60 second vent:
Assume that;

V = 6 m^3
P_1 = 21 bar abs
Z = 0.977 (interpolation from Table 3)

then

$d\ = 93 \times [6 \times Ln(2.0137^{-1} \times 21) \times (0.977^{0.5} \times 60)]^{0.5}$
$= 93\ [6\ X\ 2.345 \times 0.0169]^{0.5}$
$= 45$ mm.

$Q_{st} = 0.415\ (21)(45)^2(0.977)^{0.5}$
$= 17850\ m^3\ h^{-1}$ (st).

Then, when pressure has fallen to 1.5 bar abs (0.5 barg):

$Q_{st} = 1260\ m^3\ h^{-1}$ (st).

APPENDIX 13 : DATA FOR ASSESSMENT OF LARGE GAS COMPRESSOR LOADS

The following information is required to assess the possible effect of gas compressor loads. In many instances some of the items included will not be applicable to the system being considered and extra sheets will need to be attached where necessary.

Much of the information listed may not be known at an early stage in the specification of the system. In these cases provide as much detail as is available with any items which are assumed or are based on similar systems clearly identified.

For more than one type of compressor use the appropriate number of forms.

Supply details

Installation name/identification

Supply pipe diameter	mm	Supply pressure	MAX bar	MIN bar	NORMAL bar

Any special features of supply for example any other upstream loads close to the supply?

Is pressure regulated at entry to site? YES / NO

Outline details of regulator system

Load details under standard conditions

Maximum flow rate	$m^3\ h^{-1}$	Minimum normal flow rate	$m^3\ h^{-1}$

Any special features of load, for example minimum load on/load off time

Metering system details

Maximum flow rate for metering system	$m^3\ h^{-1}$	Metering pressure	bar

Meter type/size

Any special features of metering systems for example pressure limits?

Installation pipework and layout

Attach a sketch showing the essential features of the installation. Include length/ diameter of pipework from meter outlet to compressor inlet.

Describe any special features of the pipework for example pressure limits

cont/....

Details of any other loads supplied from the meter installation

Is the supply pressure to these loads regulated	YES / NO

Describe any special features of the other loads (for example particular sensitivity to pressure changes)

Compressor system

Number of compressors and their make/model			
Type of machine (reciprocating/screw/other)		Maximum rated flow of machine	$m^3\ h^{-1}$
Is P&ID available for machine/system (or a typical example)? if YES, attach	YES / NO	Is the supply pressure regulated at the compressor inlet	YES / NO
If compressor system includes a spill back or by-pass, what is its volume?	m^3	Compressor outlet pressure	bar
Volume of receiver on machine outlet	m^3	Volume of receiver on machine inlet	m^3

For a reciprocating machine

Arrangement, for example 2-cylinder, 2 stage		Layout of first stage for example single cylinder, double acting	
Bore and stroke of first stage cylinder(s)	m^3	Drive speed of compressor	rpm
Is the level of pulsation damping on machine inlet specified? If so what is it?	YES / NO	Methods(s) of control, for example step, spillback, inlet throttle, motor speed etc.	

cont/....

For a screw machine

Method(s) of control (for example slide valve, spillback, motor speed, etc)

For any other type of compressor

Operating principle

Method(s) of control

Compressor system supply safeguards

What under/overpressure protection devices are provided on the compressor inlet? (for example low pressure trips, relief valve, etc.)

Sheet completed

The user

Name (individual and/or company)

Address

Tel. No.

Comments of the GT

Name

Date

END

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