NHS National Services Scotland

Scottish Health Technical Memorandum 02-01:

Medical gas pipeline systems
Part A: Design, installation, validation and verification

Health Facilities Scotland
Engineering and Environment

June 2012

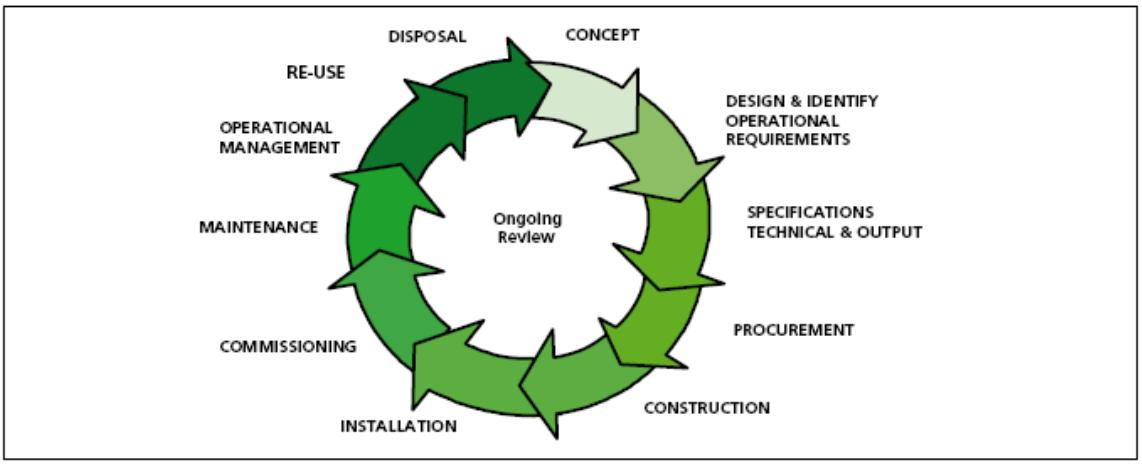
Contents

Preface

About Scottish Health Technical Memoranda

Scottish Health Technical Memoranda (SHTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle:



Healthcare building life-cycle

Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Scottish Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to unnecessarily repeat international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Scottish Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The new core suite of eight subject areas provides access to guidance which:

- is more streamlined and accessible;
- encapsulates the latest standards and best practice in healthcare engineering;
- Provides a structured reference for healthcare engineering.

Structure of the Scottish Health Technical Memorandum suite

The new series of engineering-specific guidance contains a suite of nine core subjects:

Scottish Health Technical Memorandum 00: Policies and principles (applicable to all Scottish Health Technical Memoranda in this series)

Scottish Health Technical Memorandum 01: Disinfection and sterilization

Scottish Health Technical Memorandum 02: Medical gases

Scottish Health Technical Memorandum 03: Ventilation systems

Scottish Health Technical Memorandum 04: Water systems

Scottish Health Technical Memorandum 05: Reserved for future use

Scottish Health Technical Memorandum 06: Electrical services

Scottish Health Technical Memorandum 07: Environment and sustainability

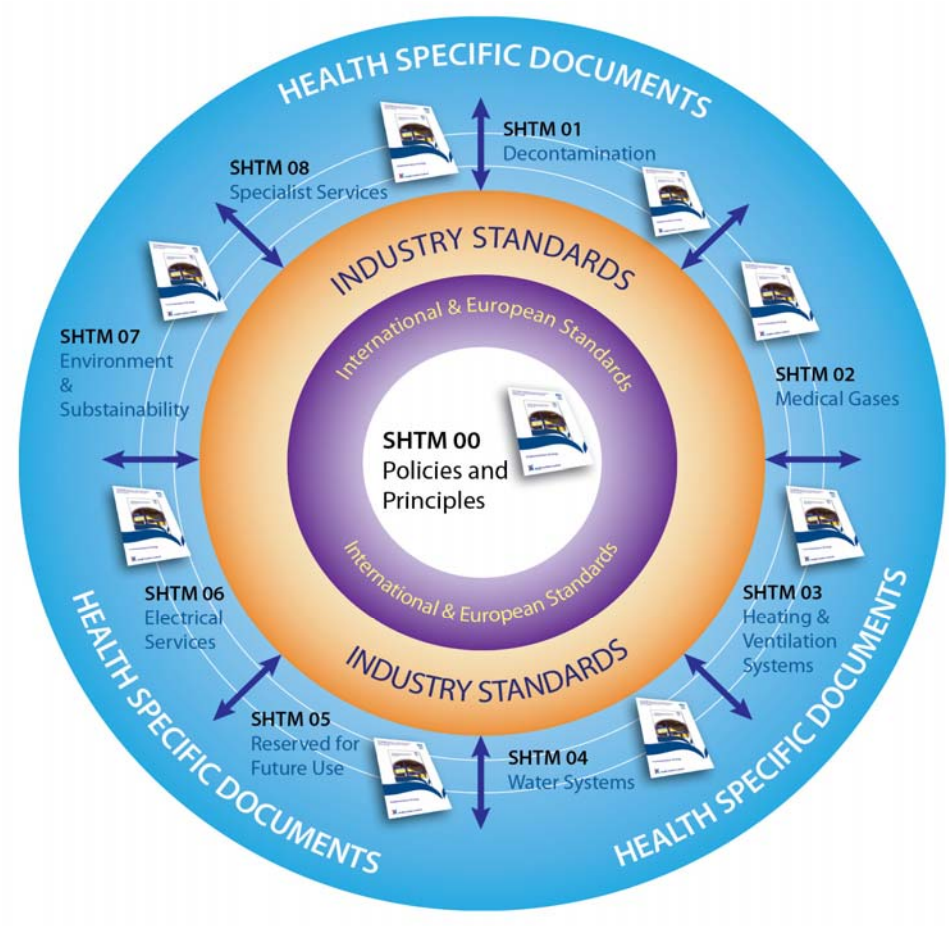
Scottish Health Technical Memorandum 08: Specialist services

Some subject areas may be further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc. Example: Scottish Health Technical Memorandum 06-02 Part A will represent: Electrical Services – Safety – Low Voltage. In a similar way Scottish Health Technical Memorandum 07-02 will simply represent:

Environment and Sustainability – EnCO_2de.

All Scottish Health Technical Memoranda are supported by the initial document Scottish Health Technical Memorandum 00 which embraces the management and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.



Engineering guidance

Acknowledgements

Health Facilities Scotland would like to thank the steering group led by the Department of Health for their efforts in producing the HTM 02-01 Part A document.

HTM 02-01 has been updated, expanded and amended by Health Facilities Scotland for use in NHSScotland as SHTM 02-01 Part A. The significant contribution by the following is gratefully acknowledged.

Alex Black Alex Black & Associates Limited

Graeme Dunn Atkins Limited

Ian Sandford Hulley & Kirkwood Consulting Engineers Limited

Executive summary

Introduction

A medical gas pipeline system (MGPS) is installed to provide a safe, convenient and cost-effective system for the provision of medical gases to the clinical and nursing staff at the point-of-use. It reduces the problems associated with the use of gas cylinders such as safety, porterage, storage and noise.

This Scottish Health Technical Memorandum is divided into two parts. Guidance in this part (Part A) covers piped medical gases, medical and surgical air, and medical vacuum installations: it applies to all medical gas pipeline systems installed in healthcare premises and anaesthetic gas scavenging disposal systems. Specifically, it deals with the issues involved in the design, installation, and validation and verification (testing and commissioning) of an MGPS. Part B covers operational management.

The guidance given in this document should be followed for all new installations and refurbishment or upgrading of existing installations. All new works should be subject to a design review / validation prior to installation by the AP, AE or CSO.

It is not necessary to apply the guidance retrospectively unless patient or staff safety would be compromised. In this case, the guidance given in this document should be followed.

Existing installations should be assessed for compliance with this guidance document. A plan for upgrading the existing system should be prepared, taking account of the priority for patient safety. Managers will need to liaise with medical colleagues and take account of other guidance published by the Scottish Government Health Directorates in order to assess the system for technical shortcomings.

Scottish Health Technical Memorandum 02 supersedes all previous versions of Scottish Health Technical Memorandum 2022. Where SHTM 2022 has been used as the contractual document within current projects, SHTM 2022 would be applicable.

Sources of supply for pipeline installations

Oxygen

Oxygen is generally supplied from:

- a liquid source such as a large vacuum insulated evaporator (VIE);
- liquid cylinders or compressed gas cylinders; or
- a combination of these to provide the necessary stand-by/back-up capacity.

Oxygen can also be supplied from an oxygen concentrator (pressure-swing adsorber). Such systems are usually installed where liquid or cylinders are expensive, unavailable or impracticable.

Medical air

Medical air is usually supplied from a compressed air plant that includes high-quality drying and filtration equipment. Blending oxygen and nitrogen on-site to provide a high-quality product with minimum maintenance can also provide medical air. Where such systems are installed to provide both oxygen and medical air, nitrogen can be used for the power source for surgical tools.

Other gases

All other gases are supplied from cylinders.(On-site blended oxygen/nitrous oxide mixture is a possibility if bulk liquid supplies of nitrous oxide are available, although this system is unlikely to be adopted in the UK.)

Basic principles of design

Patient safety is paramount in the design, installation, commissioning and operation of medical gas pipeline systems. The basic principles of safety are achieved by ensuring quantity of supply, identity of supply, continuity of supply and quality of supply.

Quantity of supply

This is achieved by ensuring that the design of the pipeline installation and capacity of the supply plant is sufficient to provide the required flows of gases and vacuum for the intended number of patients to be treated at any one time. Adequacy of supply is established during commissioning of the systems.

Identity of supply

This is achieved by ensuring that all points to which the user can connect medical equipment (terminal units) and user-replaceable components are provided with gas-specific connectors. Such connectors are also identified by symbol and often colour. The gas specificity is maintained by comprehensive tests and checks during installation and commissioning, and during any work or maintenance on the systems.

Continuity of supply

This is achieved by installing, as a minimum, duplex components and providing additional means of supply provision in the event of failure of the primary and secondary plant supply system. Systems are also connected to the essential electrical supply.

Quality of supply

Quality of supply is ensured by the use of gaseous or liquid sources that are provided to an appropriate product specification, usually a recognised European

Pharmacopoeia (Ph. Eur.) monogram. In the case of compressor-based systems, filtration equipment to a known and agreed standard is installed. To ensure that the product is not adulterated in the distribution system, pipeline installations and components are required to meet agreed specifications. There are strict Ph. Eur. requirements for medical gases.

General uses of gas and pipeline installations

- oxygen is one of the most extensively used gases for respiratory therapy and life-support and is additionally used in anaesthetic procedures;
- medical air is mainly used in respiratory therapy as a power source for patient ventilators, and for blending with oxygen; it is also used as the driving gas for nebulised drugs and chemotherapy agents;
- surgical air (of medical air quality) is also used, at a higher pressure, to power a variety of surgical tools and other devices such as tourniquets. (As an alternative, nitrogen can be used for this purpose.);
- nitrous oxide is used for anaesthetic and analgesic purposes, being mixed with air, oxygen, and nebulised agents;
- pipeline systems for a 50% mixture of oxygen and nitrous oxide are widely installed in the UK for analgesic purposes, particularly in maternity departments;
- helium/oxygen mixture is used to treat patients with respiratory or airway obstruction and to relieve symptoms and signs of respiratory distress; guidance on pipeline systems is now included;
- carbon dioxide is used less commonly now as a respiratory stimulant, and for insufflation during surgery. Pipeline systems for respiratory use have not been installed in the UK but they are now being installed for this latter purpose;
- piped vacuum is provided in most clinical areas by means of centrally sited vacuum pumps;
- the control of occupational exposure to waste anaesthetic gas (nitrous oxide) and nebulised agents is a legal requirement under the Control of Substances Hazardous to Health (COSHH) Regulations 2002. Where nitrous oxide is provided for anaesthetic purposes, scavenging systems are installed.

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1. Scope

Guidance in this document

1.1 This Scottish Health Technical Memorandum is divided into two parts. Guidance in this part (Part A) covers piped medical gases, medical and surgical air, and medical vacuum installations; it applies to all medical gas pipeline systems installed in healthcare premises. Anaesthetic gas scavenging disposal systems are also included. Specifically, it deals with the issues involved in the design, installation, and validation and verification (testing and commissioning) of an MGPS. Part B covers operational management.

1.2 The guidance given in this document should be followed for all new installations and refurbishment or upgrading of existing installations.

1.3 It is not necessary to apply the guidance retrospectively unless patient or staff safety would be compromised. In this case, the guidance given in this document should be followed.

1.4 Existing installations should be assessed for compliance with this guidance document. A plan for upgrading the existing system should be prepared, taking account of the priority for patient safety. Managers will need to liaise with medical colleagues and take account of other guidance published by the Scottish Government Health Directorates in order to assess the system for technical shortcomings.

1.5 Throughout this document, “medical gas pipeline system(s)” will be described by the term MGPS.

Other guidance

1.6 Model Engineering Specification C11: ‘Medical gases’ It is anticipated that this publication will be subject to review for compliance with current standards.

1.7 Guidance on the provision of MGPS is given in the Scottish Health Planning Notes (SHPN’s) Health Building Notes that are still applicable in Scotland and other relevant British, European, and International standards.

2. General principles

Introduction

2.1 An MGPS is designed to provide a safe and effective method of delivering medical gases, medical air and surgical air from the source of supply to the appropriate terminal unit by means of a pipeline distribution system. Medical vacuum is also provided by means of a pipeline system. Anaesthetic gas scavenging disposal systems are provided to control occupational exposure to waste anaesthetic gases and agents.

2.2 It is essential to ensure that there is no possibility of a cross-connection between any system and that all parts of each system to which connections can be made by users are gas-specific.

2.3 Dental compressed air and vacuum systems have differing requirements, and these are covered in Scottish Health Technical Memorandum 2022, Supplement 1: 'Dental compressed air and vacuum systems'. Scottish Health Technical Memorandum 2022 Supplement 2 is concerned with piped medical gases in ambulance vehicles.

2.4 During the installation stage, extensive tests are carried out to verify that there is no cross-connection.

2.5 Medical gas systems may be extended to those departments where respiratory equipment or surgical tools are serviced, such as in electronic and biomedical equipment (EBME) workshops and sterile services departments (SSDs). Specific additional uses of air systems are covered in Sections 7 and 8.

2.6 MGPS should not be used to supply university, pathology and dental laboratories or workshops, steriliser equipment, seals, chamber ballast or controls, washer/disinfection and endoscope drying procedures, air conditioning or other mechanical services. Consideration can be given to the use of MGPS where a university theatre or room teaching medical procedures forms part of the hospital complex.

2.7 Separate installations should be provided for pathology and general laboratories and workshops, although it is recommended that they be constructed to the same specification as MGPS. They should not be provided with medical gas terminal units. Scottish Health Technical Memorandum 08-06 refers.

Note 1: Portable suction devices should be used in infectious disease units.

Quality requirements for medical gases and air

2.8 Medical gases supplied from cylinder or liquid sources comply with the appropriate sections of the current edition of the European Pharmacopoeia (Ph. Eur.). The Ph. Eur. also specifies the approved testing methods to be adopted for gas identity.

2.9 The quality specification for medical, surgical and synthetic air, and oxygen-enriched air produced from a pressure swing adsorber (PSA) system, is as given in Table 42. The medical air and synthetic air should also comply with the appropriate sections of the current edition of the Ph. Eur. (see Table 43).

2.10 The quality of piped medical compressed air, and the particulate content, dryness and concentration of impurities should comply with the requirements for maximum concentrations given in Table 43. Information on testing procedures is given in Section15 “Validation and verification”.

2.11 Bacteria filters should be included in medical and surgical compressor systems to reduce the risk of delivering spores or other infectious material to vulnerable patients.

2.12 Micro-organisms can penetrate a bacteria filter if the material is wet. Therefore it is essential that the dryness of the medical air supplied to a bacteria filter is checked regularly (at least every three months) at the test point, using the test equipment specified in Section15.

Sources of supply

2.13 Both BS EN 737-3: 2000 and BS EN ISO 7396-1: 2007 + A2: 2010 (which replaced the former standard from 30 April 2009) propose that all medical gas supplies should comprise three sources of supply identified as “primary”, “secondary” and “reserve”, although the latter is more commonly referred to as a third means of supply. The supply system should be designed to achieve continuity of supply to the terminal units in normal condition and in a single fault condition. A single fault condition is where a single means for protection against a safety hazard in equipment is defective or a single external abnormal condition is present. Loss of supply due to maintenance of a supply source (or a component within it) is not considered a single fault condition. Failure of the pipeline is considered a catastrophic event and is not regarded as a single fault condition.

2.14 With respect to individual banks of a cylinder manifold installation, this Scottish Health Technical Memorandum (SHTM) refers to separate banks of an automatic manifold as primary and secondary supplies as prescribed within BS EN ISO 7396-1: 2007 + A2: 2010. This SHTM will classify an automatic manifold as a single source of supply, when applied to liquid oxygen, medical and surgical air systems.

2.15 Regardless of these classification differences, the choice of central source will be defined by the ability of the source not only to provide a continuous supply of gas over a range of possible flow rates but also to offer security of supply by virtue of adequate capacity.

2.16 For these reasons, types, capacities and locations of primary, secondary and reserve sources of supply will be based on both system design parameters and the need for supply security, identified by a risk assessment during the planning stage. Security of medical air supplies must be given a high priority. Tables 1–9

describe the various options for gas supply. For each, the primary, secondary and reserve sources are identified.

Primary supply	Secondary supply	Reserve supply (third source of supply
Duty bank of a fully automatic manifold. Number of cylinders based on system design.	Standby bank of a fully automatic manifold.	Manual emergency reserve manifold - to come on line automatically via a non-return valve in the event of a single fault condition and to act as a reserve supply during maintenance / repair works. Type and capacity of supply to be determined by risk assessment.

Table 1: Compressed gas cylinder manifold systems

Primary supply	Secondary supply	Reserve supply (third source of supply)
Simplex VIE (vacuum insulated evaporator) vessel system	Automatic cylinder manifold system. To come on-line in the event of plant failure	Automatic cylinder manifold system. May be sited to support high-dependency areas or whole site OR Locally-based integral valved cylinders with regulators/flowmeters attached.
One vessel of a duplex VIE (vacuum insulated evaporator) vessel system (on same plinth).	Second vessel of a duplex VIE system.	Automatic cylinder manifold system. May be sited to support high-dependency areas or whole site.
One vessel of a duplex VIE vessel system (on separate plinths).	Second vessel of a duplex VIE system (on separate plinths). NB split-site systems are intended primarily for systems where the risk assessment has identified that the site for the primary supply is limited in size or presents too high a risk having both tanks on the same site. These supply systems should be fitted with appropriate non-return valved connections to prevent gas loss in the event of one tank/system failing.	Type and capacity of supply to be determined by risk assessment. May not be required when remote dual supplies are connected to a ring main or to a mains (linked) pipeline distribution system. (Note: a ring main or distribution pipeline is not regarded as a reserve supply (third source of supply)

Table 2: Bulk liquid oxygen VIE systems

Primary supply	Secondary supply	Reserve supply (Third source of supply)
Liquid cylinder or liquid cylinder manifold system. NB: The latter is NOT a changeover manifold. All cylinders are on-line simultaneously.	Automatic cylinder manifold system. To come on-line in the event of plant failure.	Automatic cylinder manifold system. May be sited to support high-dependency areas or whole site OR Locally-based integral valved cylinders with regulators/flow meters attached.

Table 3: Liquid oxygen cylinder system

Primary supply	Secondary supply	Reserve supply (Third source of supply)
Multiplex compressors and columns (adsorbers). Subject to design.	Automatic cylinder manifold system. To come on-line in the event of plant failure. May be fitted with third party cylinders, or filled from compressor of main plant. Number of cylinders should have sufficient connected capacity to supply the site for at least 4 hours. Locally filled cylinders or gas suppliers' cylinders can be used.	Type and capacity of supply to be determined by risk assessment.

Table 4: PSA plant

Primary supply	Secondary supply	Reserve supply (Third source of supply)
First compressor of a duplex compressor system.	Second compressor of a duplex compressor system.	Automatic cylinder manifold system. To come on-line automatically in the event of plant failure. Type and capacity of supply to be determined by risk assessment.
First compressor of a triplex compressor system.	Second compressor of a triplex compressor system.	Third compressor of a triplex compressor. In addition, an automatic cylinder manifold system to support a dedicated department(s) or whole site.
Two compressors of a quadruplex compressor system.	Other two compressors of a quadruplex compressor system.	Automatic cylinder manifold system to support whole site.

Table 5: Compressor-driven medical air systems

Primary supply	Secondary supply	Reserve supply (Third source of supply)
Primary oxygen and nitrogen VIE vessels and mixer unit.	Secondary oxygen and nitrogen VIE vessels and mixer unit.	Type and capacity of supply to be determined by risk assessment.

Table 6: Synthetic air plant

Primary supply	Secondary supply	Reserve supply (Third source of supply)
First compressor of a duplex compressor system.	Second compressor of a duplex compressor system.	Two automatic cylinder manifold systems: one dedicated to support medical air (MA4) system. one dedicated to support surgical air (SA7) system. All to come on-line in the event of plant failure. Type and capacity of supply to be determined by risk assessment.
First compressor of a triplex compressor system.	Second compressor of a triplex compressor system.	Third compressor of a triplex compressor system. In addition, an automatic cylinder manifold system to support whole site. SA7 and MA4 with independent ERMs see above for duplex compressors.
Two compressors of a quadruplex compressor system.	Other two compressors of a quadruplex compressor system.	Automatic cylinder manifold system to support whole site. One for MA4 and one for SA7 see above for duplex compressors.

Table 7: Combined medical/surgical air plant

Primary supply	Secondary supply	Reserve supply (Third source of supply)
Simplex compressor unit.	Automatic cylinder manifold system to come on-line in the event of plant failure. Type and capacity of supply to be determined by risk assessment.	Locally based integral valved cylinders with regulators/flow meters attached.
First compressor of a duplex compressor system.	Second compressor of a duplex compressor system.	Automatic cylinder manifold system.

Table 8: Compressor-driven surgical air systems

Primary supply	Secondary supply	Reserve supply (Third source of supply)
First pump of a triplex pump system.	Second pump of a triplex pump system.	Third pump of a triplex pump system with additional portable suction equipment available.
Two pumps of a quadruplex pump system.	Other two pumps of a quadruplex pump system.	Portable suction equipment.

Table 9: Central medical vacuum systems

Notes to Tables 1-9: General guidance on vacuum systems is contained in Appendix L. a) Where duplex vacuum plant is currently installed, a risk assessment should be carried out to establish if a third vacuum pump or replacement plant is required to meet the recommendations of this Scottish Health Technical Memorandum;

b) for duplex and triplex compressor systems and triplex vacuum pump systems, each compressor/pump will be sized to provide the system's full design flow;

c) for quadruplex systems, each compressor/pump will be sized to provide half the system design flow;

d) for all compressor systems with a design flow greater than 500 litres/min, two receivers, each able to be isolated individually, should be installed. For compressor systems with a design flow less than 500 litres/min with a single receiver, a valved bypass line should be installed;

e) all plant is to be connected to the essential electricity supply;

f) for vacuum provision during total electricity supply failure, cylinder – or medical-gas-system-powered vacuum generators can be used;

g) the use of venturi-type vacuum generators is recommended only for emergency use, as these units are generally driven from the medical oxygen system and use large amounts of gas. This can lead to oxygen enrichment and present a potential fire hazard and may result in the emission of pathological material;

h) the emergency reserve manifold supporting a fully automatic manifold is usually sited with the manifold system. If a risk assessment indicates that this is not in the interests of supply security, they may be sited remotely from the manifold. In all circumstances, care should be taken to ensure that appropriate backflow protection (or non-return valves) are used to protect the system from failure of either manifold;

i) manifolds supporting medical air, surgical air and PSA systems should be sited remotely from the compressor systems. Appropriate backflow protection should be provided, as above;

j) surgical air plant may be used as an emergency supply to the medical air 4 bar system;

k) a valved by-pass arrangement around compressor and VIE-plant non-return valves should be considered to facilitate valve replacement or servicing of the non-return valve to avoid disruption to the service without plant shutdown;

l) fitting non-return valves one pipe size larger will reduce flow resistance, if this is shown to be a critical factor in system design;

m) all sources of supply should be fitted with a test point consisting of a terminal unit and lockable isolating valve. Where the test point is located externally, this should be located within a weatherproof enclosure.

Sizing information for gas supply sources

2.17 Table 10, below, provides guidance on suggested maximum sizes for gas sources. Final decisions on plant and manifold capacities will depend on both available accommodation and risks to supply security.

Source	Service	Number of cylinders	Cylinder size	Notes
Automatic manifold	Oxygen	2 x 10	J	Used as a stand-alone manifold or support for cryogenic system / PSA plant
	Medical air	2 x 10	J	Used as a stand-alone manifold or support for compressor plant
	Surgical air	2 x 6	J	For nitrous oxide, a 2 x 2 or 2 x 4 installation may be adequate in some cases – cylinder sizes should be subject to local manual handling operations.
	Oxygen/nitrous oxide mixture	2 x 8	G	
	Nitrous oxide	2 x 6	G	
	Carbon dioxide	2 x 4	VF	
	Helium/oxygen	2 x 4	H	
	Nitrogen	2 x 6	W	
Manual manifold	Oxygen	2 x 2	J	As reserve supply for an automatic manifold system
	Medical air	2 x 2	J	
	Surgical air	2 x 1	J	
	Oxygen/nitrous oxide mixture	2 x 2	G	
	Nitrous oxide	2 x 1	G	
	Carbon dioxide	2 x 1	VF	
	Helium/oxygen	2 x 1	H	
	Nitrogen	2 x 2	W	

Table 10: Suggested sizes for gas sources

Source	Service	Plant size	Receiver / Reservoir Capacity
Duplex compressor system	Medical air	Each compressor sized at full design flow capacity	Receiver water capacity sized at 50% free air delivery (FAD) in 1 minute
Triplex compressor system	Medical air	Each compressor sized at full design flow capacity	
Quadruplex compressor system	Medical air	Each compressor sized at half design flow capacity	
Simplex compressor system	Surgical air	Compressor sized at 1/3 design flow (when design flow <500 litres/min). For design flows >500 litres/min, refer to Table 33.	Refer to Table 33 (para. 8.9)
Duplex compressor system	Surgical air	Each compressor sized at 1/3 design flow (when design flow <500 litres/min). For design flows >500 litres/min, refer to Table 33.	
Triplex pump system	Medical vacuum	Each pump sized at full design flow capacity	Water capacity of reservoir sized at design flow in 1 minute
Quadruplex pump system	Medical vacuum	Each pump sized at half design flow capacity	

Table 10: (cont'd) Suggested sizes for gas sources

2.18 Sizing of vacuum insulated evaporator (VIE) systems, liquid cylinder storage systems, PSA plant and synthetic air plant should be based on historical consumption data and appropriate risk assessments carried out with the medical gas supplier. Allowance should be made for increases in the use of medical gases and changes to the gas demands caused by local developments and strategic issues. For a completely new site, the proposed gas supplier will need to be consulted so that a review of their historical data can be conducted for similar sites. The graph shown in Appendix M will give an approximate indication of expected annual consumption, based on the number of hospital beds. It should be noted that higher consumption could be expected when, for example, high numbers (>20) of continuous positive airway pressure (CPAP) machines are in frequent use (>40 hours per week).

Note 2: a) Automatic cylinder manifolds are generally expected to hold a minimum of two days' supply on each bank.

b) Sufficient cylinders for changing one complete bank should be stored in the manifold room for all gases except nitrous oxide/oxygen mixture, for which two complete changes should be stored in the manifold room;

c) Sufficient additional cylinders should be held in the medical gas store to ensure continuous supply for one week.

Pipeline distribution system design

2.19 The following general information is required to design an MGPS:

- schedule of provision of terminal units;
- design flow rates and pressure requirements at each terminal unit;
- diversified flows for each section of the pipeline system;
- total diversified flow.

2.20 Guidance on deriving and calculating the above parameters is given in Sections 3 and 4 of this Part A.

2.21 The definition of “departments”, which may comprise several wards, treatment rooms etc, should be agreed at the project design stage to avoid confusion.

Safety

2.22 The safety of an MGPS is dependent on four basic principles:

- identity;
- adequacy;
- continuity;
- quality of supply.

2.23 **Identity** is assured by the use of gas-specific connections throughout the pipeline system, including terminal units, connectors etc, and by the adherence to strict validation and verification procedures of the system.

2.24 **Adequacy** of supply depends on an accurate assessment of demands and the selection of plant appropriate to the clinical/medical demands on the system.

2.25 **Continuity** of supply is achieved by:

- the specification of a system that (with the exception of liquid oxygen systems which may include a secondary vessel) has duplicate components;
- the provision of a reserve (third means of) supply;
- the provision of alarm systems; and
- connection to the emergency power supply system.

2.26 **Quality** of supply is achieved by the use of gases purchased to the appropriate Ph. Eur. requirements or produced by plant performing to specific standards, by the maintenance of cleanliness throughout the installation of the system, and by the implementation of the various validation and verification procedures.

Installation/supply of equipment/maintenance

2.27 The installation of an MGPS should be carried out only by specialist firms who are either registered to BS EN ISO 9001: 2008 /BS EN ISO 13485: 2003 or who can demonstrate that they are actively working towards registration with the scope of registration appropriately defined.

Modifications

2.28 Special precautions are required when existing installations are to be modified or extended, to ensure that all sections of the pipeline system remaining in use are not contaminated, and that the supply to patients is not compromised. The section to be modified should be physically isolated from the section in use. Closure of isolating valves is insufficient for this purpose. Where area valve service units (AVSUs) and/or line valve assemblies (LVAs) have been installed, blanking spades should be used. On older installations where the valve design does not include blanking spades, the pipeline must be physically isolated from the valve with the open ends protected to prevent ingress of dust etc.

2.29 Modification of existing systems may be detrimental to the overall performance of the system. In the case of older systems, there may be insufficient capacity to permit the system to operate safely with the flows typically encountered in use today. Any proposal to extend the system should be subject to a design review to ensure the system has sufficient capacity for adequacy of performance.

2.30 Any work involving alteration, extension or maintenance work on an existing system should be subject to the permit-to-work procedure (see Part B, Section 8).

Removal of pipework

2.31 Removal and cutting out of redundant medical gas pipelines and equipment can present as great a hazard to patient safety as any other modification. All such removal (including cutting into existing pipelines, and capping off and removal of redundant pipework and equipment) should be carried out by specialist medical gas contractors only. General demolition contractors should not carry out this work.

Note 3: Removal of vacuum systems may present additional microbiological hazards and should be undertaken in accordance with routine hygiene practices, that is, covering of open wounds and immediate cleansing and dressing of cuts/scratches received while carrying out the work. Immunisation against certain diseases may be required by the Hospital's occupational health department or the employer of tradespeople, therefore, all operatives should ensure that this requirement has been met. Further advice should be sought from the Hospital's Infection Control Team.

Validation and verification

2.32 The objective of validation and verification is to ensure that all the necessary safety and performance requirements of the MGPS will be met. Validation and verification procedures will be required for new installations, additions to existing installations and modifications to existing installations. The scope of work will dictate the specific programme required. This is described in Section15.

Note 4: The concept of the existing quality assurance BSI scheme schedule QAS 3720. 1/206/A1 is currently under review. Further guidance will be given when appropriate

General fire precautions

General

2.33 The siting and general structural principles for the design of liquid oxygen storage accommodation are given in Section 6, and the requirements for plantrooms and gas manifold rooms in Section14.

2.34 Guidance on cylinder storage and handling is given in Part B.

Fire detection system

2.35 Smoke or heat detector heads should be installed in the plantrooms, medical gases manifold rooms and (when internal) medical gases cylinder stores in any hospital having a fire detection system in accordance with Scottish Health Technical Memorandum SHTM 85: 'Firecode: alarm and detection systems'. External stores may also require fire detection systems.

Electricity supply to medical gas installations

General

2.36 Electrical installations should be carried out in accordance with the current edition of BS7671 wiring regulations and associated guidance documents.

2.37 Provision of electrical supply and distribution should take account of guidance issued in Scottish Health Technical Memorandum 06-01: 'Electrical services: supply and distribution'.

Resilience of supply

2.38 Medical gas pipeline systems, associated equipment and alarms are a critical service within a healthcare establishment. Due consideration should be given to ensure the continuity of service under mains power failure conditions.

2.39 Each item of plant with respect to medical / surgical air and medical vacuum should be supplied from a dedicated, final sub-circuit which is considered "essential" within the electrical distribution strategy. Alternative means of supply should be considered in the event that internal sub-distribution is compromised.

2.40 In the event of power failure or interruption, all systems should continue to function as they did before the interruption occurred. For example, except for automatic cycling compressors, dryers, pumps etc, the same compressor and dryer (or vacuum pump) set should be on-line, and for manifold systems the same bank should be running.

2.41 All electrical systems, including plant control systems, alarm interfaces etc, should be designed in accordance with electromagnetic compatibility (EMC)

directives. For further details, see the “EMC section” within Scottish Health Technical Memorandum 06-01: ‘Electrical services: supply and distribution’.

2.42 It is important that operational managers and designers are fully aware of stand-by electrical supply arrangements and availability and that plans are available to deal with the total loss of electricity under adverse circumstances.

Electrical installation

2.43 Wiring systems for medical gas installations should be selected in accordance with BS7671 wiring regulations with particular regard to the environment and risk from mechanical damage. In this regard, PVC-insulated MICS (mineral-insulated copper-sheathed) cable for external/ internal locations and heat-rated singles cable in galvanised conduit for plantrooms are considered suitable. For large equipment, fire-rated SWA (steel wire armoured) cable may be appropriate.

2.44 Care should be taken when installing both electrical systems and medical gas pipeline systems to avoid occasional contact between pipework and electrical cables, conduit or trunking. When physical separation is impractical or contact with extraneous metalwork occurs (for example where the pipeline is carried in metal partitions or where terminal units are mounted on metal bed-head units), the pipeline should be effectively bonded to the metalwork in accordance with BS7671 wiring regulations.

2.45 The final connection to any equipment (for example alarm panels or control panels) should be made using a key operated (double pole) fused connection unit should be available to permit work authorised on the equipment.

2.46 Where electrical systems and medical gas pipeline systems are enclosed in a boom, rigid pendant or multi-purpose-type enclosure, care should be taken to ensure that Low Voltage (LV), Extra-Low Voltage (ELV) and communications and data systems are maintained together but separate from pipeline systems. There should be no access to unprotected live parts within the pendant except by the use of a tool. Reference should be made to BS EN ISO 11197: 2009 which gives clear guidance on the requirements for such separation and segregation.

Earthing

2.47 Medical gas pipelines should be bonded together and bonded to the local electrical distribution board in accordance with BS7671 wiring regulations. The pipelines should not in themselves be used for earthing electrical equipment.

2.48 Flexible pipeline connections, wherever used, should be bonded across the fixed points to ensure earth continuity.

2.49 Where a medical gas outlet or pipeline system is present within a group 2 location as defined by IEE Guidance Note 7: ‘Medical locations’, care must be taken to ensure the resistance of the bonding connection is in accordance with the required value.

3. Provision of terminal units, and the location of AVSUs, area alarm panels and LVAs

General

3.1 Terminal unit provision, location of area valve service units (AVSUs) and area alarm panels are given in Table 11. Medical treatment policy is evolutionary, however, and the project team should review requirements for individual schemes.

Terminal units

3.2 Terminal units should be mounted in positions that result in the shortest practicable routes for flexible connecting assemblies, between the terminal unit and apparatus. Terminal units may be surface or flush-mounted. They may also be incorporated with electrical services, nurse call systems, televisions, radio and audio services, in proprietary fittings such as medical supply units, wall panel systems and pendant fittings etc. When they are installed within such fittings, it is essential to maintain the concentricity of the terminal unit bezel with the fascia plate aperture; if the installation is highly eccentric, the bezel will bind on the fascia plate and the terminal unit will not function properly.

3.3 When planning the installation of operating-room pendant fittings, the location of the operating luminaire and other ceiling-mounted devices should be taken into consideration. When the operating room is provided with an ultra-clean ventilation (UCV) system, it may be more practicable (and cost-effective) to have the services (both medical gas and electrical) incorporated as part of the UCV system partial walls. It is particularly advantageous in the case of surgical air systems as rigid pipework can be used, thus avoiding pressure-loss problems that can occur with flexible assemblies used within pendant fittings.

3.4 The following are not permitted:

- floor-mounted terminal units;
- vacuum systems in which body or other fluids are drawn through a fixed pipeline connecting a terminal unit or other connector to a remote suction jar.

3.5 All terminal units should conform to BS EN ISO 9170-1: 2008. Terminal units intended for wall mounting where directly connected equipment such as flow meters are to be used must include a non-swivel device. Terminal units intended for installation with the socket axis vertical, for example on the under-surface of a pendant and intended for use with indirectly connected equipment by means of a flexible connecting assembly, do not require a non swivel device. Dimensions of probes are given in BS5682: 1998. It is essential that probes be machined from stainless steel.

3.6 An anaesthetic gas scavenging (AGS) terminal unit should be provided whenever nitrous oxide and anaesthetic agents are available for anaesthetic procedures. In recovery areas, where nitrous oxide is not provided, there is no primary source of anaesthetic gas pollution; thus, no anaesthetic gas scavenging system (AGSS) is required. Guidance on operating departments requires such areas to be mechanically ventilated. Where nitrous oxide mixed with oxygen is provided for analgesic purposes, scavenging is not generally practicable and pollution should therefore be controlled by mechanical ventilation. Details of ventilation requirements are given in Health Building Note 26 (Volume 1): 'Facilities for surgical procedures'. For dental departments, scavenging is possible by means of nasal masks at a reduced flow of 45 litres/min, and reference should be made to Scottish Heath Technical Memorandum 2022 (Supplement 1): 'Dental compressed air and vacuum systems' (see also Section10).

3.7 The terminal unit (AGS) is specified in BS EN ISO 9170-2: 2008. AGSS's are covered in Section10.

Note 5: Reference should be made to the Department of Health's (1996) 'Advice on the implementation of the Health & Safety Commission's occupational exposure standards for anaesthetic agents'. Further guidance is given in the Health & Safety Executive's (1996) 'Anaesthetic agents: controlling exposure under COSHH'.

3.8 Where respiratory equipment or surgical instruments are serviced, such as in EBME workshops, it is normally necessary to install the full range of medical gas terminal units. AGS should be provided as a dedicated system.

3.9 The fixing of terminal units into medical supply systems or to wall surfaces etc. should be such that the following forces can be applied:

- a lateral force of 20 N applied at 50mm from the surface of the terminal unit without dislodgement or breakage;
- an axial force of 500 N without dislodgement or breakage.

3.10 Where an array of terminal units is provided at a location, they should be arranged as follows (see Figure 1):

- for a horizontal array, when viewed from the front, left to right: oxygen, nitrous oxide, nitrous oxide/oxygen mixture (50% v/v), medical air, surgical air, vacuum, anaesthetic gas scavenging, helium/oxygen mixture. If this arrangement is impracticable, a number of rows can be used;
- for a vertical array, with oxygen at the top and in the sequence as for a horizontal array. In many cases a vertical array is impracticable and a more convenient arrangement will comprise a number of rows/columns;
- for a circular array, for example where terminal units are installed on the under-surface of a pendant, with the sequence as for a horizontal array, in a clockwise direction when viewed from below. The AGS terminal unit may occupy the centre of such an array;

- On occasion, the user may require the configuration of outlets to be out of sequence from that shown in Figure 1 a) to d), however, this should be agreed in line with contractual requirements.

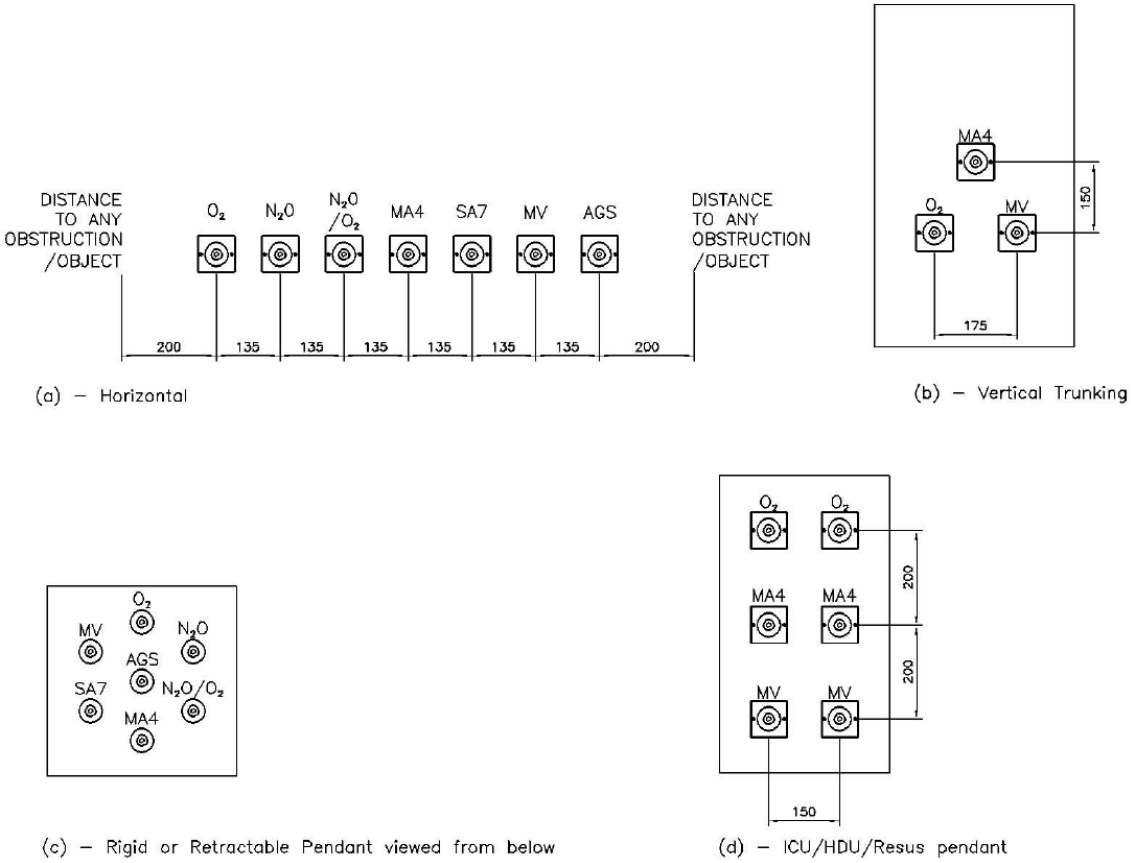


Figure 1: Terminal unit mounting order

3.11 Oxygen/carbon dioxide mixture systems have been installed, but are no longer covered by this Scottish Health Technical Memorandum.

3.12 Helium/oxygen mixtures may be required to be supplied by pipeline in some critical care areas. Systems for these are included in Section 11.

3.13 Mounting heights for terminal units should be between 900mm and 1,600mm above finished floor level (FFL) when installed on walls or similar vertical surfaces – the optimum height for the convenience of users of the medical gas system is 1,400mm (see Figure 2). When terminal units are incorporated within a horizontal bedhead service trunking system, which also provides integrated linear lighting for general room and/or patient reading illumination, it should be of a design that does not compromise the convenience of the medical gas facility. Where there is a desire to mount terminal units below 900mm e.g. below worktops in some dental surgery configurations, prior agreement should be sought from the User.

3.14 When installed in pendants or similar, terminal units should be of a type suitable for mounting within the specified fitting.

3.15 Pressure losses across terminal units should be in accordance with BS EN ISO 9170-1: 2008. The standard does not give pressure loss data for surgical air at 350 litres/min, but this can be ≥150 kPa when connected via a ceiling NIST

(non-interchangeable screw thread) connector and 5m of hose. This pressure drop could be reduced by removing the non-return valve within the NIST connector and installing a line valve directly upstream of the NIST connector to facilitate future servicing / repair / hose replacement.

3.16 Terminal units that are wall mounted should be located as follows (Figure 2 refers):

- the distance between the centre of the terminal unit and a potential obstruction on either side (for example when installed in a corner) should be a minimum of 200mm on either side;
- distance between centres of adjacent horizontal terminal units should be;
  - 135 ± 2.5mm for three or more terminal units;
  - 150 ± 2.5mm for two terminal units only;
- distance between centres of adjacent horizontal terminal units;
- care should be taken to ensure that connected medical gas equipment and hoses do not foul other nearby equipment and services during use. Particular attention should be given to terminal unit positioning with respect to worktops, electrical sockets, cupboards, equipment rails, ventilation flaps and door openings. A minimum radial clearance of at least 200mm from these items is suggested, but this may have to be increased depending on the nature of connected equipment.

Note 6: To promote a more “domestic” environment, some in-patient accommodation is provided with terminal units installed in recesses behind covers/decorative panels etc. To accommodate this it is necessary to allow an additional 100mm on each side of the outermost terminal units and 200mm from centre to top of recess and 300mm from centre to bottom of recess. The depth of the recess should be 150mm. The surface should be clearly marked with suitable legend denoting medical equipment is installed within.

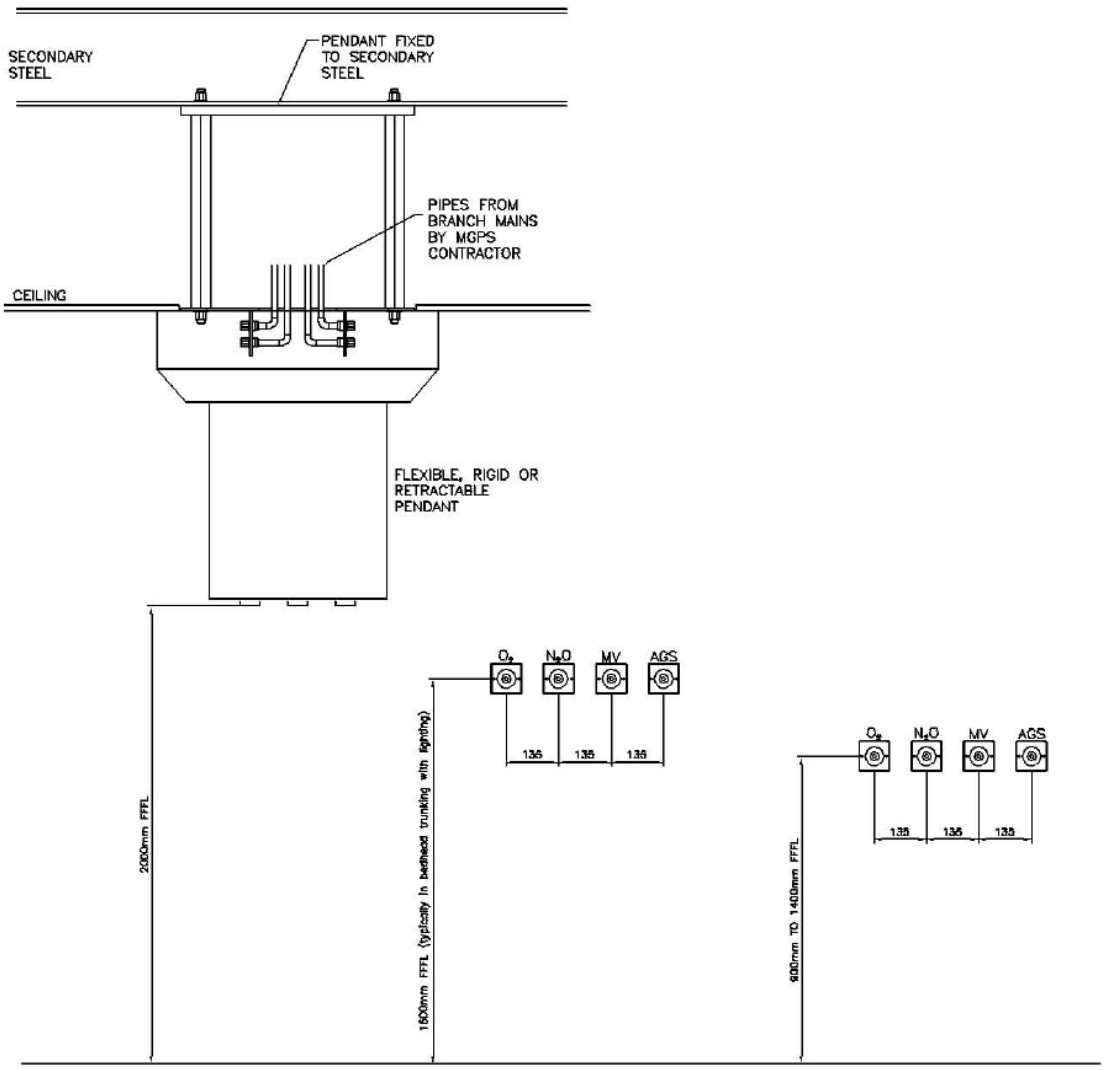


Figure 2: Terminal unit mounting heights

Terminal units for helium/oxygen mixture

3.17 BS EN ISO 9170-1: 2008 does not include a terminal unit for helium/oxygen mixture. They will be included in a new edition of BS5682:1998.

Nitrogen for surgical tools

3.18 BS EN 739:1998 gives details of connectors for nitrogen for driving tools. The body of the NIST connector should form the wall outlet.

Area Valve Service Units (AVSUs)

3.19 AVSUs should be mounted at a convenient height (typically between 1, 000 – 1,800mm) such that they can be operated comfortably by staff without their needing to stoop or overreach (see Figure 3). The order of the location of individual valves in an array should follow that for terminal units, for example: O_2, N_2O and/or N_2O/O_2, MA4, SA7, MV, He/O_2. If the array exceeds 1,000mm in height from top to bottom, it may be preferable to arrange them in two columns. Care must be taken to ensure that AVSUs cannot be obscured by opening doors etc. Details of the design of AVSUs are given in Section13.

Note 7: The minimum height of 1,000mm is the optimum. In critical care areas where dual circuits are installed, it may be necessary to reduce this to 800mm to avoid an excessive number of columns of AVSUs.

Area alarm indicator panels

3.20 The placing of area alarm indicator panels should be such that they are readily visible by staff. Notices, partitioning, screens, etc. should not obscure them. The mounting height should be such that in the event of an audible alarm sounding, staff can activate the “mute” switch without overreaching, and be a maximum 1,800mm above finished floor level (see Figures 3a and 3b).

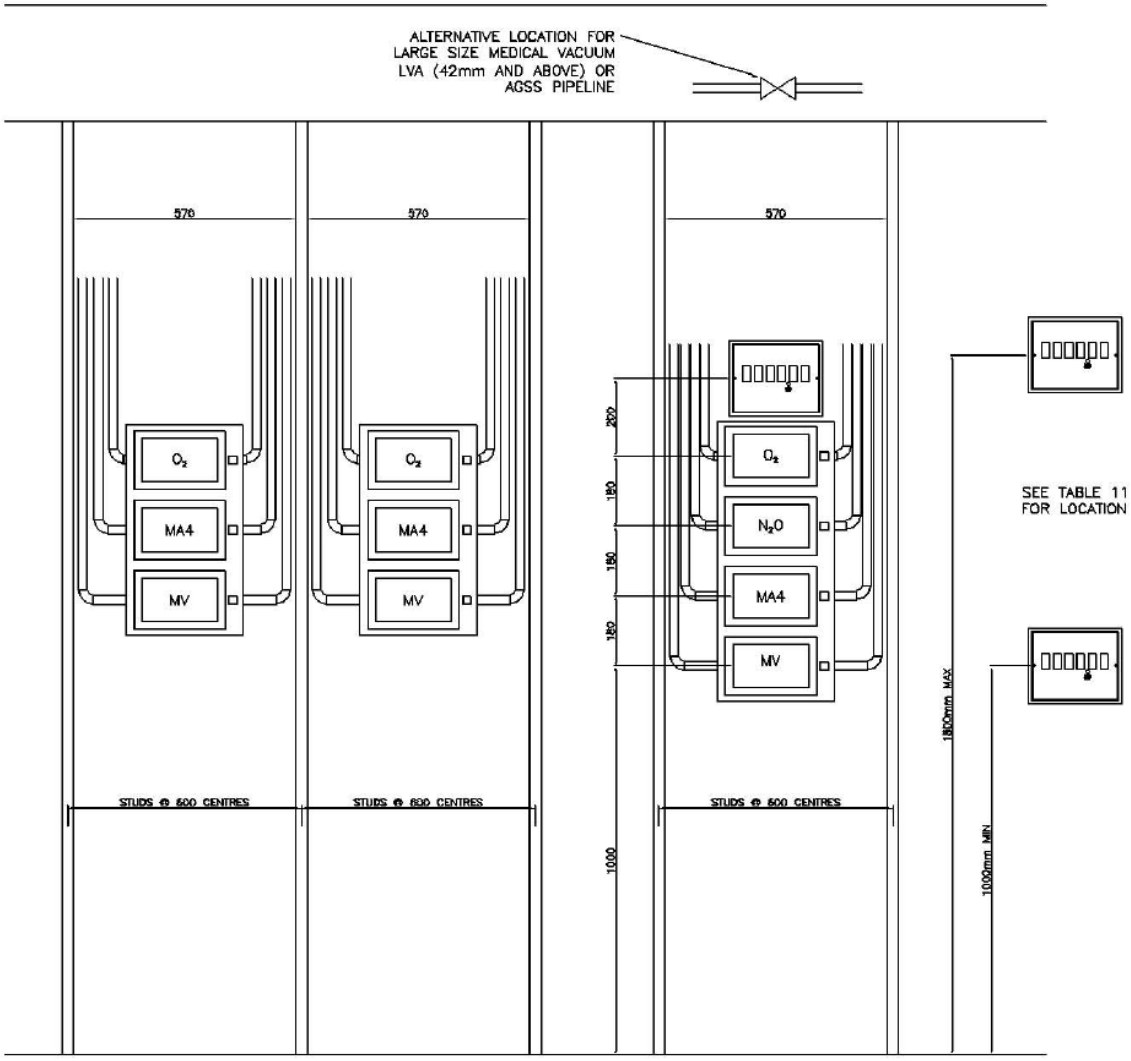
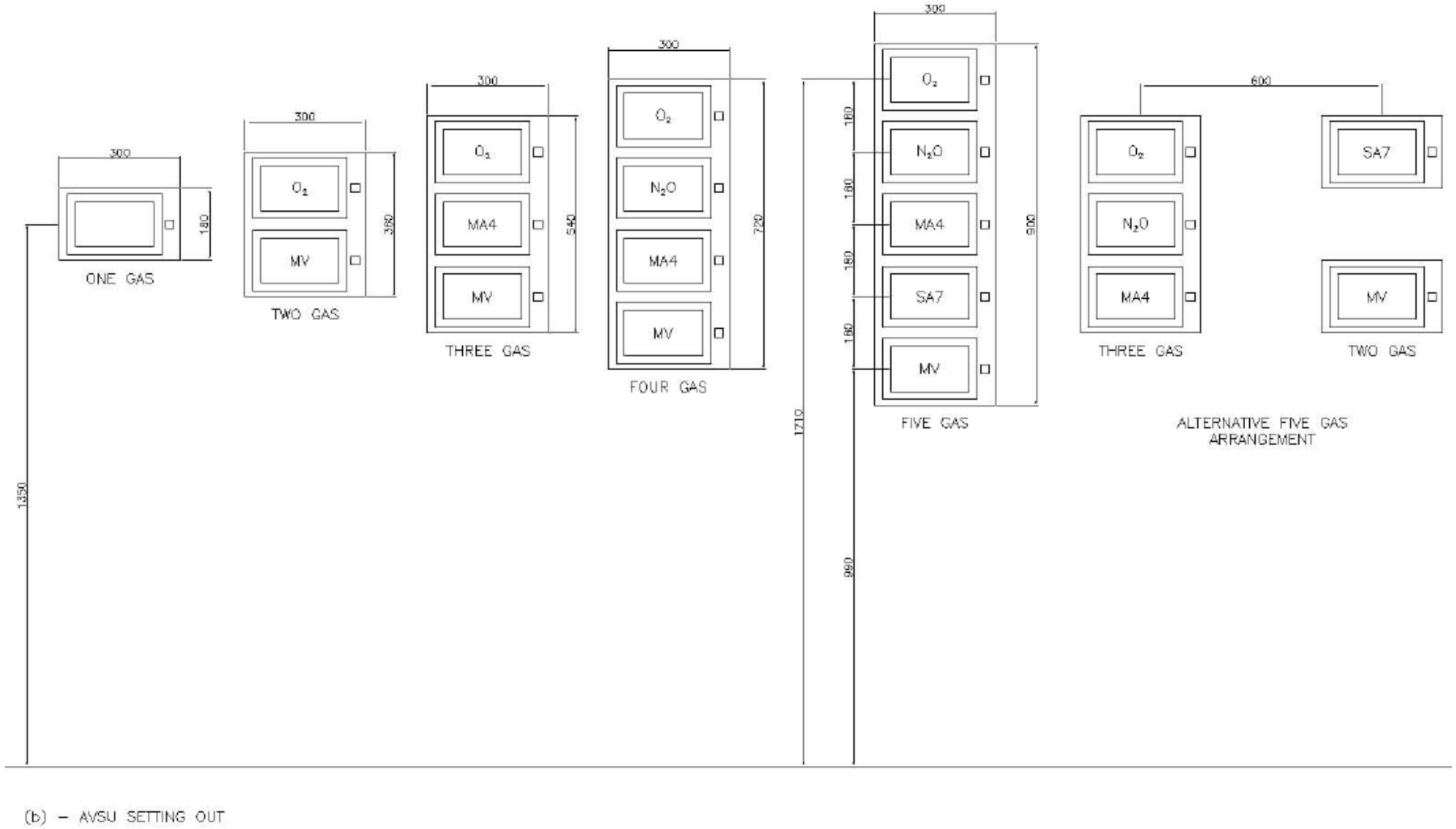


Figure 3a: AVSU and alarm panel mounting heights



(b) – AVSU SETTING OUT

Figure 3b: AVSU and alarm panel mounting heights

Line valve assemblies (LVAs)

3.21 LVAs should be installed at branches from risers, branches from main runs, and where pipelines pass into or out of a building. Details of the design of LVAs are given in Section13.

Specific labelling requirements

3.22 All AVSUs should be labelled to identify the individual rooms, sets of terminal units, etc. controlled. They should be provided with flow direction arrows.

3.23 In critical care areas where dual circuits and/or subdivision of circuitry occur, terminal units require to be identified as associated with the specific AVSU. Correspondingly, AVSUs should be similarly labelled to identify the terminal units controlled.

Table 11: Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Accident and Emergency									1 set (1)	1 set hp/lp (9)
Resuscitation room, per trolley space **Note:** One set either side of the trolley space, if installed in fixed location, e.g. trunking: or both sets in an articulated supply pendant that can be positioned either side of the bed space.	2	2	-	2	-	2	2	-	2 Sets *	
Major treatment/plaster room per trolley space	1	1	1p	1	1p	1	1	-	1 set per 8 TUs	
Post-anaesthesia recovery per trolley space **Note:** One set either side of the bed space, if installed in fixed location, e.g. trunking: or both sets in an articulated supply pendant that can be positioned either side of the bed space.	2	-	-	2	-	2	-	-	2 sets*	
Fracture Clinic, plaster room	1	1	1 (paed)	1p	1p	1	1	-	1 set (1)	1 set hp/lp (9)
Treatment room/cubicle	1	-	-	-	-	1	-	-	1 set per 8 TUs	

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Operating department									1 set [1]	
Anaesthetic rooms (all)	1	1	-	1	-	1	1	-	With associated theatre suite	
Operating room, orthopaedic:										
Anaesthetist	2	1	-	2	-	2	1	-	1 set per suite [2] [3]	1 set per suite hp/lp [10]
Surgeon	-	-	-	-	4	2	-	-		
Note: Orthopaedic surgery is normally performed in operating rooms provided with ultra-clean systems. Such systems are much more effective in terms of airflow when provided with partial walls. These walls may be effectively used to include terminal units that can be supplied by rigid pipework. Such installations do not suffer from excessive pressure loss when surgical air is required at high flows.										
Operating room, neurosurgery:										
Anaesthetist	2	1	-	2	-	2	1	-	1 set per suite [2] [3]	1 set per suite hp/lp [10]
Surgeon	-	-	-	-	2	2	-	-		
Note: If multi-purpose pendants are used, there may be some loss of performance of surgical tools because of bore restrictions and convolution of the flexible connecting assemblies at the articulated joints.										

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Operating department (cont'd)									1 set [1]	
Operating room, general surgery, etc.:										
Anaesthetist/surgeon (see [14] regarding CO_2) **Note:** Terminal units installed in separate pendants: p = project team option where some orthopaedic overspill surgery may be performed	2	2	-	2	2p	2	2	-	1 set per suite [2] [3]	1 set per suite hp/lp [10]
Post anaesthesia recovery, per bed space **Note:** One set either side of the bed space, if installed in fixed location, e.g. trunking: or both sets in an articulated supply pendant that can be positioned either side of the bed space	2	-	-	2	-	2	-	-	2 sets * [5]	1 alarm for both sets of AVSUs hp/lp [11]
Equipment service room ** per work space	1	1	-	1	1	1	1	-	1 set	1 set hp/lp [12]

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Maternity department									1 set (1)	1 set hp/lp (9)
LDRP room (normal/abnormal):									1 set per 6-8 rooms (5)	
Mother (normal)	1	-	1	-	-	2	-	-		
Mother (abnormal)	1	1	-	-	-	2	1	-		
Baby (per cot space) (allow for 2 cots only)	1	-	-	1	-	1	-	-		
Operating suite:									1 set	1 set hp/lp(10)
Anaesthetist	1	1	-	1	-	1	1	-		
Obstetrician	-	-	-	-	-	2	-	-		
Paediatrician (per cot space) (allow for 2 cots only)	1	-	-	1	-	1	-	-		
Post anaesthesia recovery, per bed space	1	-	-	1	-	1	-	-	1 set per 6-8 spaces (5)	1 set hp/lp (11)
Equipment service room ** per work space	1	1	1	1	1	1	1	-	1 set	1 set hp/lp (12)

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Maternity department (cont'd)									1 set (1)	1 set (9)
Neonatal unit, per cot space **Note:** One set either side of the bed space, if installed in fixed location, e.g. trunking: or both sets in an articulated supply pendant that can be positioned either side of the bed space. It is recommended that the Neonatal unit / SCBU have dedicated departmental AVSUs in addition to those identified for the Maternity department with dual circuits downstream of these AVSUs.	2	-	-	2	-	2	-	-	2 sets (4) (5) *	1 for both sets of AVSUs hp/lp (11)
Equipment service room ** per work space	1	-	-	1	-	1	-	-	1 set	1 set lp (12)
In-patient accommodation:									1 set for ward unit	1 set hp/lp (11)
Single bed room	1	-	-	-	-	1	-	-		
Multi-room, per bed space	1	-	-	-	-	1	-	-		
Nursery, per cot space **Provision for 2 cots only irrespective of number ofcot spaces**	1	-	-	-	-	1	-	-		

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Diagnostics department									1 set (1)	
Special procedures room	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
Anaesthetic room	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
Holding and recovery	1	-	-	1p	-	1	-	-	1 set	1 set hp/lp(p) (11)
Ultrasound	1	-	-	-	-	1	-	-	1 set per group	Part of the department. If remote from main alarm 1 set per group lp (11)
Fluoroscopy	1	-	-	-	-	1	-	-	1 set per group	
Urography	1	-	-	-	-	1	-	-	1 set per group	
Tomography	1	-	-	-	-	1	-	-	1 set per group	
Magnetic Resonance Imaging (MRI) suite	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
CT room	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
Angiography	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
Endoscopy	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
Linac bunker	1	1	-	1	-	1	1	-	1 set	1 set hp/lp (10)
General purpose room	1	-	-	-	-	1	-	-	1 set per group	1 set per group lp (11)

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
In-patient accommodation									1 set for the ward unit (1)	1 set hp/lp (11)
Single bed room	1	-	-	1	-	1	-	-		
Multi-bed room, per bed space	1	-	-	1	-	1	-	-		
Infectious Diseases rooms	1	-	-	1	-	Refer to App L	-	-	1 set (1)	1 set hp/lp (11)
Treatment room (Appropriate for adult acute, children and elderly)	1	-	-	1	-	1	-	-		
Renal department									1 set	1 set hp/lp (11)
Per dialysis station	1	-	-	1	-	1	-	-	1 set per group	1 set hp/lp (11)
Per bed space	1	-	-	1	-	1	-	-	1 set per group	1 set hp/lp (11)

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Critical Care Department									1 set [1]	
Intensive Therapy Unit (ITU)/ Intensive Care Unit (ICU)	4	2p	2p	4	-	4	2p	2p	2 sets * [4][6][7]	1 set for both AVSUs hp/lp[11]
Coronary Care Unit, per bed space	4	-	-	4	-	4	-	-	2 sets * [4][6][7]	1 set for both AVSUs hp/lp[11]
High Dependency Unit, per bed space	4	-	-	4	-	4	-	-	2 sets * [4][6][7]	1 set for both AVSUs hp/lp[11]
Burns Unit	2	2p	2p	2	-	2	2p	-	2 sets * [4][6][7]	1 set for both AVSUs hp/lp [11]
Note: For all the above Critical Care Departments, one set either side of the bed space, if installed in fixed location, e.g. trunking; or both sets in an articulated supply pendant that can be positioned either side of the bed space.										
Equipment service room, per work space	1	1p	1p	1	-	1	1p	-	1 set	1 set hp/lp [12]

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Table 11: (cont'd) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Adult mental illness accommodation									1 set	
Electro-convulsive therapy (ECT) room	1	1	-	1	-	1	1	-	1 set (1)	1 set hp/lp (10)
Post-anaesthesia recovery, per bed space	1	-	-	1	-	1	-	-	1 set per 6-8 rooms (5)	1 set hp/lp (11)
Adult acute day care accommodation									1 set	
Treatment room:										
Anaesthetist	1	1p	-	1p	-	1	1p	-	1 set	1 set hp/lp (10)
Surgeon	-	-	-	-	-	2	-			
Post-anaesthesia recovery, per bed space	1	-	-	1p	-	1	-	-	1 set per 6-8 rooms (5)	1 set hp/lp(p)(11)
Day patient accommodation									1 set (1)	
Single bed room	1	-	-	-	-	1	-	-	1 set (1)(13)	1 set hp/lp(p) (11)
Multi-bed room, per bed space	1	-	-	-	-	1	-	-		
Treatment room	1	-	-	1p	-	1	-	-		
Endoscopy room	1	1p	-	1p	-	1	1p	-	1 set (2)(13)	1 set hp/lp(p) (10)

Table 11: (concluded) Provision of terminal units, AVSUs and area alarms

Department	O_2	N_2O	N_2O/O_2	MA4	SA7	VAC	AGSS	He/O_2	AVSU	Area Alarm
Oral surgery, orthodontic department									1 set [3]	1 set hp/lp [9]
Consulting / treatment room, type 1	1	1p	-	1	Dental air required	†	1p	-	1 set per 4-6 rooms	
Consulting / treatment room, type 2 and 3	1	-	-	1		†	-	-	1 set per 4-6 rooms	
Recovery room, per recovery position	1	-	-	1	-	1	-	-	1 set	
Appliance laboratory, per work space	1	1p	-	1	1	1	1p	-	1 set	1 set hp/lp[11]
Out-patient department										
Treatment room / cubicles	1	-	-	1	-	1	-	-	1 set [1][8]	1 set hp/lp[9]
Sterile services department									1 set [1]	1 set lp [9]
Wash room	-	-	-	1[18]	1[18]	1[18]	-	-		
Inspection, assembly and packing (IAP) room	-	-	-	1[18]	1[18]	-1[18]				
Clinical / surgical training facilities [19]	1p	1p	1p	1p	1p	1p	1p	-	1 set [1]	1 set hp/lp [9]
EBME	1	1	-	1	1	1	1	-	1 set [1]	1 set hp/lp [9]
Other departments (as required by project team)									1 set[1]	1 set[9-12] located as required

Notes applicable to Table 11:

*	Dual circuits
**	Where the delivery and neonatal units are in close proximity, the equipment service room can be shared.
†	Dental vacuum only
p	Project team option
hp/lp	high-pressure and low-pressure alarms..
lp	low pressure alarm.

Ref: (1)	Departmental AVSUs installed on the hospital street side of fire compartment doors – due consideration should be given to the security of these valves in public areas.
Ref: (2)	Installed immediately outside the room.
Ref: (3)	Where air is used to control movable pendant fittings, it should be taken from the 700 kPa surgical air system. However where surgical air is not available medical air 400 kPa may be used if suitable for the particular pendant manufacturer's requirements.
Ref: (4)	In addition to the dual circuits, additional AVSUs will be required to sub-divide the number of terminal units controlled (typically between 4-8 bed spaces). This subdivision should be based on the layout of the accommodation: for example, if the recovery area is divided into a number of separate room/areas, each would have a separate sub-set (see Figures 4 and 5).
Ref: (5)	This is intended to provide some flexibility and the exact number will depend on the total number of rooms within the department.
Ref: (6)	If a high-dependency unit is included within general in-patient accommodation, a separate set of AVSUs should be provided for the unit. In addition to the departmental valves or the ward as a whole, an additional set will be required to control the single-bed, multi-bed and treatment rooms.
Ref: (7)	Department AVSUs may be required if the units are large and separate from, for example, the critical care area.
Ref: (8)	Additional AVSUs may be required in a large unit: the aim should be to have about 8-12 rooms controlled by a set of AVSUs – discretion is required to arrive at the logical number.
Ref: (9)	Installed in reception area.
Ref: (10)	Installed in the operating room in the "main panel" or within the room, or an ante-room, e.g. control room of an MRI device.
Ref: (11)	Installed at the main staff base (nurses' station).
Ref: (12)	Installed in the room space with the AVSUs.
Ref: (13)	Separate AVSUs will be required if endoscopy room is included.
Ref: (14)	Carbon dioxide is used for insufflation during some surgical procedures. A pipeline installation is a project team option and is covered in Section 11. Two NIST connector bodies units should be installed.
Ref: (15)	Where medical gases are required in Decontamination rooms, such as in A&E, the medical gas should be provided by a dedicated source e.g. gas cylinder or portable vacuum pump.

Ref: [16]	Where grouping of similar type rooms are possible, e.g. Renal departments, Diagnostics (e.g. ultrasound, general purpose rooms) the grouping should be to have an even number of rooms controlled by a set of AVSUs – discretion is required to arrive at the logical number.
Ref: [17]	Where medical gas terminal units are to be provided in areas such as; en-suite bathrooms/shower rooms, etc. the location of the terminal unit should not be in direct contact with water, or cleaning fluids (soaps, etc.). The designer and User should liaise to establish an acceptable location.
Ref: [18]	Dedicated medical/surgical air and vacuum plant should be provided separately for this department.
Ref: [19]	The medical gases provision and method of supply for dedicated clinical / surgical training facilities should be determined in consultation with the training facility management.

General

Normally, departmental AVSUs would be installed at the hospital street side of the entrance doors to a department and would reflect the method of horizontal evacuation in the event of an emergency. In some large departments, for example an operating department, the clean-service corridor is likely to cross one or more fire compartment walls. Additional AVSUs may therefore be required to reflect the evacuation route.

If a department includes one or more floors, a set of AVSUs should be provided for each floor, which will act as emergency overall fire valves.

AVSUs for zones within critical care areas should be located where they can be seen by staff – not necessarily at the staff base.

Area alarms within critical care areas should be provided for the individual space; that is, if a critical care area of, say, 18 beds is sub-divided into three separate six-bed wards, there should be one alarm only for each space (not one for each of the dual circuits).

Where an anaesthetic room is directly linked to an operating room, the anaesthetic room shall be controlled by the theatre AVSUs. Where the anaesthetic room is remote from a theatre(s) separate AVSUs with area alarm panel should be provided.

When an anaesthetic room forms part of a special procedures suite then one set of AVSUs serving both rooms is permissible. Consideration should be given to the general department layout with regard to the degree of valving required where procedures will not require anaesthetics to be applied.

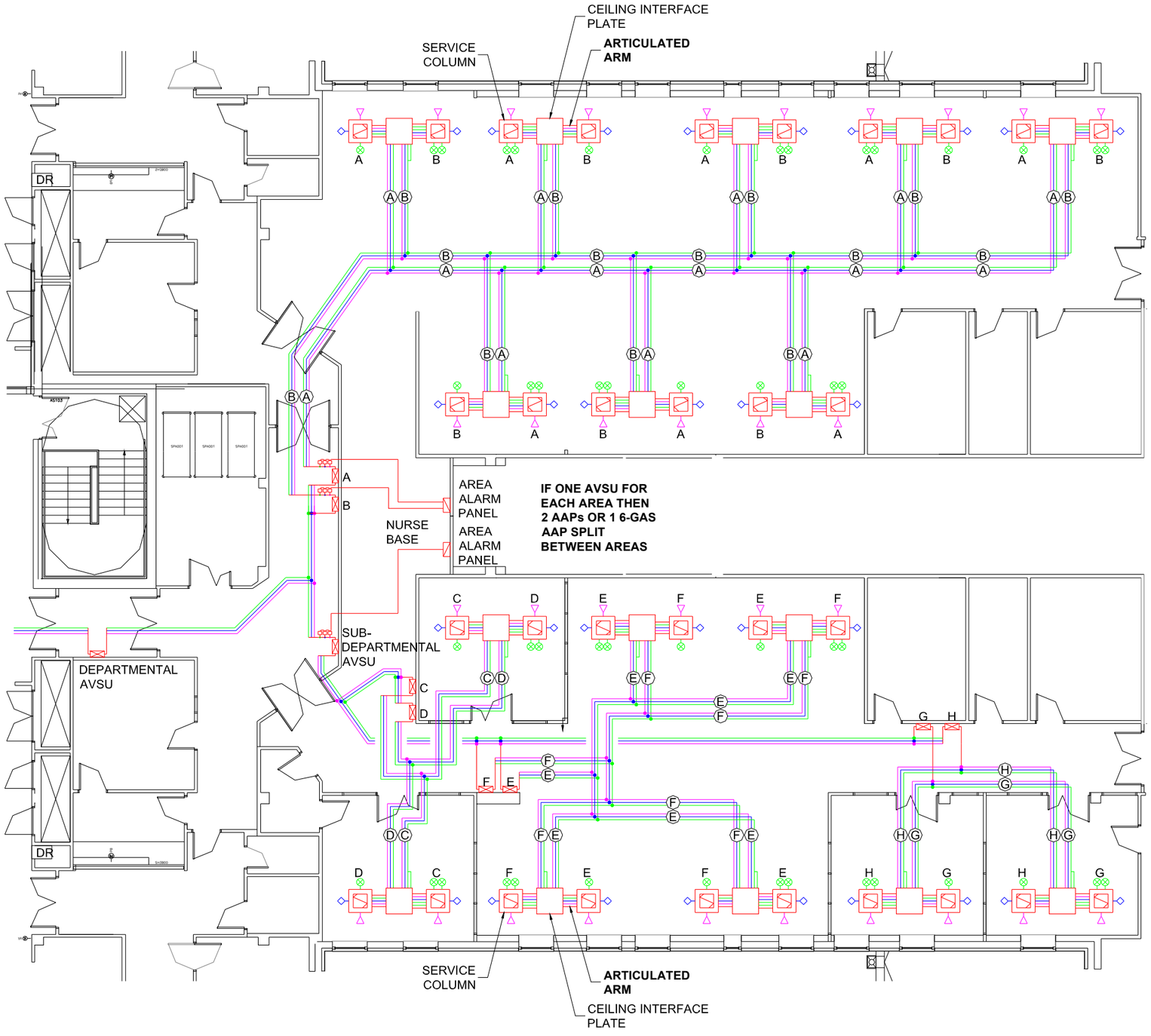


Figure 4: Larger critical care area with open plan and isolation room configuration

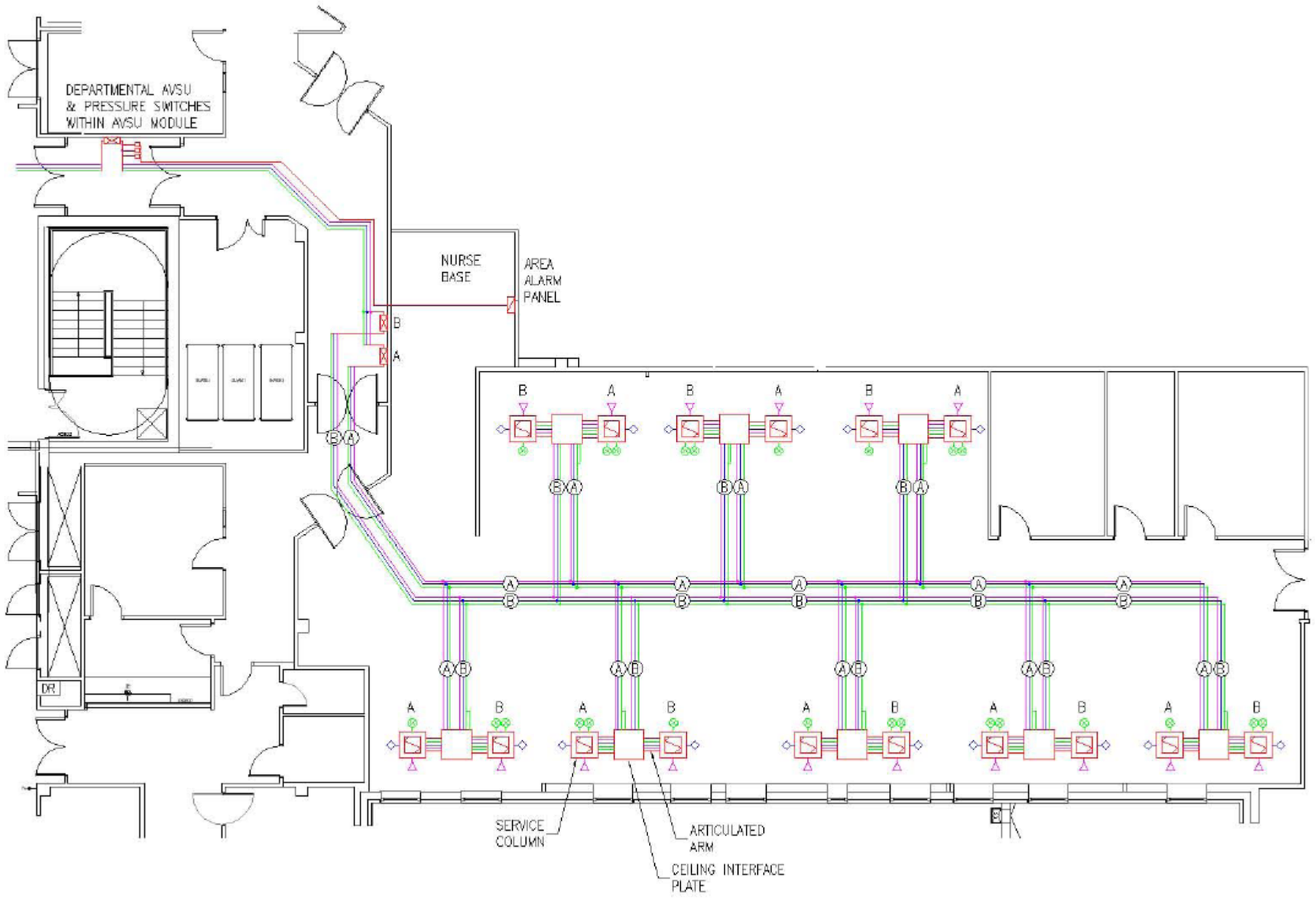


Figure 5: Smaller open plan critical care area

4. Gas flow

General

4.1 Various layouts of an MGPS are shown throughout this document, and each will need to be designed to take into account the anticipated design flow. Appendix N provides a conversion table for various units of measurement that may be encountered.

4.2 There are several aspects of gas flow to consider when designing the pipeline distribution system:

1. the test flow that is required at each terminal unit for test purposes (this flow is essentially to establish that the terminal unit functions correctly and that there are no obstructions; see Table 12);
2. the typical flow required at each terminal (this is the maximum flow likely to be required at any time in clinical use; see Table 12);
3. the likely numbers of terminal units in use at any time;
4. the flow required in each sub-branch of the distribution;
5. the total flow to the ward/department;
6. the flow in the main branches/risers, that is, the summation of all diversified flows;
7. the flow required at the plant, that is, the sum of all diversified flows to all like departments and wards, plus individual or dissimilar departments.

4.3 The pipeline system should be designed so that the flows given in Table 12 can be achieved at each terminal unit: the flows are expressed in free air. Diversified flows are used for the purposes of pipe size selection.

4.4 The designer should always ensure that due account is taken of the stated use of a particular department.

4.5 There is a limited range of pipe sizes, and where there is any doubt about flow requirements, a larger pipe size should be selected.

Note 8: When calculating diversified flows, it is the number of bed spaces, treatment spaces or rooms in which the clinical procedure is being performed that is used; this is not the individual number of terminal units since, in many cases, more than one is installed. For example, a bed position in a critical care area may have four or more oxygen terminal units.

4.6 The overall pipeline design should be based on a 5% pressure drop from the plant/source of supply to that measured at the rear of the terminal unit outlet at the specified test flows. For multi-movement pendant hoses the 5% pressure drop is only applicable to the pipeline up to the inlet of a NIST connector (refer to Figure 8). For vacuum, this should be 50mmHg pressure loss.

Terminal unit flows

4.7 At the design stage, the project team should define the individual room/space requirements. Departments usually comprise several ward units, treatment rooms and other spaces. In order to avoid confusion, the nomenclature for each clinical space should be clearly defined so that the appropriate gas flow requirements can be established at the commencement of the design stage.

Pipeline flows

4.8 Precise prediction of pipeline flow is not possible, but there are guidelines that can be used which have been shown to be adequate in practice.

4.9 For vacuum systems, the minimum vacuum should not fall below 300 mmHg at the front of each terminal unit at a design flow of 40 litres/min.

4.10 The design of the pipework system is based on the diversified flows and the permissible pressure loss from the source of supply to the terminal unit excluding the terminal unit pressure loss. The pipe sizes should be selected to ensure that the pressure loss is below 5% of the nominated pipeline pressure. (See Figures 6–9 and Appendix G).

4.11 Pressure requirements for surgical air are based on the requirement that the minimum pressure should be 700 kPa at the terminal unit at a flow of 350 litres/min.

4.12 Details of pressure requirements for all systems are described in paragraphs 4.42–4.49.

Service	Location	Nominal pressure (kPa)	Design / Test flow (Litres/min)	Typical flow required (Litres/min)
Oxygen	Operating rooms and anaesthetic rooms in which N_2O is provided for anaesthetic purposes	400	100[a]	20
	Continuous positive airway pressure (CPAP)	400	75	30
	All other areas	400	10	6
Nitrous oxide	All areas	400	15	6
Nitrous oxide/Oxygen mixture	LDRP(labour, delivery, recovery, post-partum) rooms	400[b]	275	20
	All other areas	400	20	20
Medical air 400 kPa	Operating rooms	400	40[c]	40
	Critical care high dependency units	400	80[c]	80
	Neonatal	400	40	40
	Other areas	400	20	10[c]
Surgical air/nitrogen	Orthopaedic and neurosurgical operating rooms	700	350[d]	350
	Where multi-movement pendants are installed	900[e]	350	350
	Other areas	700	350	350
Vacuum	All areas	400mmHg – 47 kPa absolute (53 kPa below atmospheric pressure). All further figures will be in 'below atmospheric pressure'	40	40 maximum, further diversities apply
Helium/oxygen mixture	Critical care areas	400	100	40

Table 12: Gas flow – flows required at terminal units

Notes applicable to Table 12:

(a) During oxygen flush in operating and anaesthetic rooms;

(b) For nitrous oxide / oxygen mixture the pressure at the intermittent patient demand regulator should not be less than 310 kPa;

(c) These flows are for certain types of gas-driven ventilators under specific operating conditions, and nebulisers etc.

(d) Surgical air is also used as a power source for tourniquets;

(e) Surgical air pressure losses across pendant NIST connections, hoses and terminal unit assemblies can be up to 200 kPa (which exceeds the BS EN ISO 9170-1: 2008 requirement) plus regulator and pipeline tolerances. Refer to paragraph 3.15;

(f) Pipeline sizing is designed to meet the total design flow at 5% losses which in practice provides a safety margin over the normal hospital flow demands. For surgical air, some regulator adjustment may be required.

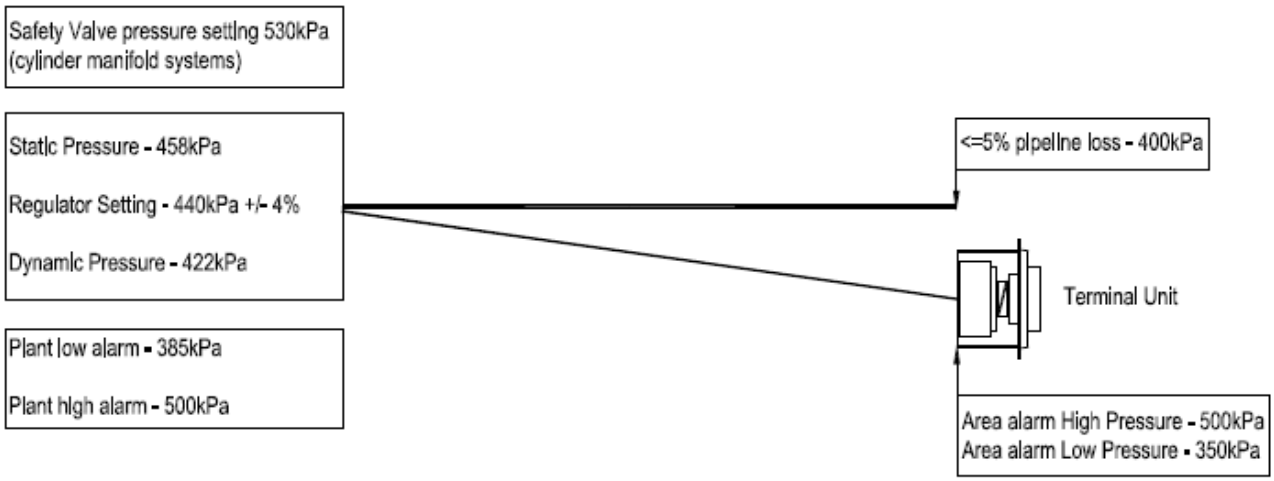


Figure 6: Typical pressures in oxygen/medical air/nitrous oxide/nitrous oxide-oxygen mixture system under design flow conditions

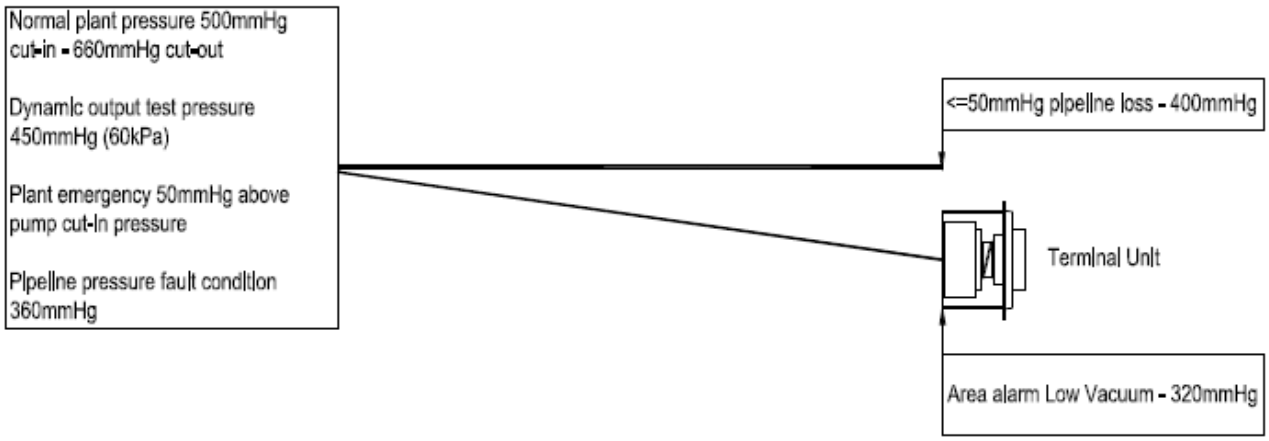


Figure 7: Typical pressures in medical vacuum system under design flow conditions

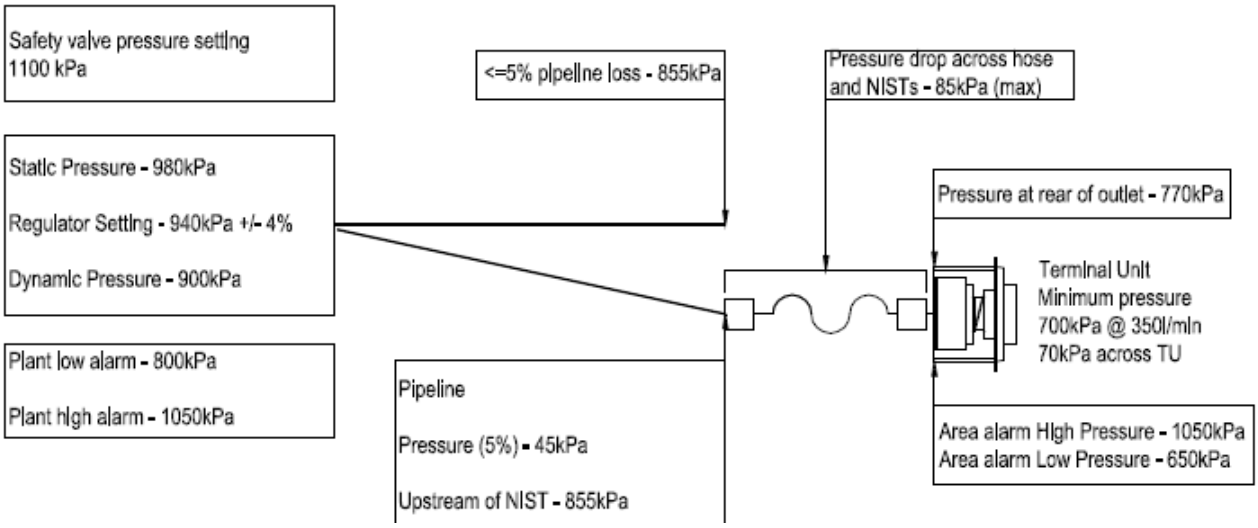


Figure 8: Typical pressures in a single pressure reduction surgical air system under design flow conditions with a multi-movement pendant fitted

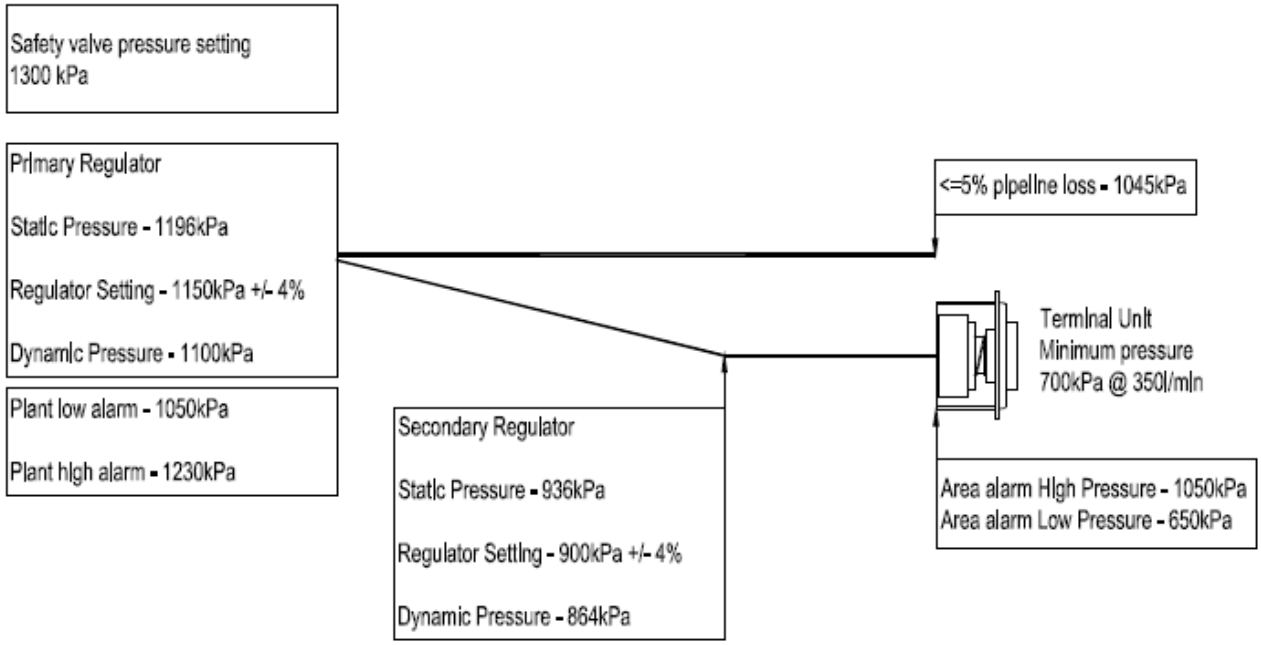


Figure 9: Typical pressures in a double pressure reduction surgical air system under design flow conditions

Oxygen

In-patient accommodation

4.13 Oxygen is used at a typical flow of 5–6 litres/min. Each terminal unit should, however, be capable of passing 10 litres/min (at standard temperature and pressure (STP)) at a supply pressure of 400 kPa (nominal) as shown in Table 12, in case nebulisers or other respiratory equipment are used. Table 13 contains the formula for arriving at diversified flows.

4.14 For a 28-bed ward unit comprising single and four-bed rooms and a treatment room, the diversified flow is calculated on the assumption that one bed space requires 10 litres/min, and one in four of the remainder require 6 litres/min. For the purpose of pipe size selection, the diversified flow at entry to the ward is

taken as 50 litres/min (strictly 50.5 litres/min).It is assumed that a patient will use oxygen in a ward or in the treatment room but not both.

4.15 A department may comprise several ward units as above. The diversified flow for each department Qd is based on Qw for the first ward unit, plus 50% of the flow for the remaining ward units. For the purposes of this calculation, the first ward unit is taken as the largest within the department.

4.16 If one ward unit is significantly larger than the others, the flows from the ward units should be averaged to obtain a more realistic value.

Operating departments

4.17 The diversified flow for operating departments is based on 100 litres/min required for the oxygen flush. Therefore each oxygen terminal unit in the operating room and anaesthetic room should be able to pass 100 litres/min. It is unlikely that an oxygen flush will be administered simultaneously in several operating rooms. The diversified flow Q is based on 100 litres/min for the first operating room and 10 litres/min for the remainder.

4.18 For anaesthetic rooms, each terminal unit should be capable of passing 100 litres/min (it may be necessary to use oxygen “flush”), but the actual flow likely to be used is 6 litres/min or less. As it is unlikely that a patient would be anaesthetised at the same time that a patient in the associated operating room was continuing to be treated under an anaesthetic (and because the duration of induction is short), no additional flow is included.

4.19 In post-anaesthesia recovery, it is possible that all bed spaces may be in use simultaneously; hence, no diversity is applied.

Critical care, coronary care and high-dependency units

4.20 The flow for these units assumes that all bed spaces may be in use simultaneously, hence no diversity is applied.

4.21 Oxygen should not be used as the driving gas for gas-powered ventilators if they are capable of being powered by medical air. The minimum flow that has been shown to be adequate to drive current types of ventilator is 80 litres/min at 355 kPa.

4.22 If oxygen has to be used to power ventilators and/ or ventilators are operating in CPAP mode, the high flows that may be encountered should be taken into account both when designing the pipeline and when sizing the supply vessel. These ventilators use exceptional amounts of oxygen, particularly if adjusted incorrectly. If incorrectly set, they can use in excess of 120 litres/min, but their therapeutic benefit will be effective at lower flows. To allow for some flexibility, and additional capacity, a diversified flow of 75 litres/min for 75% of beds has been included. If significant numbers of beds are required to treat patients using CPAP ventilation, consideration should be given to running a separate pipeline from the source of supply. Care should be taken when calculating air exchange rates in wards/rooms in which large numbers of CPAP machines may be in use simultaneously and where failure of mechanical ventilation could result in raised

ambient oxygen concentrations. Consideration should be given to installation of systems to warn of ventilation failure and oxygen concentrations above 23%.

Maternity

4.23 For LDRP (Labour, Delivery, Recovery, and Post-partum) rooms, the diversified flow is based on10 litres/min for the first terminal unit and 6 litres/min for one third of the remaining bed spaces. Two cot spaces may be provided, each with a terminal unit. Only one will be considered to be in use. The diversified flow for cot spaces is based on10 litres/min for the first and 50% of the remainder at 3 litres/min.

4.24 In the event of multiple births, the additional gas usage will have negligible overall effect on the total flow.

4.25 Maternity department operating rooms are designed as a suite; that is, it is presumed that oxygen will be provided either in the anaesthetic room or in the operating room. In post-anaesthesia recovery, it is possible that all bed spaces may be in use simultaneously, hence no diversity is applied.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
In-patient accommodation (ward units)		
Single, 4-bed rooms and treatment rooms	10	$Q_w = 10 + [(n - 1)6/4]$
Ward block/department		$Q_d = Q_w[1+ (nW - 1)/2]$
Accident & Emergency Department:		
Resuscitation room	100	$Q = 100 + [(n - 1)10/4]$
Major treatment / operating procedures	100	$Q = 100 + [(n - 1)10]$
Plaster room per trolley space	10	$Q = 10 + [(n - 1)6/4]$
Post-anaesthesia recovery per trolley space	10	$Q = 10 + [(n - 1)6/4]$
Treatment room/cubicle	10	$Q = 10 + [(n - 1)6/6]$
Operating Theatre Department:		
Anaesthetic rooms	100	No additional flow
Operating rooms	100	$Q = 100 + (nT - 1)10$
Post-anaesthesia recovery	10	$Q = 10 + (n - 1)6$
Maternity Department:		
LDRP Rooms:		
Mother	10	$Q = 10 + [(n - 1)6/3]$
Baby	10	$Q = 10 + [(n - 1)3/2]$
Operating Theatre Suite:		
Anaesthetist	100	$Q = 100 + (n - 1)10$
Paediatrician, baby resuscitation	10	$Q = 10 + [(n - 1)6/2]$
Post-anaesthesia recovery	10	$Q = 10 + [(n - 1)6]$

Table 13: Oxygen: design and diversified flows

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
In-patient accommodation:		
Single/multi-bed wards	10	Q = 10 + [(*n* – 1)6/4]
Nursery, per cot space	10	Q = 10 + [(*n* – 1)3/2]
Neonatal unit (SCBU)	10	Q = 10 + (*n* – 1)6
Radiological:		
All anaesthetic and procedures rooms with nitrous oxide for anaesthetic purposes	100	Q = 100 + [(*n* – 1)6/3]
Without nitrous oxide	10	Q = 10 + [(*n* – 1)6/3]
Recovery per bed	10	Q = 10 + [(*n* – 1)6/4]
Critical Care Areas: Including Intensive Therapy Unit (ITU), Coronary Care (CCU), High Dependency (HDU), Burns Unit.	10	Q = 10 + [(*n* – 1)6]
CPAP ventilation*	75	Q = 75n x 75%
Renal	10	Q = 10 + [(*n* – 1)6/4]
Adult mental illness accommodation:		
Electro-convulsive therapy (ECT) room	10	Q = 10 + [(*n* – 1)6/4]
Post-anaesthesia recovery per bed space	10	Q = 10 + [(*n* – 1)6/4]
Adult acute day care accommodation:		
Treatment rooms	10	Q = 10 + [(*n* – 1)6/4]
Post-anaesthesia recovery per bed space	10	Q = 10 + [(*n* – 1)6/4]
Day patient accommodation		As “In-patient accommodation”
Oral surgery/orthodontic:		
Consulting rooms, type 1	100	Q = 100 + [(*n* – 1)10/2]
Consulting rooms, types 2&3	10	Q = 10 + [(*n* – 1)6/3]
Recovery room, per bed space	10	Q = 10 + [(*n* – 1)6/6]
Out-patient: Treatment rooms	10	Q = 10 + [(*n* – 1)6/4]
Equipment service rooms, sterile services etc.	100	No additional flow

Table 13 (cont’d): Oxygen: design and diversified flows

Note 9: The main branch line to a department or floor should only allow for 1 oxygen flush of 100 litres/min.

Legend for Tables 13-21:

Q = diversified flow for the department;

Q_w = diversified flow for the ward;

Q_d = diversified flow for the department (comprising two or more wards);

n = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed;

*n*S = number of operating suites within the department (anaesthetic room and operating room);

*n*W = number of wards;

*n*T = number of theatres.

Hyperbaric oxygen chambers

4.26 Hyperbaric oxygen chambers should be supplied from a separate branch from the main riser/ distribution pipe. The pipeline system should be from a liquid supply source. Typical flows for a single patient chamber are as shown in Table 14.

	Max. time for one complete treatment	Total consumption for max. treatment time (litres)	Consumption for each additional minute (litres/min)
O_2 atmosphere and recirculation:			
On open circuit	2 hours	30,000	250
On recirculation	2 hours	7,250	40
O_2 only, no recirculation	2 hours	30,000	250
O_2 delivery by built-in breathing mask and overboard pump	2 hours	1,200	10
O_2 delivery by built-in breathing hood and overboard pump	2 hours	7,250	60

Table 14: Gas flow – hyperbaric chambers

Notes: a) The flows for a recirculating unit assume the standard method of operation is recirculation throughout the treatment. It is recommended that the pipeline should be designed for open circuit operation to ensure adequate flow under all conditions.

b) Clinical practice may require the inclusion of air during the treatment. It may also be necessary to switch to air in the unlikely event of an oxygen convulsion. Therefore consideration should be given to the provision of medical air from a separate dedicated medical air plant in accordance with Chapter 7.

c) Some hyperbaric chambers use air as a buffer and consequently less oxygen is consumed. The advice of the manufacturer should be sought. Where this is the case, the air should be supplied from a separate supply system complying with the requirements for medical air systems.

Nitrous oxide

4.27 Nitrous oxide is provided for anaesthetic purposes and occasionally for analgesic purposes. In all cases, each terminal unit should be capable of passing 15 litres/min, but in practice the flow is unlikely to exceed 6 litres/min.

4.28 When calculating diversities in a department, 15 litres/min is allowed for the first outlet and 6 litres/min for the remainder, subject to the appropriate diversity factor being applied (see Table 15).

4.29 It is assumed that, for an operating department, nitrous oxide may be in use simultaneously in all operating rooms. As it is unlikely that a patient would be anaesthetised in the anaesthetic room at the same time that a patient in the associated operating room was continuing to be treated under an anaesthetic (and because the duration of induction is short), no additional flow is included.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
Accident & Emergency: Resuscitation room, per trolley space	15	Q = 15 + [(*n* – 1)6/4]
Operating rooms	15	Q = 15 + (*n*T – 1)6
Anaesthetic rooms as part of an Operating suite	15	No additional flow included
Maternity: Operating rooms	15	Q = 15 + (*n*T – 1)6
Radiology	15	Q = 15 + [(n – 1)6/4]
Critical care areas	15	Q = 15 + [(*n* – 1)6/4]
Oral surgery/orthodontic: Consulting rooms, type 1	15	Q = 15 + [(*n* – 1)6/4]
Other departments	15	No additional flow included
Equipment service rooms	15	No additional flow included

Table 15: Nitrous oxide: design and diversified flows

Nitrous oxide/oxygen mixture

4.30 All terminal units should be capable of passing 275 litres/min for a very short period (normally of five seconds' duration) to supply inhalationary "gasps" by the patient, and a continuous flow of 20 litres/min. The actual flow would not normally exceed 20 litres/min.

4.31 The diversified flow in LDRP rooms is based on 275 litres/min for the first bed space and 6 litres/min for each of the remainder, of which only half of the women in labour will be using gas. (The peak inhalationary "gasp" is 275 litres/min, whereas the respirable minute volume will be catered for with a flow of 6 litres/min – it should also be borne in mind that a woman in labour would not continuously breathe the analgesic mixture.) For larger maternity departments with nine or more LDRP rooms, two peak inhalationary "gasps" are included.

4.32 Nitrous oxide/oxygen mixture may be used in other areas for analgesic purposes. The diversified flow is based on 20 litres/min for the first treatment space, and 6 litres/min for a half of the remainder.

4.33 Design and diversified flows for nitrous oxide/ oxygen mixtures are given in Table 16.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
Maternity:		
<9 LDRP room(s), mother	275	Q = 275 + [(n – 1)6/2]
≥9 LDRP rooms	275	Q = 275 x 2 + [(n – 1)6/2]
Other areas	20	Q = 20 + [(n – 1)6/2]
Equipment service rooms	275	No additional flow included

Table 16: Nitrous oxide/oxygen mixtures – design and diversified flows

Air

4.34 Air is used to provide power for several types of equipment including surgical tools, ventilators and nebulisers. Oxygen should be avoided as a power source because of fire risk and cost, and should not be used where medical air is available, unless specifically recommended by the device manufacturer.

4.35 Air should be provided at two different pressures but to the same Ph. Eur. Standard:

- a pressure of 400 kPa is required for medical air to drive ventilators and for other respiratory applications;
- a pressure of 700 kPa or higher is required for surgical air to drive surgical tools.

Medical Air 400 kPa

General

4.36 The use of medical air, particularly for respiratory use and during anaesthesia, has increased markedly in recent years. This service is the most critical of the medical gas services, since air-powered ventilators cease to operate in the event of failure of the supply.

4.37 Medical air is also directly inhaled by patients during ventilation. It may also be used to dilute oxygen before administration because of the potentially toxic effects of pure oxygen.

4.38 The supply system for medical air 400 kPa may be a manifold system, a compressor system or a proportioning system (synthetic air), and normally includes an emergency reserve manifold. A compressor plant, or synthetic air supply, should always be specified where air-powered ventilators are to be used.

4.39 One of the major uses of medical air is for patients' ventilators, which fall into two main categories comprising those used during anaesthesia and those used during critical care. Pneumatically-powered ventilators can use up to 80 litres/min free air continuously. The exact flow requirements will depend on the design of the ventilator. The flow and pressure requirements for some typical ventilators are given in Table 17.

4.40 Current models of anaesthetic ventilator are very similar to critical care models, and may require peak flows of up to 80 litres/min and average flows of 20 litres/min. Almost all such units are pneumatically driven and electronically controlled.

4.41 Medical air 400 kPa is also used for other equipment such as anaesthetic gas mixers, humidifiers and nebulisers. The flow rate normally required would not exceed 10 litres/min, and this flow is always in excess of the actual volume respired.

Pressure requirements

4.42 A minimum pressure required at terminal units for respiratory use is 355 kPa.

4.43 Medical air should not be used to supply mechanical services (see paragraph 7.131).

4.44 Some medical gas pendants use the medical air supply for operating the control/retraction system. This is permitted, provided that:

- a flow limiting device is provided to protect the medical air system in the event of failure of any downstream component;
- a non-return valve is incorporated to protect the system integrity;
- appropriate AVSU arrangements are in place (see Section 3).(The surgical air supply should be used to provide the power source whenever possible.)

4.45 The flow requirements should be ascertained and taken into account prior to the installation of the equipment.

Flow requirements

4.46 Flow requirements for medical air are given Table 18. In ward areas and treatment rooms, the use of medical air is most likely to be for nebulisers. In these areas they should be capable of passing 20 litres/min, although typically 10 litres/min will be required in in-patient accommodation where air is used for nebulisers.

Ventilator type	Pressure (kPa)	Flow (litres/min)
Anaesthesia, typically gas-driven, electronically controlled	Nominally 400. Max 600(1)	Pneumatically driven ventilators use up to 80 max. 20 continuous
Critical care, electrically controlled, gas-powered	Nominally 400. Max 600(1)	180 peak (2) 80 continuous
Neonatal, gas-driven, electronically controlled	Nominally 400. Max 600(1)	80 peak(2) 40 continuous
Nebulisers	400	10

Table 17: Typical pressure and flow requirements for ventilators and nebulisers

Notes applicable to Table 17:

(1) It is strongly recommended that ventilators are not connected to the 700 kPa system since blenders only work satisfactorily with a tolerance of about 10%: with high differential pressures for air and oxygen an incorrect mixture could be obtained.

(2) These flows can be achieved under certain clinical conditions. The peak flows are usually of very short duration.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
In-patient accommodation (ward units):		
Single / 4-bed and treatment rooms[1]	20	$Q_w = 20 + [(n - 1)10/4]$
Ward block/department		$Q_d = Q_w[1 + (nW - 1)/2]$
Accident & Emergency Department:		
Resuscitation room, per trolley space	80	$Q = 80 + [(n - 1)80/2]$
Major treatment room	40	$Q = 40 + [(n - 1)40/4]$
Plaster room, per trolley space	40	$Q = 40 + [(n - 1)40/4]$
Post-anaesthesia recovery, per trolley space	40	$Q = 40 + [(n - 1)40/4]$
Operating Theatre Department:		
Anaesthetic rooms	40	No additional flow included
Operating rooms	40	$Q = 40 + [(nT - 1)40/4]$
Post-anaesthesia recovery	40	$Q = 40 + [(n - 1)40/4]$
Maternity Department:		
LDRP rooms: Baby[2]	40	$Q = 40 + [(n - 1)40/4]$
Operating suites:		
Anaesthetist	40	$Q = 40 + [(n - 1)40/4]$
Paediatrician (baby resuscitation)	40	$Q = 40 + [(n - 1)40/4]$
Post-anaesthesia recovery	40	$Q = 40 + [(n - 1)40/4]$
In-patient accommodation:		
Ward units	20	As In-patient ward units
Neonatal unit (SCBU)	40	$Q = 40n$
Radiological Department:		
All anaesthetic and procedures rooms	40	$Q = 40 + [(n - 1)40/4]$
Recovery per bed	40	$Q = 40 + [(n - 1)40/4]$
Critical care areas[3] (ITU, ICU, CCU, HDU, Burns)	80	$Q = 80 + [(n - 1)80/2]$
Renal	20	$Q = 20 + [(n - 1)20/4]$
Adult mental illness accommodation:		
Electro-convulsive therapy (ECT) room	40	$Q = 40 + [(n - 1)40/4]$
Post anaesthesia per bed	40	$Q = 40 + [(n - 1)40/4]$
Adult acute day care / day patient accommodation:		
Treatment rooms (optional air requirement)	20	$Q = 20 + [(n - 1)20/8]$
Post anaesthesia recovery per bed (optional air requirement)	40	$Q = 40 + [(n - 1)40/4]$
Endoscopy (optional air requirement)	40	$Q = 40 + [(n - 1)40/4]$
Oral surgery/orthodontic:		
Major dental/oral surgery rooms	40	$Q = 40 + [(n - 1)40/2]$
Recovery	40	$Q = 40 + [(n - 1)40/4]$
All other departments	40	No additional flow allowance to be made
Equipment service rooms (sterile services etc.)	40	No additional flow included

Table 18: Medical Air 400 kPa – design and diversified flows

Notes applicable to Table 18:

(1). It is assumed that a patient will use oxygen / air in a ward or in the treatment room.

(2). Where two cot spaces have been provided in an LDRP room, assume only one will require medical air.

(3). This diversified flow is also used for helium / oxygen mixture (see paragraph 4.70).

Surgical Air 700 kPa

4.47 The pressure requirements of surgical tools are between 600 and 700 kPa and flows may vary between 200 and 350 litres/min (STP; see Table 19). Most surgical tools are designed to operate within this pressure range. Higher pressures are likely to cause damage to tools. Inadequate tool performance, however, is likely to result from the lack of flow at the specified pressure.

4.48 The introduction of synthetic air (from on-site blending of oxygen and nitrogen) leads to the possibility of using nitrogen as the power source for surgical tools.

4.49 The pipeline systems should be designed to provide a flow of 350 litres/min at 700 kPa at the outlet from the terminal unit. Existing systems may not meet this requirement (but should be capable of delivering 250 litres/min at the terminal unit).

Note 11: Some surgical tools require up to 500 litres/min at up to 1,400 kPa. These will require a separate supply, normally from cylinders.

Dual pressure surgical air systems

4.50 In many instances, particularly where multi-movement pendants have been installed, a 10 bar system is insufficient to overcome the inherent pressure losses within such units in addition to the standard losses which can occur over the desiccant dryer / filtration unit, the tolerances required across the regulator and the pipeline pressure loss. To ensure the flow requirements can be met, the compressed air plant should be capable of 13 bar operation.

4.51 Guidance is given on the pressure requirements of alternative methods of control:

- a single plant pressure reduction system that maintains all control within the plantroom and can be simply adjusted once the actual pressure losses are established following a system performance check;
- removal of the NIST check valve, which can vary in pressure loss per pendant, would assist in standardizing the pressure loss within a single regulated system. In the event that the check valve is removed, permanent labelling will be required at the NIST to indicate this. An additional Line Valve should be provided to allow maintenance;

- a double pressure reduction system with the second stage pressure regulator locally sited to each operating room or group of rooms. Some thought should be given to the siting of the regulator avoiding the easy option of installing within the ceiling void which is not easily accessible for maintenance or where entry to the void is hygienically unacceptable.

4.52 In each instance some fine adjustment of the regulators may be required to ensure 700 kPa @ 350 litres/min. flow at the terminal unit outlets. This requirement would most certainly be required at the emergency reserve manifold, the degree depending on it's location in the event of a fault condition arising. In both cases, there is a likelihood of static pressure under no flow conditions above 900 kPa at the terminal unit, therefore it is essential that nurse training covers the engagement and removal of probes at point of use.

Diversity

4.53 Surgical air 700 kPa is only required where surgical tools are to be used. This would typically involve orthopaedic and neurosurgery operating rooms, and, possibly, plaster rooms. For flexibility, and to allow for possible overspill, surgical air should be extended to two to four adjacent operating rooms. It is not required in maternity or ophthalmology operating rooms. The diversified flow is based on the assumption of 350 litres/min for the first theatre and a quarter of the remainder when there are more than four operating rooms (see Table 20).

Note 12: Scottish Health Technical Memorandum 2022, Supplement 1: 'Dental compressed air and vacuum systems' allows for the extension of surgical air into dental departments for tool use only.

4.54 Unlike dental departments, the use of surgical tools in an operating procedure takes place for a limited period of time.

Type of tool	Pressure (kPa)	Flow (litres/min)
Small air drill	600-700	200
Medullary reaming machine	600-700	350
Oscillating bone saw	600-700	300
Universal drill	600-700	300
Craniotome	620-750	300

Table 19: Typical pressure and flow requirements for surgical tools

System capacity

4.55 Unlike respirable equipment, surgical tools are used intermittently, typically for a few seconds, up to a maximum of three minutes.

Terminal units intended for equipment testing

4.56 It may be necessary to provide surgical air at 700 kPa in the equipment service workshop for testing purposes. Unless a surgical air 700 kPa pipeline is available nearby, it may be cost-effective to use portable cylinders, with a two-stage regulator.

4.57 If a pipeline supply is to be provided, each terminal unit should be capable of delivering 350 litres/min. Where several terminal units are provided, it is unlikely that more than one terminal unit will be in use at any time, and therefore the total design flow for the equipment service workshop will be 350 litres/min.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
Operating room (orthopaedic and neurosurgical operating rooms only):		
≤4 operating rooms	350	Q = 350 + [(*n* – 1)350/2]
>4 operating rooms	350	Q = 350 + [(*n* – 1)350/4]
Other departments, e.g. equipment workshops, fracture clinic	350	Q = 350
Equipment service rooms	350	No additional flow required

Table 20: Surgical Air 700 kPa – design and diversified flows

Vacuum

General

4.58 In virtually all cases, vacuum is used via a suction control device and fluid is collected in suction jars. On wards these are typically of approximately 1 litre capacity. In operating rooms, two or four 2–3 litre capacity vessels are provided for the suction control regulator.

4.59 Once full, suction jars have to be emptied. Therefore, vacuum cannot be applied continuously.

4.60 The greatest generation of fluid to be aspirated is likely to arise in the operating room, particularly during orthopaedic surgery, where jet lavage to irrigate and cleanse the wound may be in use. The maximum rate of collection is about 4 litres/min, but it is not continuous.

4.61 During induction of anaesthesia, a patient may vomit. Therefore, it is essential that oral and nasal passages can be cleared as quickly as possible. The highest likely amount of fluid to be aspirated in this case will be no more than 0.5 litres.

4.62 In order to aspirate fluid, a suction cannula is normally used, and this will aspirate air as well as the fluid to be removed. The flow required, however, is higher than would be the case if fluid only were to be removed. The ratio of air/fluid aspirated will depend upon the diameter of the cannula.

In-patient accommodation

4.63 For a 28-bed ward unit comprising single rooms, four-bed rooms and a treatment room, the diversified flow is based on 40 litres/min.

Medical supply units/bedhead trunking systems

4.64 When designing vacuum systems, it is expected that the greatest pipeline pressure losses will occur across the terminal units.

4.65 Care must be taken when sizing vacuum pipework within medical supply units with two or more bed/ treatment spaces, where availability of space will often limit the size of pipe. The largest size of pipe that can be accommodated (typically 22mm) should be used, as this will ensure that excessive pressure losses do not occur within the units. Such losses could necessitate the installation of larger diameter pipework within the rest of the system in order to ensure that the system pressure drops prescribed in this Scottish Health Technical Memorandum are not exceeded.

Operating departments

4.66 Vacuum is provided for the surgical team and anaesthetist in the operating room. It is also provided in the anaesthetic and recovery rooms.

4.67 Since it is possible for both the surgical team and anaesthetist to use vacuum simultaneously, each operating room will require 80 litres/min and each terminal unit should be capable of passing 40 litres/min (see Table 21).

4.68 As it is unlikely that a patient would be anaesthetised at the same time that a patient in the associated operating room was continuing to be treated under an anaesthetic, the need to clear an airway is extremely unlikely and no additional flow is included.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
In-patient accommodation:		
Ward unit (single, 4-bed rooms, treatment room)	40	$Q_W = 40$
Multiple ward units	40	$Qd = Q_W + [(nW - 1)40/2]$
Accident & Emergency Department:		
Resuscitation room, per trolley space	40	$Q = 40 + [(n - 1)40/4]$
Major treatment room	40	$Q = 40 + [(n - 1)40/4]$
Plaster room, per trolley space	40	$Q = 40 + [(n - 1)40/4]$
Post-anaesthesia recovery, per trolley space	40	$Q = 40 + [(n - 1)40/4]$
Treatment room/cubicle	40	$Q = 40 + [(n - 1)40/8]$
Operating Theatre Department:		
Anaesthetic rooms	40	No additional flow included
Operating room:		
Anaesthetist	40	$Q = 40$
Surgeon	40	$Q = 40$
Operating suites	80	$Q_s = 80 + [(nS - 1)80/2]$
Post-anaesthesia recovery	40	$Q = 40 + [(n - 1)40/4]$
Maternity Department:		
LDRP rooms:		
Mother	40	$Q = 40 + [(n - 1)40]/4$
Baby	40	No additional flow included
Operating suites:		
Anaesthetist	40	$Q = 40 + [(n - 1)40/4]$
Obstetrician	40	$Q = 40 + [(n - 1)40/4]$
Paediatrician	40	No additional flow
Post-anaesthesia recovery	40	$Q = 40 + [(n - 1)40/4]$
In-patient accommodation:		
Ward unit (single, 4-bed rooms, treatment room)		
Multi-ward units		$Q = 40$
Nursery, per cot space	40	
Neonatal unit (SCBU)	40	$Q = 40 + [(n - 1)40/2]$
	40	No additional flow
	40	$Q = 40 + [(n - 1)40/4]$
Radiology/diagnostic departments:		
All anaesthetic and procedures rooms	40	$Q = 40 + [(n - 1)40/8]$
Recovery per bed	40	$Q = 40 + [(n - 1)40/4]$
Critical care areas (ITU, ICU, CCU, HDU, Burns)	40	$Q = 40 + [(n - 1)40/4]$
Renal		
Day care (out-patients) plus treatment	40	$Q_d = 40 + 40$
Acute services (in-patients)	40	$Q_d = 40 + [(n - 1)40/4]$

Table 21: Vacuum – design and diversified flows

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
Adult mental illness accommodation:		
ECT room	40	Q = 40 + [(*n* – 1)40/4]
Post-anaesthesia, per bed space	40	Q = 40 + [(*n* – 1)40/4]
Adult acute day care accommodation:		
Treatment rooms	40	Q = 40 + [(*n* – 1)40/4]
Post-anaesthesia recovery per bed space	40	Q = 40 + [(*n* – 1)40/4]
Stage 1 Recovery	40	Q = 40 + [(*n* – 1)40/8]
Endoscopy	40	Q = 40 + [(*n* – 1)40/4]
Day patient accommodation (as "In-patient accommodation")		As "In-patient accommodation"
Oral surgery/orthodontic:		
Consulting rooms, type 1	300	Dental vacuum only
Consulting rooms, types 2 & 3	300	Dental vacuum only
Recovery room, per bed space	40	Q = 40 + [(*n* – 1)40/8]
Out-patient:		
Treatment rooms	40	Q = 40 + [(*n* – 1)40/8]
All other departments	40	No additional flow
Equipment service rooms	40	No additional flow

Table 21 (cont'd): Vacuum – design and diversified flows

Helium/oxygen mixture

4.69 Helium/oxygen mixture is used by patients with respiratory or airway obstruction and to relieve symptoms and signs associated with respiratory distress. It can be administered by means of a face mask, a demand valve with face mask, a nebuliser, or a ventilator.

4.70 Pipeline supply will be primarily limited to critical care areas, where the gas mixture is used for driving a ventilator. The design and diversified flows should be based on the figures given for medical air (see Table 17).

4.71 Helium/oxygen mixtures administered by means of a face mask and cannula, a demand valve with face mask and cannula attached, or a nebuliser, are normally supplied using cylinders fitted with an integral valve.

Anaesthetic gas scavenging systems

4.72 For anaesthetic gas scavenging systems, it should be assumed that for each operating suite two terminal units could be in use simultaneously, for example in the anaesthetic room and operating room (receiving systems may be left connected when patients are transferred from the anaesthetic room to the operating room). The diversified flows for other departments are as given in Table 22.

Department	Design flow for each terminal unit (litres/min)	Diversified flow Q (litres/min)
Accident & Emergency resuscitation room (per trolley space)	$V^{(1)}$	$Q = V + [(n - 1)V/4]$
Operating Theatre departments Operating room and anaesthetic room Recovery rooms	 $V^{(1)}$ $V^{(1)}$	 $Q = 2VnT$ $Q = V + [(n - 1)V/4]$
Maternity operating suites	$V^{(1)}$	$Q = 2VnT$
Radiological (all anaesthetic and procedures room)	$V^{(1)}$	$Q = V + [(n - 1)V/4]$
Oral surgery/orthodontic consulting rooms (type 1)	$V^{(3)}$	$Q = V + [(n - 1)V/4]$
Other departments	$V^{(1)}$	$Q = V + [(n - 1)V/8]$

Table 22: Anaesthetic gas scavenging – design and diversified flows

Notes applicable to Table 22:

(1). For the purpose of sizing the AGS disposal system pump, V is taken as either 130 litres/min or 80 litres/min (see paragraph 10.16).

(2). The AGS flow rate should be advised by the clinicians, in absence of such information, 130 litres/min should be used.

(3). With nasal mask application, flow is 45 litres/min.

5. Cylinder manifold installations

5.1 A cylinder manifold installation consists of an automatic manifold control system and manual emergency reserve manifold.

Automatic manifold control system

5.2 The primary and secondary supplies are provided by two banks of equal numbers of gas cylinders which are connected to the pipeline via a control panel. The changeover from the “duty” to the “stand-by” bank of cylinders should be automatic. The reserve supply is provided via a manual emergency reserve manifold. All manifolds should be capable of passing the full pipeline flow. The temperature of the gas may fall as low as –30°C as the gas passes through the regulator at maximum capacity, and the equipment should be designed accordingly. In the case of nitrous oxide and nitrous oxide mixtures it is advisable to specify control panel in-line heaters.

5.3 A schematic layout for a typical cylinder manifold system is shown in Figure 10. Total storage is usually provided on the basis of a risk assessment. Each bank of the manifold should have sufficient cylinders for two days’ use. Additional cylinders for one complete bank change should be held in the manifold room; for nitrous oxide/oxygen mixture, sufficient cylinders to change two banks should be held. Each cylinder bank should be capable of isolation of supply without individual cylinder valve closure in order to facilitate periodic testing in accordance with BS EN ISO 7396-1: 2007 + A2: 2010. Each cylinder bank should be capable of independent selection to facilitate maintenance activity, for example, via a control switch.

5.4 The nominal and usable capacities of the cylinders commonly used on manifolds are given in Table 23 (the figures are the equivalents at STP).

5.5 An automatic manifold changeover from duty to stand-by should occur at a cylinder pressure that will ensure the greatest possible utilisation of the contents of the cylinders in the duty bank. If the normal operation of the changeover control depends on an electricity supply, the design should be such that failure of the electricity supply does not disrupt the flow of gas to the distribution system. In some instances, it will be necessary to provide heaters on the manifold, e.g. for nitrous oxide or nitrous oxide/oxygen mixture. The heater should be selected by the manifold manufacturer to match the range of flows for which the manifold is designed to deliver. The heater should be provided in such a location to limit the build-up of ice on the regulator and to operate only during flow conditions.

Note 13: All systems should be designed so that both banks (duty and stand-by) supply gas in the event of a power failure.

Gas	Nominal capacity (litres) at 137 bar	Usable capacity (litres)[1]
Oxygen J-size	6,800	6,540
Nitrous oxide: J-size G-size	 18,000 9,000	 8,900
Nitrous oxide/oxygen mixture G-size	5,000	4,740
Medical air J-size	6,400	6,220 (400 kPa) 5,550 (700 kPa)
Helium/oxygen mixture K-size	-	7,000 nominal

Table 23: Capacities of medical gas cylinders used on manifolds

Notes applicable to Table 23:

1. The usable figures are for discharge to a gauge pressure of 7 bar. Two sets of figures are provided for air – for 400 kPa systems and 700 kPa systems. The latter is for discharge to 15 bar.

2. Reference should be made to the respective supplier's data charts / sheets for further information.

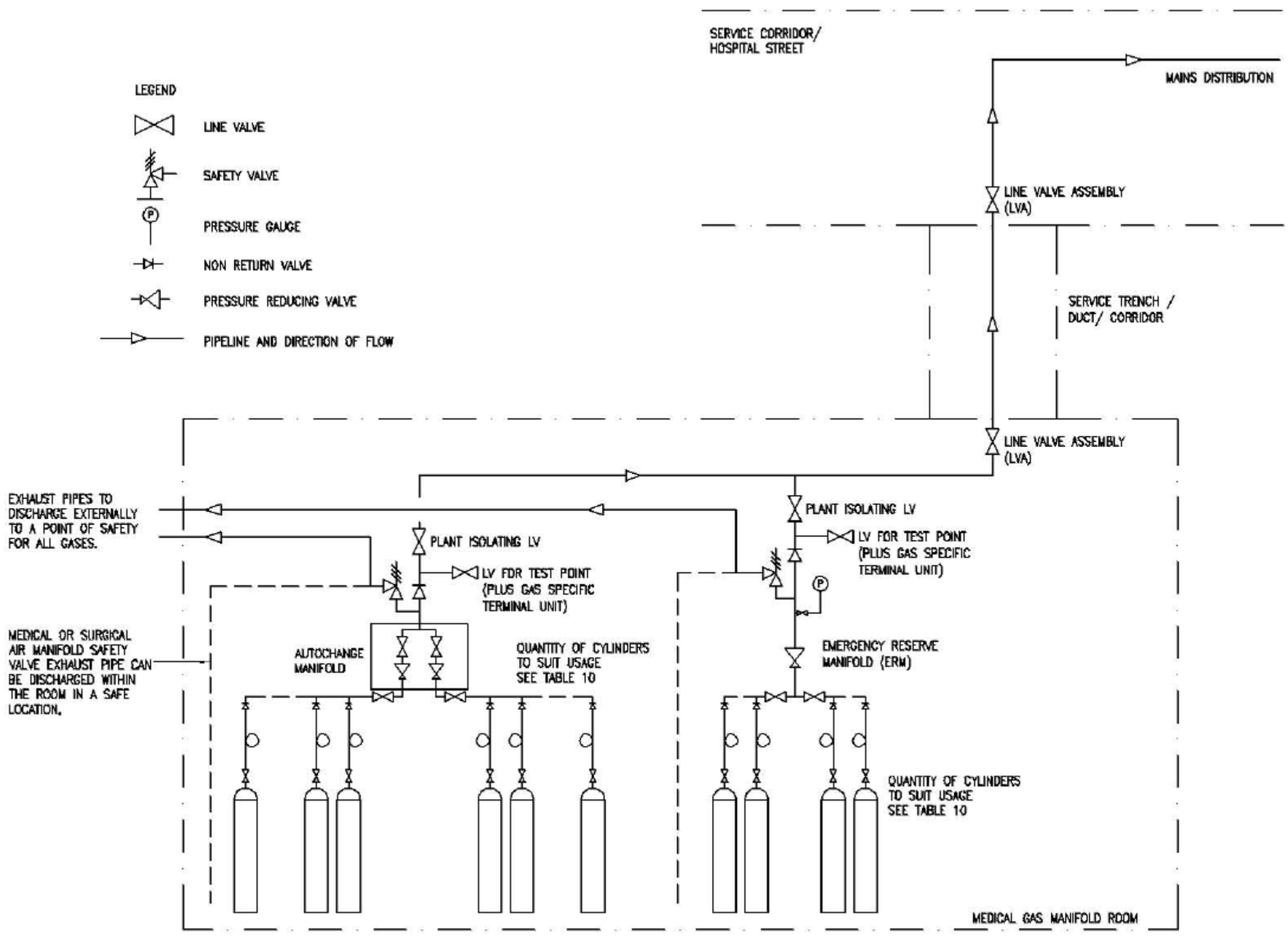


Figure 10: Typical automatic manifold arrangement with manual ERM

5.6 In the event of power failure, when the power is restored, the original “running bank” should be on-line, that is, the same bank that was the “running bank” prior to interruption of the supply.

Note14: Some manifolds default to a specific bank following a power failure, regardless of which bank was the running bank prior to interruption of the supply. **NB:** Such units will require manual resetting to the original condition.

5.7 Manifolds and control panels should be designed and certificated for use with 230 bar cylinders. The manifold headers should incorporate a renewable non-return valve to prevent the discharge of a complete bank of cylinders in the event of “tail-pipe” rupture.

5.8 The tail-pipe cylinder connector must be a pin-index yoke connector in accordance with BS EN ISO 407: 2004 for oxygen, nitrous oxide/oxygen mixture (50% v/v) and medical air. Non-metallic flexible connectors shall not be used. The connector for nitrous oxide should be a side outlet valve connector in accordance with BS341-3: 2002. The manifold connectors should be in accordance with Table 24:

Thread	Medical gas
M24 x 2	Medical air
M22 x 2	N_2O/O_2
M20 x 2	O_2
M18 x 2	N_2O

Table 24: Cylinder valve thread sizes

Where it is necessary to use non-metallic materials, consideration should be given to the use of non-halogenated polymers in high pressure systems (>3,000 kPa) delivering oxygen or gaseous mixtures with oxygen concentrations greater than that in ambient air. Consideration should also be given to fitting sintered filters upstream of non-metallic materials to minimise the risk of particle collisions and impacts, which are a potential source of ignition. In addition, there are tests that should be conducted to ensure that the risk of ignition is minimised. Attention is drawn to BS EN ISO 15001: 2010.

Note 15: Studies have shown that inadvertent ignition of halogenated polymers can lead to highly toxic by-products being delivered to the gas stream.

5.9 Pressure indication should be provided to indicate pressure in each cylinder bank and in the MGPS.

5.10 The automatic manifold and ERM should be provided with a test point comprising lockable valve and terminal unit. This should be sited within the manifold room and positioned immediately upstream of the distribution pipeline isolating valve.

Pressure control

5.11 The pressure control should maintain the nominal pipeline pressure within the limits given in Section 4. High-pressure regulators should comply with BS EN

ISO 10524-2: 2006 and be supplied with auto-ignition test results and regulator performance curves for each gas.

5.12 Separate pressure regulating valves should be provided for each cylinder bank. The control system should be designed so that the cylinders of one bank can be changed, or the pressure regulator or any component for one bank can be overhauled, without loss of continuity of the gas supply, refer to Figures 10 and 11 for provision of isolating valves.

5.13 Pressure safety valves should be of the self-closing type and be installed on each distribution pipeline downstream of the manifold line pressure regulator and upstream of the main isolation valve. A pressure safety valve should also be installed between the reserve supply and the pipeline distribution system. It should have a flow capacity at least equal to that of the pressure regulator immediately upstream of it. The discharge pipe should be at least one size larger than the main pipeline and be separate for each safety valve.

5.14 This discharge pipeline should be vented to atmosphere, outside the building, in an area where the discharge of oxygen, nitrous oxide, or nitrous oxide/oxygen mixture will not present a fire hazard or cause injury to personnel. Medical and surgical air may be vented internally normally terminating 50mm above finished floor level. Warning signs should be posted at the discharge positions; access for inspection should be provided.

5.15 Discharge pipelines should terminate at least 3m clear of any door/window that can be opened or other ventilation/air intake. The ends of the discharge pipelines should be turned downwards to prevent the ingress of dirt and moisture, and be placed and protected so that frost cannot form or be collected upon them. Similar safety valve arrangements are required for installations supplied from liquid oxygen cylinders.

Note 16: High pressure cylinders with integral pressure regulation can be used on manifold systems.

Manifold monitoring and indicating system

5.16 The monitoring and indicating system should perform the following functions:

- overall manifold monitoring;
- manifold condition indication;
- overall supply plant indication.

5.17 All functions should be appropriately identified. Indicators should have a design life of at least five years. The system should be capable of automatic reinstatement after restoration of the power supply.

5.18 Manifold monitoring, indicating and alarm systems should be on the essential electrical supply.

Manifold control unit

5.19 The control unit should include a green “mains supply on” indicator.

Manifold monitoring

5.20 Each automatic manifold should be provided with monitoring to detect:

a) duty bank operating;

b) duty bank empty and stand-by bank operating;

c) stand-by bank below 10% capacity, when the duty bank is empty;

d) each emergency reserve manifold bank below nominal 14 bar (for nitrous oxide) and below 68/100 bar pressure for other gases (typically 50% of cylinder contents);

e) pipeline pressure faults outside the normal range.

Manifold indicator unit

5.21 There should be indicators to show the following conditions:

a) for each automatic manifold;

b) a green “running” indicator for each bank. This should display when the bank is supplying gas, irrespective of the pressure;

c) a yellow “empty” indicator for each bank when the running bank is empty and changeover has occurred;

d) a yellow “low pressure” indicator for each bank to be illuminated after changeover, when the pressure in the bank now running falls to the low pressure setting;

e) for each emergency reserve bank, a yellow indicator to be illuminated when the pressure in the bank falls below 14 bar for nitrous oxide or below 68/100 bar for other gases(typically 50% of cylinder contents)- this will require the use of separate pressure sensors – one for each bank);

f) for the pipeline distribution system, a red “low pressure” and a red “high pressure” indicator to be illuminated when the respective conditions occur.

Alarm signal status unit

5.22 The following indication of manifold conditions should be provided:

a) green “normal”: *normal*;

b) yellow “duty bank empty, stand-by running”: *change cylinders*;

c) yellow “duty bank empty, stand-by low”: *change cylinders immediately*;

d) yellow “emergency reserve bank low”: *reserve low*;

e) red “pipeline (high or low) pressure fault”: *pressure fault*.

5.23 Conditions (b) to (e) in Paragraph 5.22 should be transmitted to the central alarm system. Where relays are used, they should be normally energised relays, which de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA. Volt-free, normally closed contacts rated at 50 V d.c. and 50 mA should be provided for transmission of conditions (b) to (e) to the central alarm system.

5.24 The panel can be incorporated into the manifold control unit or be a separate unit within the plantroom. If mounted separately, the cabling should be monitored for open/short circuit. In the event of such a cable fault, a red “system fault” lamp should be illuminated on the alarm signal status unit, together with the appropriate alarm condition.

Manifold management

5.25 Connections should be provided that allow monitoring of manifold alarm conditions (b) to (e) and manifold running for each “bank”. These connections should be Volt-free contacts normally closed for each condition having a minimum rating of 50 V d.c. and 50 mA. The building management system should not be used to control the manifold.

Emergency reserve manifold

5.26 An emergency reserve manifold system should be provided to form a reserve source of supply, for emergency use or to permit servicing or repair.

5.27 The supply should be designed to provide the design flow of the primary system. When such provision would result in more than ten cylinders on each bank, the additional cylinders should be held in the manifold rooms. A non-return valve and isolating valve should be installed immediately upstream of the reserve manifold connection to the pipeline distribution system.

5.28 The requirements for the emergency reserve supply capacity should be set out in the operational policy document; this should take into account the arrangements for the supply of cylinders and the flow that the system is required to provide. The gas supplier should be consulted.

5.29 The specific requirements will depend on the method of primary supply. Where this results in an unrealistic number of cylinders being kept on site, the operational policy should be set out, giving details of procedures to be followed in an emergency to ensure continuity of supply.

5.30 For large installations, it may be impractical to rely on a cylinder manifold system; thus, consideration should be given to either a bulk liquid or liquid cylinder emergency/reserve supply in the case of oxygen and for two or more compressed air plants sited separately for medical / surgical air applications.

5.31 The operational policy document should set out the location of emergency manifolds, cylinders etc and the action to be taken in the event of loss of the primary source of supply.

Emergency reserve supply for manifold installations

5.32 The reserve supply system for cylinder manifold systems should normally be located in the manifold room adjacent to the automatic manifold. All cylinder valves should be permanently open so that gas is immediately available, but one of the manifold header isolating valves should be closed. A typical system is shown in Figure 10.

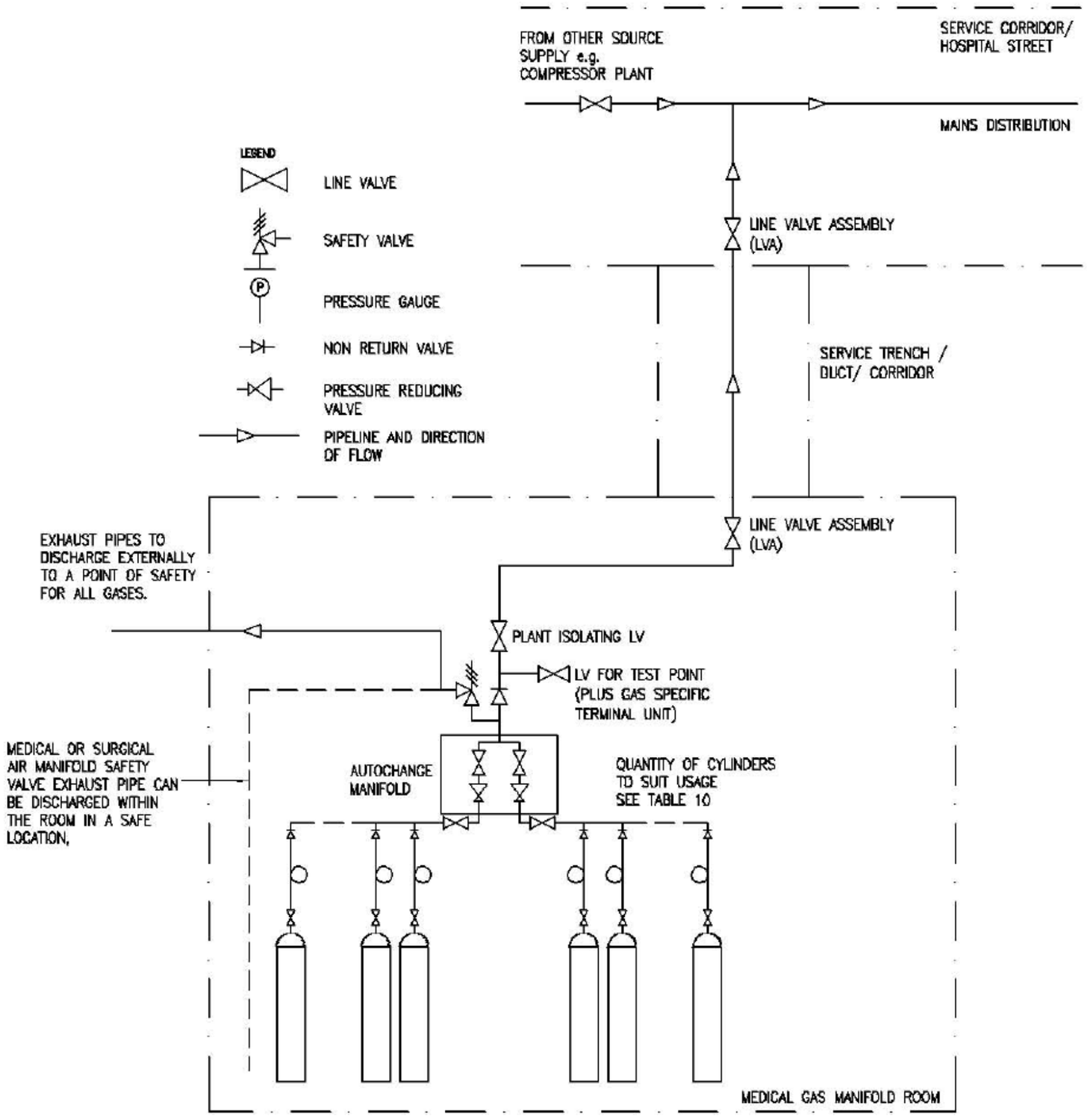


Figure11: Typical automatic changeover emergency reserve manifold for liquid oxygen and medical/surgical air plant

5.33 The supply system should go into operation automatically via a non-return valve, and the emergency reserve manifold (ERM) isolating valve should remain open.

Reserve supply for air compressors/liquid oxygen/oxygen concentrators (PSA)

5.34 The supply should comprise a two-bank fully-automatic manifold system as described in paragraphs 5.1–5.24 (except for (d) in paragraph 5.20; (e) in paragraph 5.21; and (d) in paragraph 5.22, which do not apply). The manifold system(s) should be installed in an appropriate manifold room(s) separate from the plant. A typical system is shown in Figure 11.

6. Oxygen systems

Liquid oxygen systems

General

6.1 Over the last ten years, there has been a significant increase in the use of medical oxygen for treating patients in healthcare facilities, with some hospitals seeing annual increases well in excess of 10%. The introduction of the European Standard on medical gas pipeline systems (BS EN 737) has also had implications. Parts 1-4 of BS EN 737 have since been replaced with the standards BS ENISO 9170 and BS EN ISO 7396. Refer to Part B Section 3 for further information.

6.2 The scope of the advice provided by this Section covers the supply of liquid oxygen to healthcare facilities from delivery into bulk storage vessels for the larger hospitals to the supply of liquid oxygen in liquid cylinders to hospitals with lower demands. The guidance given is intended to cover all the aspects of a bulk cryogenic liquid system commonly known as a vacuum insulated evaporator (VIE).

6.3 This chapter also covers the supply of medical oxygen from on-site generation using PSA plant, or in medical cylinders, other than (in the case of the latter) as a means of back-up to the main supply system.

6.4 It does not specifically cover bulk liquid nitrogen installations, but its principles may be applied to hospitals where these gases are used in sufficient quantities to make the use of a VIE cost-effective.

6.5 Significant changes since publication of Scottish Health Technical Memorandum 2022: 2001 include:

- the use of risk assessment as a tool to assist in the development of the medical oxygen installation;
- adoption of the principles outlined in BS EN 737-3: 2000 / BS EN ISO 7396-1: 2007 + A2: 2010;
- new methods of sizing the medical oxygen vessels and back-up manifolds;
- designation of vessel contents as “operational” or “reserve” stock.

A checklist for planning and upgrading an oxygen system is given in Appendix H.

Risk assessment

6.6 Risk assessment is used to assist in the development of the medical oxygen installation to produce a safe and practical design and ensure that a safe supply of oxygen is available for patient use at all times. It is used for all aspects of the process; from the initial concept designs through installation and operation to the routine assessment of the installation, once in service.

6.7 Advice is given on setting up risk assessment teams and choosing the correct mix of personnel to ensure that all aspects of the associated risks are considered.

6.8 Throughout this section, non-exclusive risk criteria lists are provided to assist these teams in identifying the unacceptable risks and suggesting how they might be addressed. It recommends that annual risk assessments are carried out throughout the life of the system to ensure that a safe system of supply is maintained and any new risks are identified.

6.9 The prime responsibility to ensure that adequate stocks of medical oxygen are available for patient use should remain firmly with the hospital's management team. However, the hospital may agree with its gas supplier or facilities management supplier that they should manage the supplies of medical oxygen and maintain adequate stocks in the vessel. These arrangements should be clearly documented within the MGPS operational policy and procedures document. The effectiveness of these arrangements will need to be assessed as part of the risk assessment review and be validated to ensure that they can be met.

6.10 Consideration should be given to the operational management consequences of using different suppliers to supply medical oxygen to different supply systems on the same pipeline system.

6.11 Any contracts involving different suppliers should clearly state the obligations and limitations of liabilities; and any facilities management agreement between the hospital and the medical gas supplier must define the responsibilities of each party.

6.12 There must be no modification to the design or any part of the medical liquid oxygen system without written authorisation from the gas supplier.

6.13 This guidance adopts the principles outlined in BS EN ISO 7396-1: 2007 + A2: 2010 'Medical gas pipeline systems – Part 1: Pipeline systems for compressed medical gases and vacuum' which introduces to the UK the concept of having three sources of supply for medical gas systems. This is covered in Section 2.

New methods of sizing

6.14 New methods of sizing the medical oxygen vessels and back-up manifolds are covered, together with advice on appropriate location of vessels on site using principles of risk assessment. This ensures the provision of a secure source of supply that reflects the degree of risk associated with the hospital's location and its level of dependency on medical oxygen.

Designation of vessel contents as "operational" or "reserve" stock

6.15 The operational stock is the volume of product that the gas supplier uses to manage deliveries to the hospital; when this stock is exhausted, the vessel should be refilled under normal conditions.

6.16 The reserve stock is the volume of product that is used to provide additional stock to take account of fluctuations in demand or when the supplier fails to make a scheduled delivery.

6.17 Both operational and reserve stock levels are calculated using the risk assessment principles embodied within this document (see Figures 12–17).

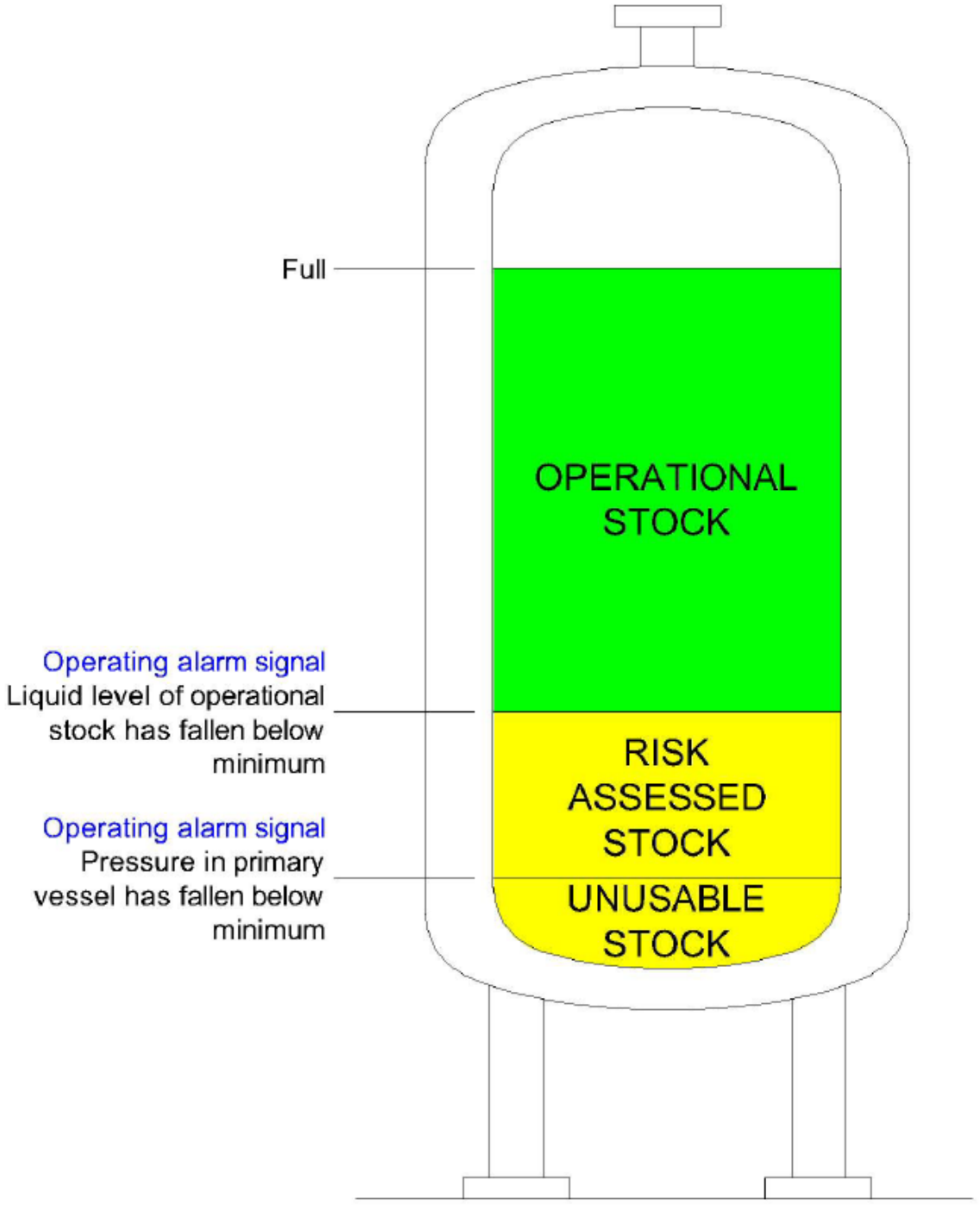


Figure 12: Primary supply (VIE)

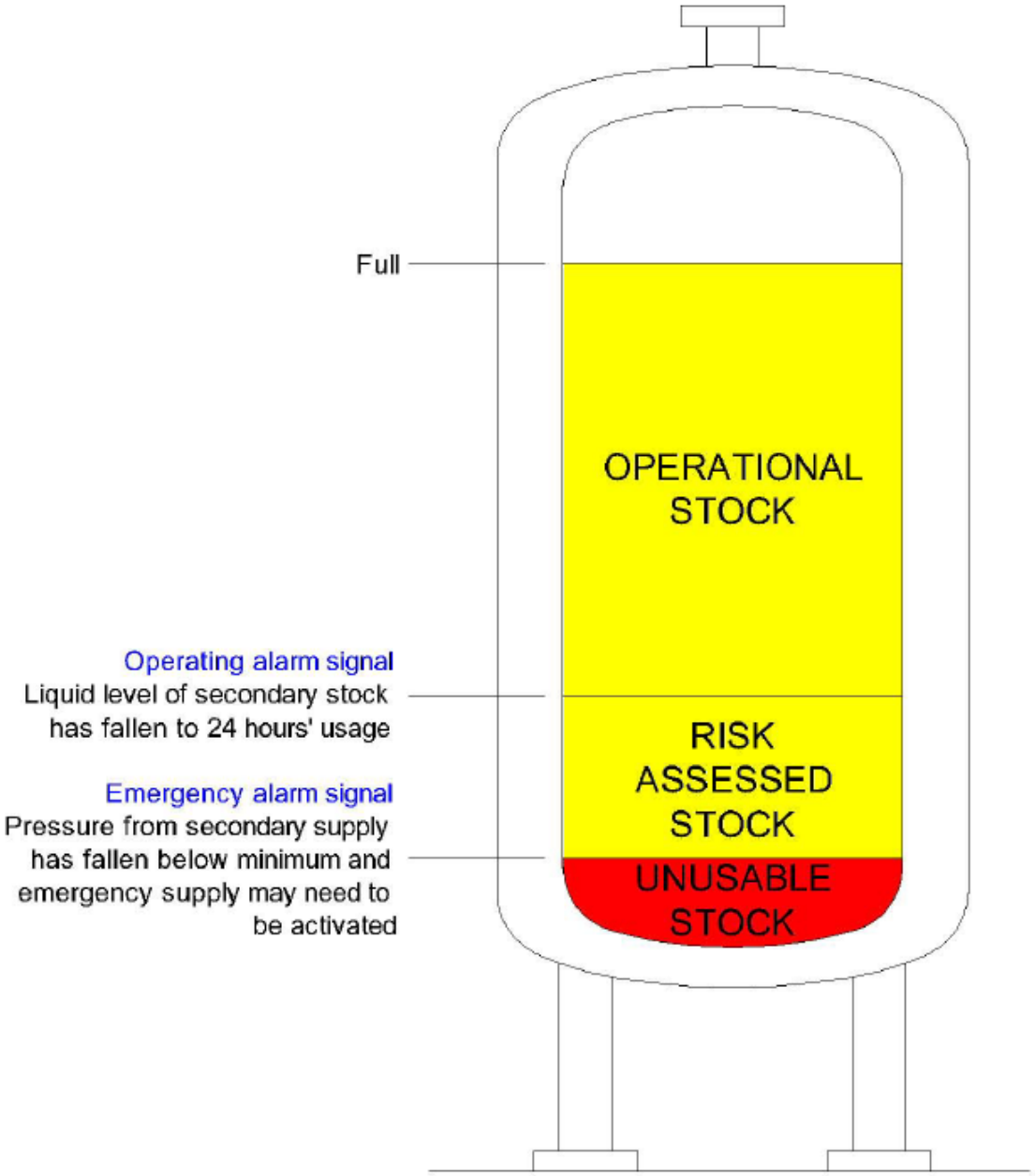


Figure 13: Secondary supply (VIE)

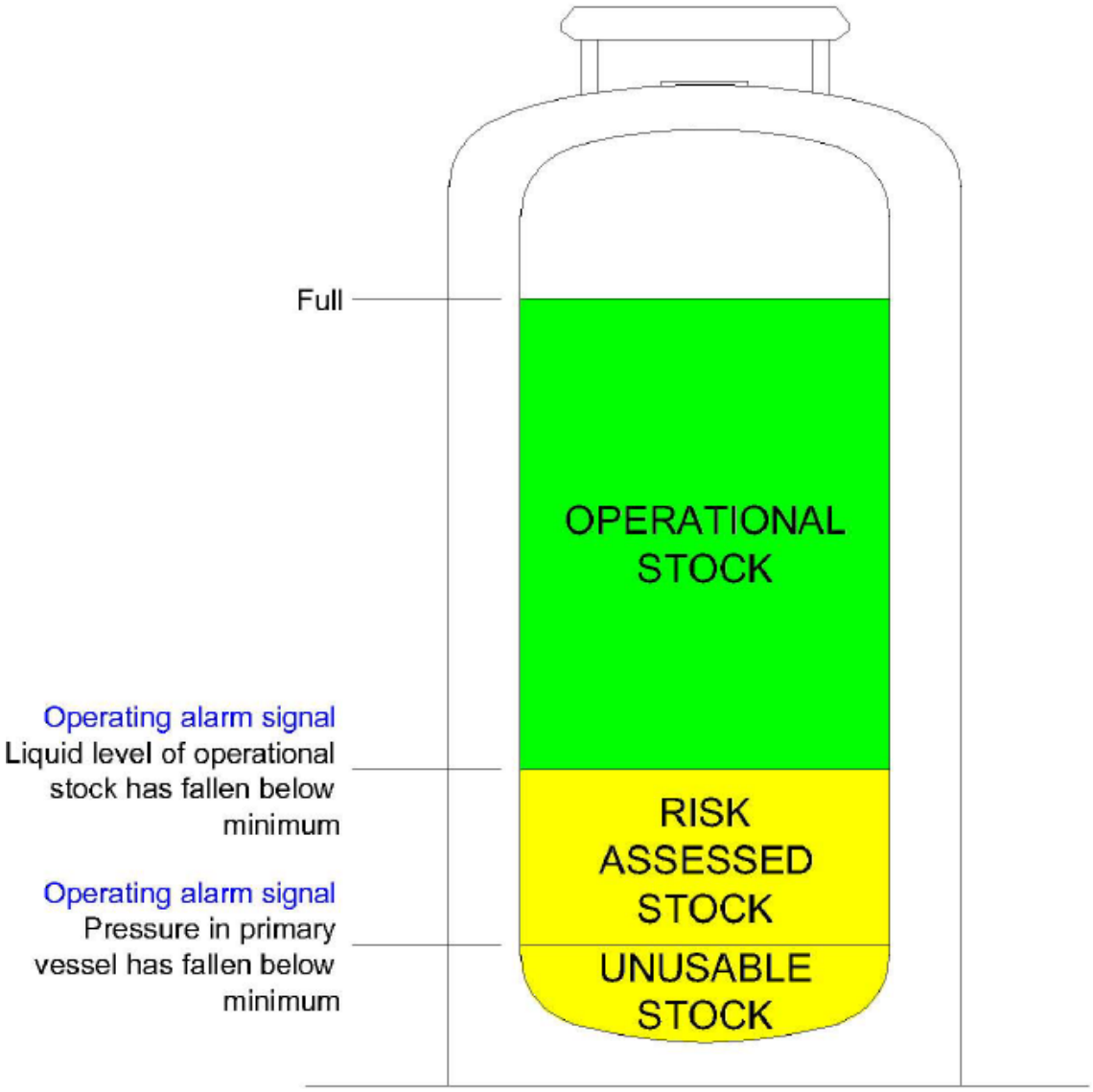


Figure 14: Primary supply (liquid cylinder)

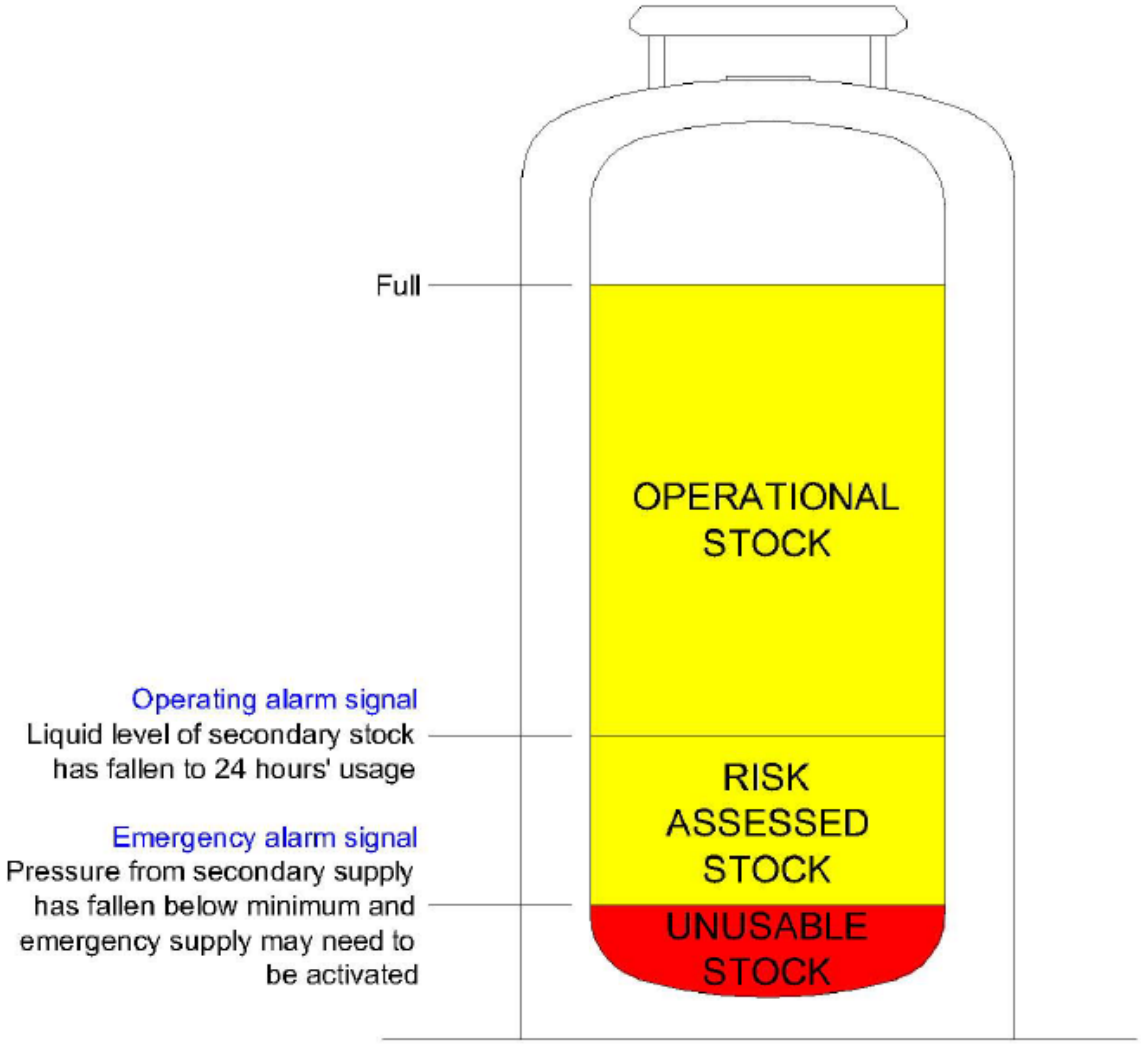


Figure 15: Secondary supply (liquid cylinder)

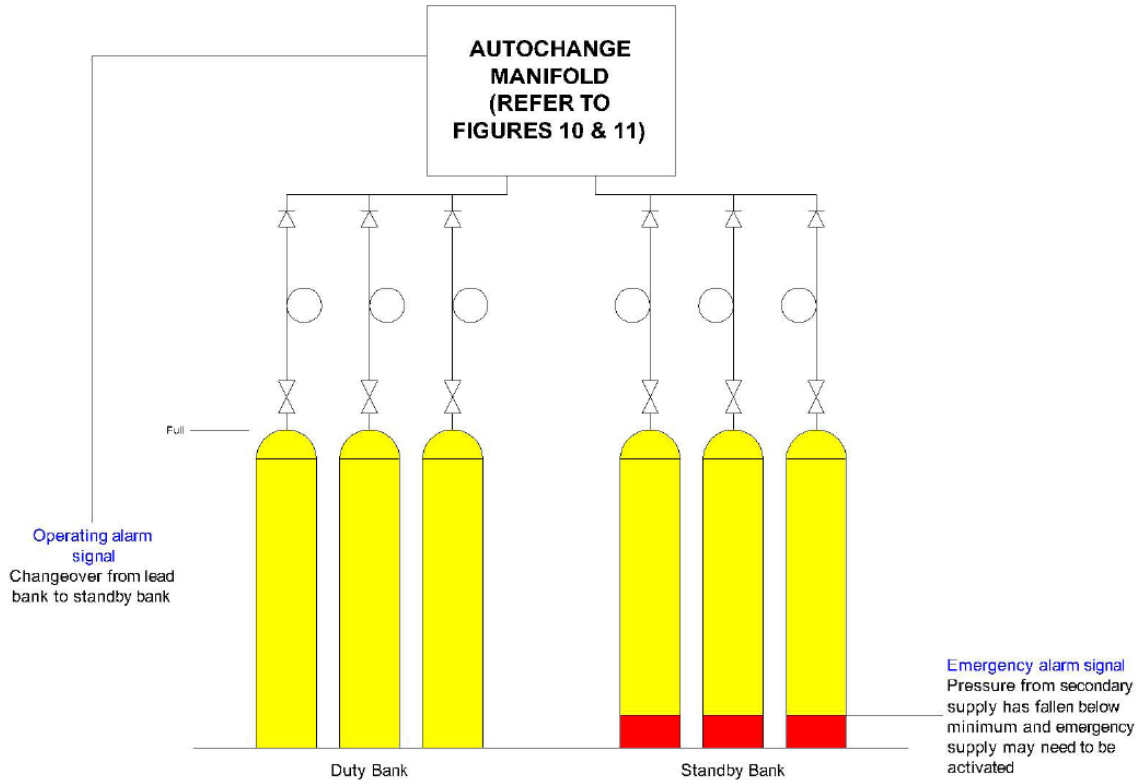


Figure 16: Secondary supply (gaseous cylinder)

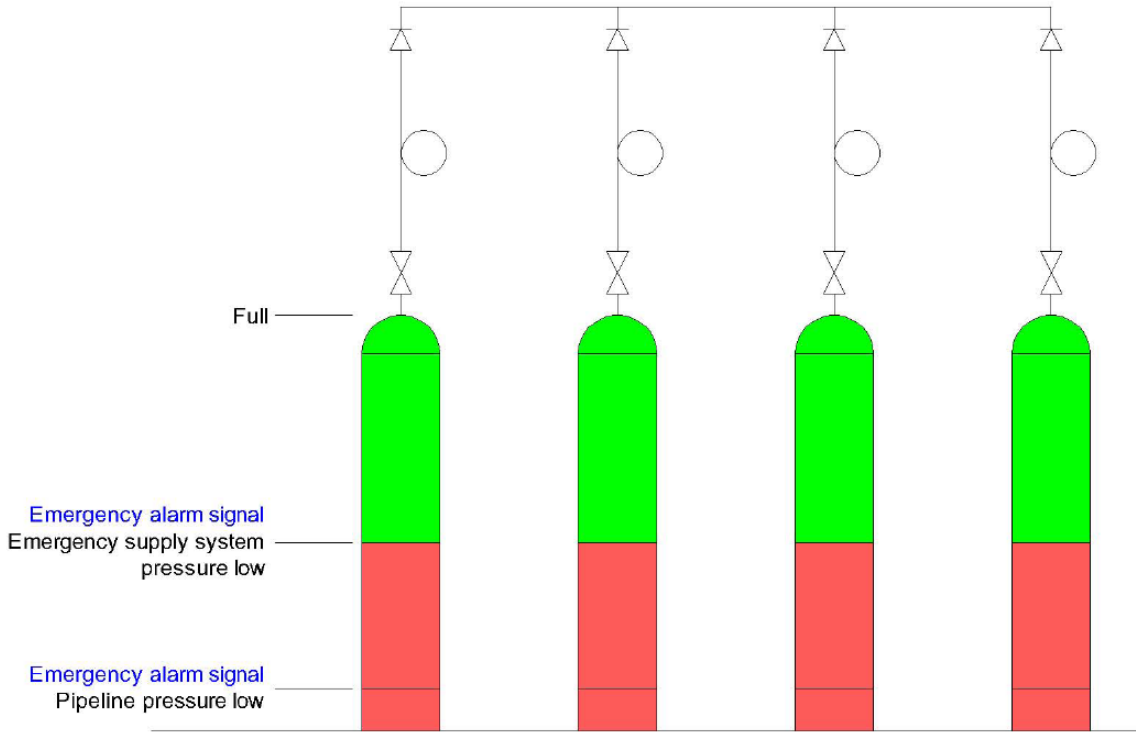


Figure 17: Secondary supply (liquid cylinder manifold)

Choosing an oxygen supply system

6.18 When designing or reviewing an installation to supply medical oxygen to a hospital, the most appropriate method of supplying the gas will be determined by the potential size and variability of the hospital's medical oxygen demand.

6.19 To determine the most suitable and cost-effective method of supplying medical oxygen and the appropriate size of the installation, comprehensive demand figures should be provided to the designer.

6.20 These demand figures (prepared as a part of the risk assessment) should be based on:

- the current average daily gas usage based on the past twelve months' supplies;
- the maximum potential daily demand volumes based on peak flow conditions, as below;
- any planned extensions to the hospital/pipeline that may affect the demand;
- the expected natural annual growth in the use of medical oxygen.

Portable ultrasonic flowmeters for non-invasive pipeline measurement are a useful tool for arriving at average and peak demand flows.

6.21 The maximum potential daily demand should be based on the peak flow conditions measured between 8.00 am and 6.00 pm, with all operating rooms in use and with maximum demand being provided to pipeline outlets. It should not be based on the theoretical pipeline design flow conditions. Where actual flow monitoring is impracticable, daily cylinder or liquid consumption figures should be used.

Note 17: a) Control panels should be capable of passing the maximum design flow of the oxygen system's pipeline distribution system. This may necessitate installing two control panels in parallel.

b) Plant certification should be issued by the liquid oxygen supply company to demonstrate, on site, the capability of providing the maximum flow as determined as part of the risk assessment process of paragraphs 6.20 and 6.22 within the +/- 4% regulator tolerances required by this Scottish Health Technical Memorandum.

6.22 Additionally, historic consumption records should be reviewed to assess the current usage and the natural growth of the medical oxygen demand. The growth predictions should take into account any planned extensions to the hospital's facilities or pipeline systems and changes in clinical practices in the hospital that could affect the medical oxygen demand. Natural growth in usage of medical oxygen, due to changes in clinical practice, is about 8% to 10% per annum, but individual hospitals will need to establish this growth figure during the risk assessment process. Any planned extensions or estimated natural

growth forming part of the risk assessment process should incorporate a pipeline distribution system reappraisal.

6.23 For new hospitals, where no historic information is available, the estimated demand should be based on the proposed size and type of the hospital and the usage figures of like facilities.

6.24 It is essential to review periodically the average daily demand with the gas supplier and agree either to revise delivery frequencies to maintain the operational stock levels or increase the size of the storage system on site. Any planned increase in demand due to hospital site developments, pipeline extensions or changes in clinical practice should be notified to the gas supplier to ensure that the changes do not jeopardise security of supply.

6.25 The medical liquid oxygen demand should be reviewed with the gas supplier at least annually (or after a significant extension to the pipeline causing increase in demand) to re-assess the size of the installation.

6.26 As the agreed stocks used for the supply of liquid oxygen are all based on an average daily demand, as the demand grows so the storage volume requirements will increase. With the increased volume requirements for the reserve stock, the volume available for operational stock will reduce. Having reviewed the average daily demand with the gas supplier, it is necessary to agree either revised delivery frequencies to maintain the operational stock levels or to increase the size of the storage system on site.

6.27 The review of the medical liquid oxygen installation should also include a review of the risk assessment to ensure that no other conditions on site have been changed that jeopardise the security of the gas supply.

6.28 For smaller hospitals, where the demand is typically below 3,000m^3 per annum, the most cost-effective method of supplying medical oxygen is from a compressed gas cylinder manifold.

6.29 As the demand increases, it becomes less practicable to use compressed gas cylinders and more cost-effective to use medical liquid oxygen. A cylinder manifold larger than 2 x 10 J cylinders is likely to prove impracticable because of the manual handling difficulties with the number of cylinders involved. Liquid cylinders, which are ideally suited to an annual consumption of between 3,000m^3 and 40,000m^3, can be connected together by a manifold to provide adequate storage capacity and flow rate.

6.30 For hospitals with larger demands, a bulk medical oxygen VIE will generally be used. There is a nominal overlap of annual consumption between 27,500m^3 and 40,000m^3, where either a bulk VIE or a liquid cylinder installation could be considered, either to satisfy a particular requirement, or to accommodate possible site restrictions.

6.31 The main benefit of using gas cylinders is that installation costs of manifold systems are significantly lower than those of a liquid oxygen system. However, the cost of the medical oxygen in compressed gas cylinders is higher than the

cost of medical liquid oxygen (supplied either into liquid cylinders or into a VIE). As the demand grows, so the lower unit cost of the liquid oxygen offsets the higher installation costs of the liquid oxygen systems.

6.32 Cryogenic liquid systems are normally used where the demand is high enough to make bulk supplies cost-effective and where the demand makes cylinder supplies impracticable. The demand should be greater than the rate of heat loss to avoid pressure build up.

6.33 Liquid oxygen provides a flexible approach to both the size and the choice of installation design. Its provision is determined by factors such as the size of the hospital, the availability of space for both the installation and the delivery vehicle, the proximity of the gas supplier and the size of the demand for medical oxygen.

6.34 There are a number of operational benefits in using a medical liquid oxygen system over compressed gas cylinders, including:

- greater volume of medical oxygen stored on site;
- improved security of supply;
- reduced storage area for the medical gas cylinders;
- reduced manual handling requirements for cylinder handling.

6.35 When determining the cost-effectiveness of specific proposals from suppliers, the total supply costs should be assessed, including costs for the site preparation and vessel installation, vessel rental and liquid supply over the total period of the contract.

System configurations

6.36 In order to comply with the requirements of BS EN ISO 7396-1: 2007 + A2: 2010, it is necessary for all medical oxygen installations to have three independent supply sources capable of feeding medical oxygen to the pipeline.

6.37 These three sources are referred to as:

- **the primary supply** – the main source of medical oxygen on site, providing gas to the pipeline;
- **the secondary supply** – the secondary source of medical oxygen on site, providing gas to the pipeline and capable of providing the total oxygen flow requirement in the event of a primary supply failure;
- **the reserve supply** – the final source of supply to specific sections of the pipeline, capable of meeting the required demand in the event of failure of the primary and secondary supplies, or failure of the upstream distribution pipework. For the larger development or where the existing hospital acts as the emergency supply source to a PFI/PPP project, refer to paragraph 6.41.

6.38 For smaller hospitals, the primary supply can be fed from compressed gas cylinders but as the demand grows, the most practicable supply source will be either liquid cylinders or a VIE system.

6.39 A fully automatic gas cylinder manifold will normally be used as the secondary supply system for smaller VIEs and liquid cylinder systems. Where it is impracticable to maintain supplies to the hospital using a cylinder manifold, a secondary liquid oxygen system will be necessary.

6.40 Emergency supplies will not normally be fed from a liquid oxygen supply system, as it is not possible to prevent the boil-off of the liquid oxygen over extended periods when the emergency system is not in use.

6.41 In major acute hospitals, the foremost consideration of the assessment process should be to locate the primary and secondary supply systems on separate sites. For the larger developments, this consideration can be extended to installing secondary back-up VIEs to each site. Each site should have independent control, monitoring systems and duplex supply routes into the hospital pipeline distribution system and be valved accordingly to ensure that the systems remain independent outwith an emergency situation. The inherent safety of the present control system of a VIE should not be compromised or rely on minimal distribution pipeline pressure differences to determine the primary site, each site should share the hospital load with emergency valving incorporated in the event of a fault condition arising. Alternatively, consideration can be given to each site serving, at high pressure, a common control panel, the secondary supply incorporating an economy circuit, within the hospital manifold room. Section 13 provides additional guidance on dual supply and ring mains.

6.42 Where it is not feasible to utilise two sites, the risk assessment should evaluate the greater level of risk associated with using a single site and define the appropriate actions that should be established to obviate the higher risks, such as using twin or ring-main pipeline systems, siting of the emergency supply manifold or installing suitable protection for the installation.

6.43 The overall ‘same site’ system should be designed so that the primary supply is used first, with the secondary supply automatically switching in when the primary supply is either empty or fails to supply.

Cryogenic liquid systems / VIE

6.44 These systems, commonly referred to as vacuum insulated evaporators (VIEs), are used to store the medical gas as a liquid at cryogenic temperatures and to vaporise it into a gas at ambient temperature for distribution through the hospital pipeline.

Plant

6.45 The VIE system consists of:

- a vacuum insulated cryogenic storage vessel to store the bulk liquid;

- one or more ambient-heated vaporisers to convert the cryogenic liquid into a gas for supply to patients via a pipeline;
- control equipment to control the pressure and flow of gas to the pipeline.

6.46 The liquid oxygen is stored at cryogenic temperatures (down to minus 183°C) and converted to a gas at ambient temperature by passing it through an air-heated vaporiser.

6.47 The cryogenic storage vessel is normally constructed from a stainless steel inner pressure vessel that is supported in a mild steel outer shell. The space between the vessels is filled with a high performance insulating material, maintained under a vacuum, to minimise heat transfer to the inner vessel, which reduces the rate of evaporation of the liquid oxygen.

6.48 A pressure-raising regulator that permits the flow of liquid to the pressure-raising vaporiser, as required, automatically controls the pressure in the liquid oxygen system. The vaporised liquid is fed back to the top of the vessel or liquid cylinder to maintain the pressure in the system.

6.49 Under normal operating conditions for a VIE system, the gas supply to the hospital will be maintained by feeding liquid oxygen to the main vaporiser system where it is converted to a gas and warmed towards ambient temperature. There is a tendency for the vaporiser system to “ice up” where hospital demands are high or continuous, or airflow to the vaporisers is restricted. Under these circumstances the options to be considered should include:

- installation of additional vaporisers;
- an auto-changeover system between vaporizers – refer to Note 18;
- hot water/electrically heated vaporisers;
- increasing size of vaporiser;
- repositioning.

Note 18: In the event of power failure, control valves on all vaporisers should fail “open”.

6.50 Where hospital demands are low or very erratic, the natural heat transfer into the vessel causes the liquid oxygen to boil and the vessel pressure to rise. When the vessel pressure rises to a set point, the hospital pipeline can be fed by valve changeover from the top gas to prevent the vessel pressure rising above the safety-valve setting. On safety-valve operation, oxygen must be able to vent safely to atmosphere. All secondary VIEs should incorporate an economiser circuit which will feed into the hospital distribution system on reaching a predetermined VIE pressure level.

6.51 In all cases, the pipeline pressure is controlled using a system of duplex pressure regulators and valves. It is essential that all materials used in the construction of the vessels, control equipment and pipeline are compatible with

oxygen at the operating temperatures that could be encountered under normal operation with single fault condition. The risk assessment will determine the exact configuration.

6.52 The control panel design should comply with the design requirements specified in BS EN ISO 7396-1: 2007 + A2: 2010 and be sized to provide the system design flow.

Telemetry

6.53 The use of telemetry on the liquid storage system is recommended because it permits both the hospital and the gas supplier to monitor relevant supply conditions continuously, including storage vessel levels and pressure. In addition, it can be used to transmit other operational data from the storage vessel, pipeline and associated equipment for monitoring purposes. It may be beneficial to make this information available to the relevant person(s) in the healthcare organisation. By having continuous monitoring of stock available through the telemetry system, an existing vessel could be retained. This solution is only acceptable provided that an appropriate risk assessment, following the guidance given in this chapter, supports the decision.

Siting

6.54 The Authorised Person (MGPS) will be responsible for agreeing the final location of the liquid oxygen compound(s), taking into consideration any issues raised in the initial risk assessment. It is the supplier's responsibility to assess the space requirements for vehicular access.

6.55 When considering the space requirements for the liquid oxygen compound(s), there may be operational advantages in having two compounds in different areas on the hospital site, rather than one larger site utilising either a single large vessel or multiple tanks. This arrangement may also have benefits with respect to both planning permission and meeting the safety distances specified in the British Compressed Gases Association's (BCGA) Code of Practice 19 (CP19): 'Bulk liquid oxygen storage at users' premises' (henceforth known as BCGA CP19; see Table 25).

6.56 Each supply system should be located in a secure fenced compound, which should be sized to allow adequate access to all of the control equipment.

6.57 The site should essentially be level but designed to have adequate falls to prevent water accumulating beneath equipment.

6.58 The location of drains in the vicinity of the site should comply with the requirements specified in BCGA CP19 (see Table 25).

6.59 Only under extreme conditions should the safety distances specified in BCGA CP19 be reduced. Any relaxation of these safety distances needs to be agreed with the supply company's safety representative and the Authorised Person (MGPS). Both parties must ensure that an equivalent level of safety is achieved, and this should be approved and documented.

6.60 The layout of the liquid oxygen installation should provide adequate access to all of the relevant components of the system and permit adequate airflow for the ambient vaporisers.

6.61 The plinth should be of concrete construction. The area in front of the vessel(s) (tanker apron) should be non-porous concrete. Under no circumstances should tarmac be used in the vicinity of the liquid oxygen filling point, or areas where liquid oxygen spillage may occur.

6.62 The location of the liquid oxygen compound should permit the supplier to gain safe access with the appropriately sized tanker. It is the supplier's responsibility to assess the space requirements for vehicular access.

6.63 The design of the liquid oxygen installation should take into account the gas supplier's requirements for discharging the liquid oxygen from the cryogenic tanker. The area directly in front of the vessel should be kept clear to provide access for the delivery vehicle at any time. Under no circumstances should unauthorised vehicles be permitted to park in front of the compound.

6.64 The compound should not be used for the storage of other equipment. For ease of maintenance, the liquid oxygen control panel should be housed in an adjacent bricked room or medical gas manifold room particularly where the secondary supply consists of cylinders.

6.65 Where the secondary or emergency supply system is fed from a cylinder manifold, it should be in a manifold room and have adequate space to permit safe cylinder changeover. Spare cylinders should not be held in the VIE compound or liquid cylinder compound but stored in the nearest medical cylinder store.

6.66 A pipework and installation diagram (P&ID) of the plant should be displayed clearly to indicate the appropriate valves that are necessary to operate the plant safely. The medical gases supplier should make the Authorised Person (MGPS), and others in the hospital that may operate the system, aware of its general operating principles. (Typical plant installations are shown in Figures 18–20.)

Safety distances from exposure to vessel/point where oxygen leakage or spillage can occur	Up to 20 tonnes (metres)	Over 20 tonnes (metres)
Areas where open flames/smoking permitted	5	8
Places of public assembly	10	15
Offices, canteens and areas of occupancy	5	8
Pits, ducts, surface water drains (untrapped)	5	8
Openings to underground systems	5	8
Property boundaries	5	8
Public roads	5	8
Railways	10	15
Vehicle parking areas (other than authorized)	5	8
Large wooden structures	15	15
Small stocks of combustible materials, site huts etc	5	8
Process equipment (not part of installation)	5	8
Continuous sections of flammable gas pipelines	3	3
Flanges in flammable gas pipelines (over 50mm)	15	15
Fuel gas vent pipes	5	8
Compressor/ventilator air intakes	5	8
Fuel gas cylinders (up to 70m^3)	5	5
LPG storage vessels (up to 4 tonnes)	7.5	7.5
LPG storage vessels (up to 6 tonnes)	15	15
Bulk flammable liquid storage vessels (up to 7.8m^3)	7.5	7.5
Bulk flammable liquid storage vessels (up to 117m^3)	15	15
MV or HV electrical sub-stations	5	8

Table 25: Safety distances to comply with BCGA CP19

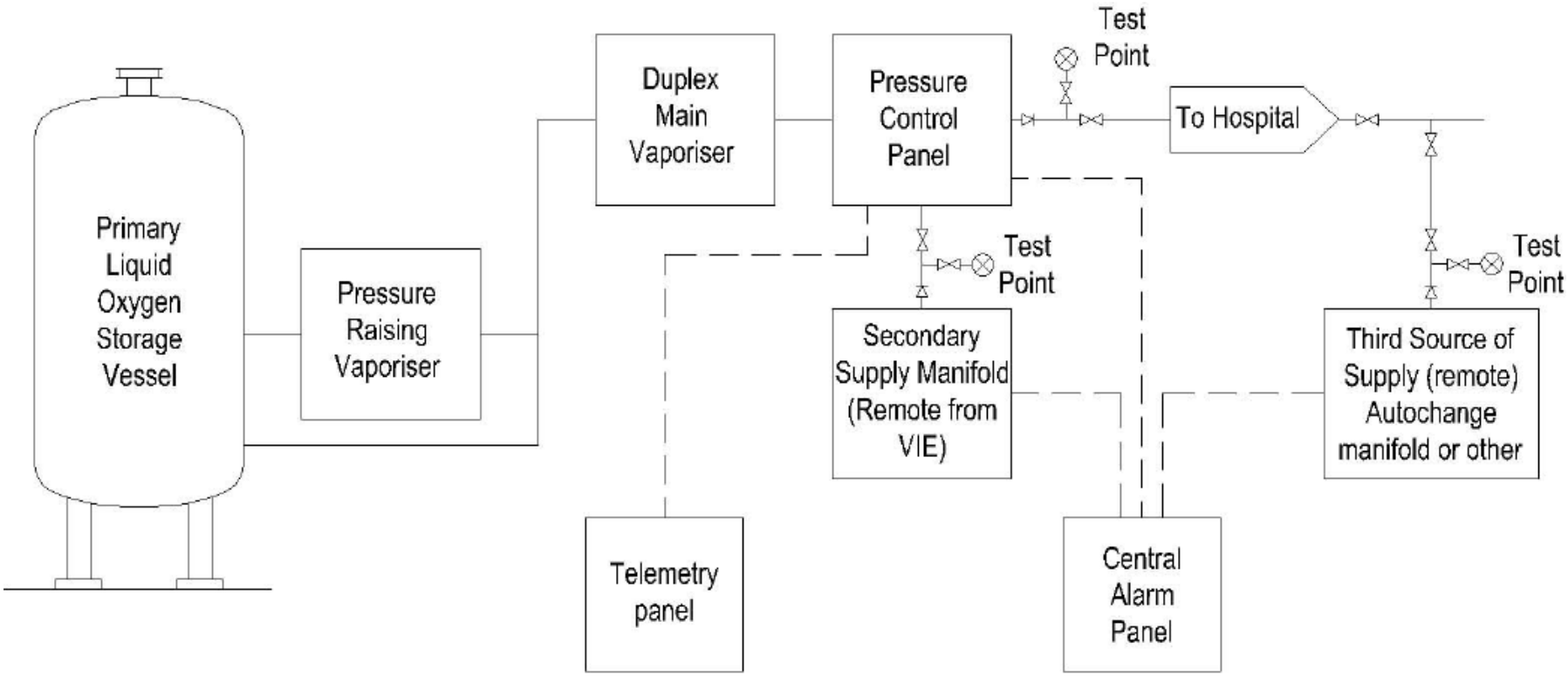


Figure 18: Primary supply VIE system with secondary supply compressed gas cylinder manifold

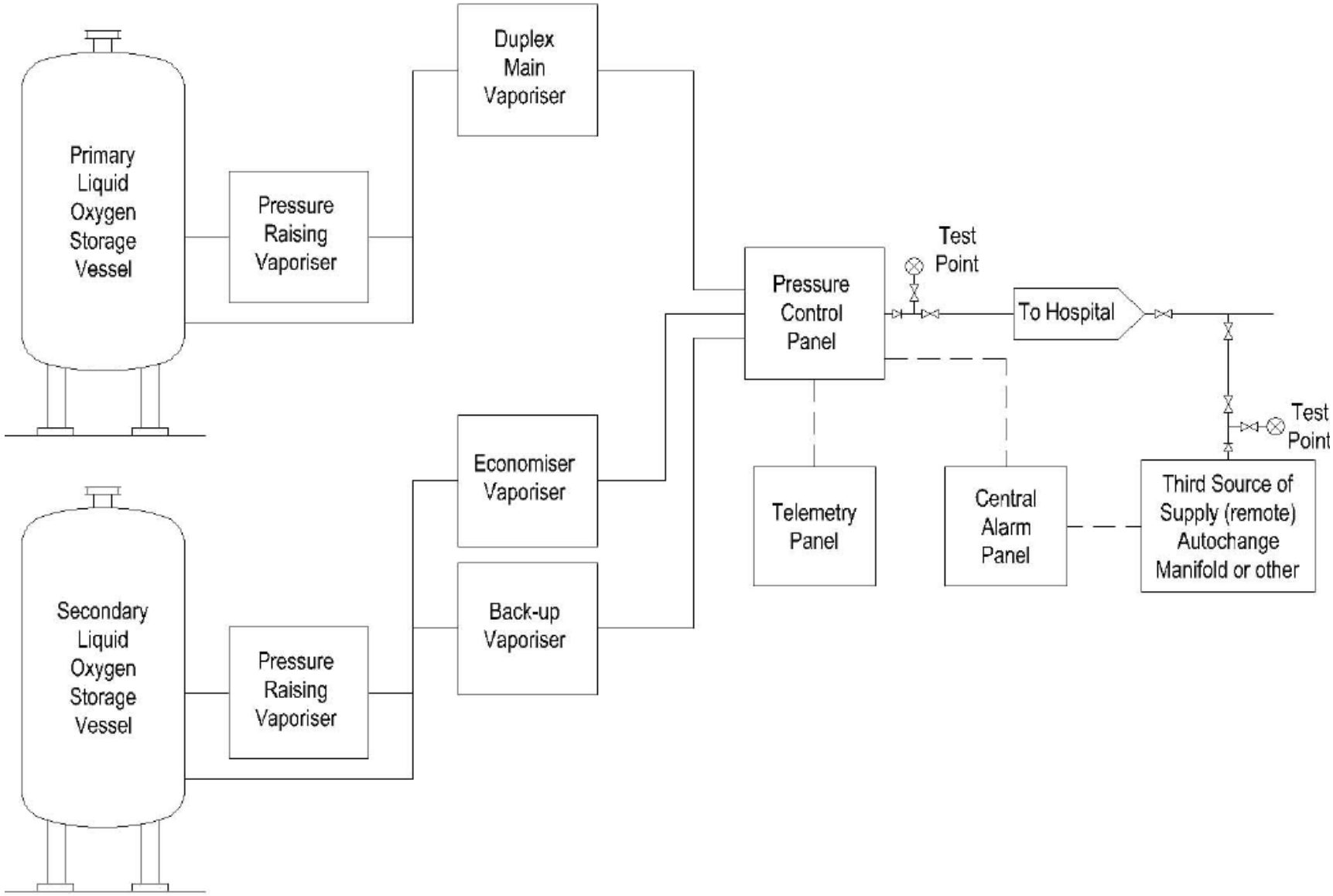


Figure 19: Primary and secondary supply VIE system on single plinth with remote third source supply compressed gas cylinder manifold

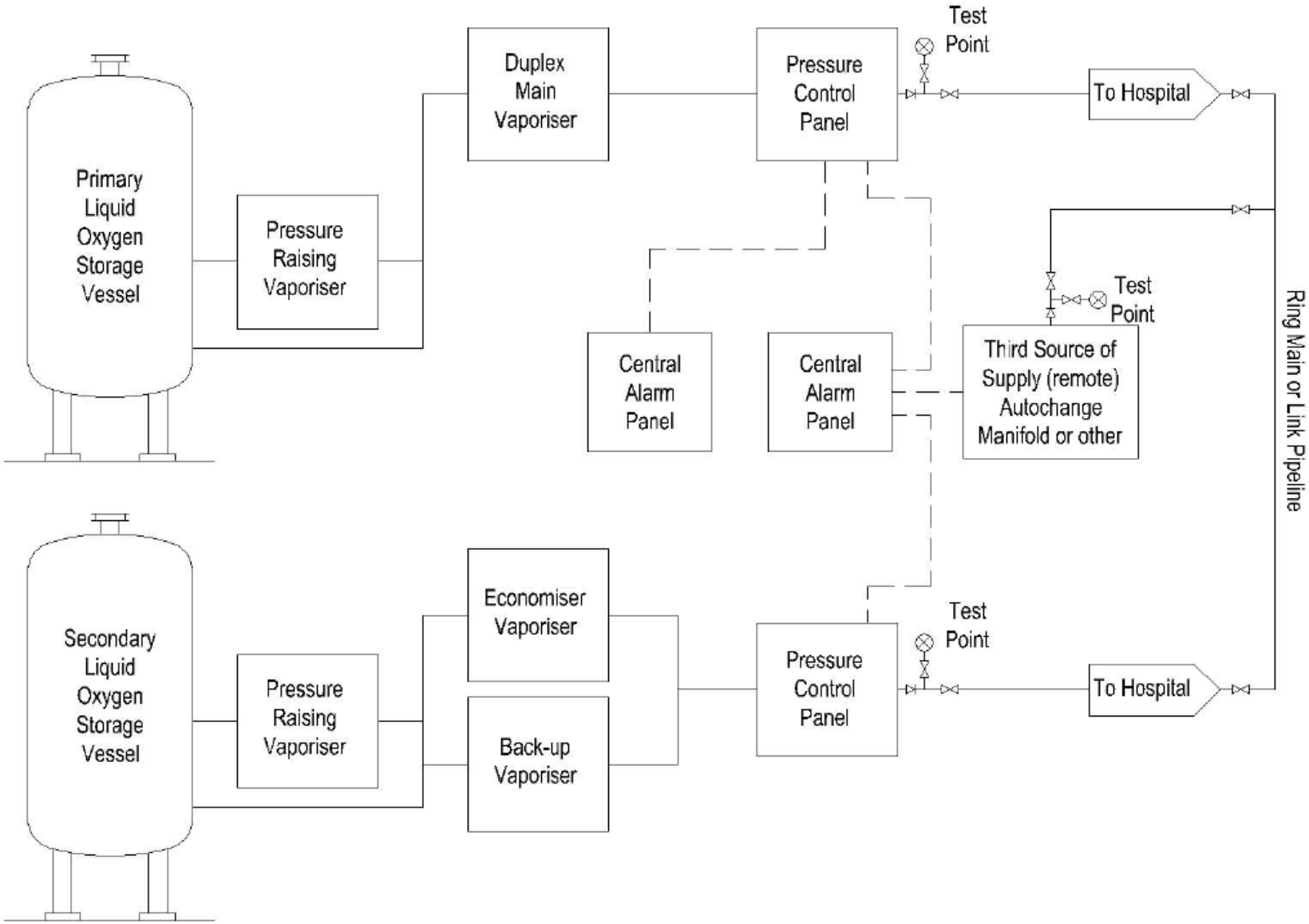


Figure 20: Primary and secondary supply VIE system on separate plinths with remote third source supply compressed gas cylinder manifold

Liquid cylinder systems

Plant

6.67 Liquid cylinder systems can also be used to store the medical gas as a liquid at cryogenic temperatures and to vaporise it into a gas for patient use. These systems are used where the demand is too high for compressed gas cylinders to be a practicable option but where it is neither economic nor possible to supply bulk medical liquid oxygen in a VIE system.

6.68 Liquid cylinders are constructed in a similar way to vacuum insulated cryogenic storage units, that is, as double-walled vessels. However, unlike the VIE, the liquid cylinder has an internal vaporiser coil to convert the liquid into a gas.

6.69 The size of the liquid cylinder can vary between 200 litres and 1,000 litres water capacity. To obtain sufficient storage capacity and to meet the hospital's flow requirements, a number of liquid cylinders can be connected together via a manifold.

6.70 The liquid cylinder system consists of:

- a number of vacuum insulated liquid cylinders;
- a system to manifold the liquid cylinders together to store sufficient liquid on site to meet the hospital's demand;
- control equipment to regulate the pressure and flow of gas to the pipeline.

6.71 Although liquid cylinders are suitable for transportation when full, they are normally installed as a fixed installation and remotely filled whilst in situ.

6.72 Liquid cylinders are designed and supplied with gas-specific liquid-fill and gas-use connections (including the connection on the remote liquid-fill connection where the liquid cylinders are filled in situ).

6.73 The connections used are:

- liquid fill: CGA 440;
- gas use: ISO 5145.

Siting

6.74 Where there is no alternative, a liquid cylinder manifold may be installed in a building or confined area, but only if the vent header (to which all liquid cylinder vents will be connected) is piped to a safe area via a back-pressure control valve. This valve should be set at a pressure below that of the liquid cylinder relief valve setting, thus ensuring that any excess pressure is safely vented.

6.75 Where installed in buildings, generous ventilation should be provided by means of fully-louvred access doors to the outside. Additional protection of supply and extract ventilation controlled by oxygen monitoring equipment should be

considered. Further guidance on ventilation requirements is given in BCGA CoP No. 4. The appropriate calculation must be made to ensure adequate ventilation, especially during the filling of the vessels, when they may be venting freely to atmosphere inside the manifold room.

6.76 A P&ID of the plant should be displayed clearly to indicate the appropriate valves necessary to operate the plant safely. The Authorised Person (MGPS) and others in the hospital who may work with the VIE system should be made aware of its general operating principles by the medical gas supplier. (Figure 21 shows a typical liquid cylinder manifold installation with cylinder backup.)

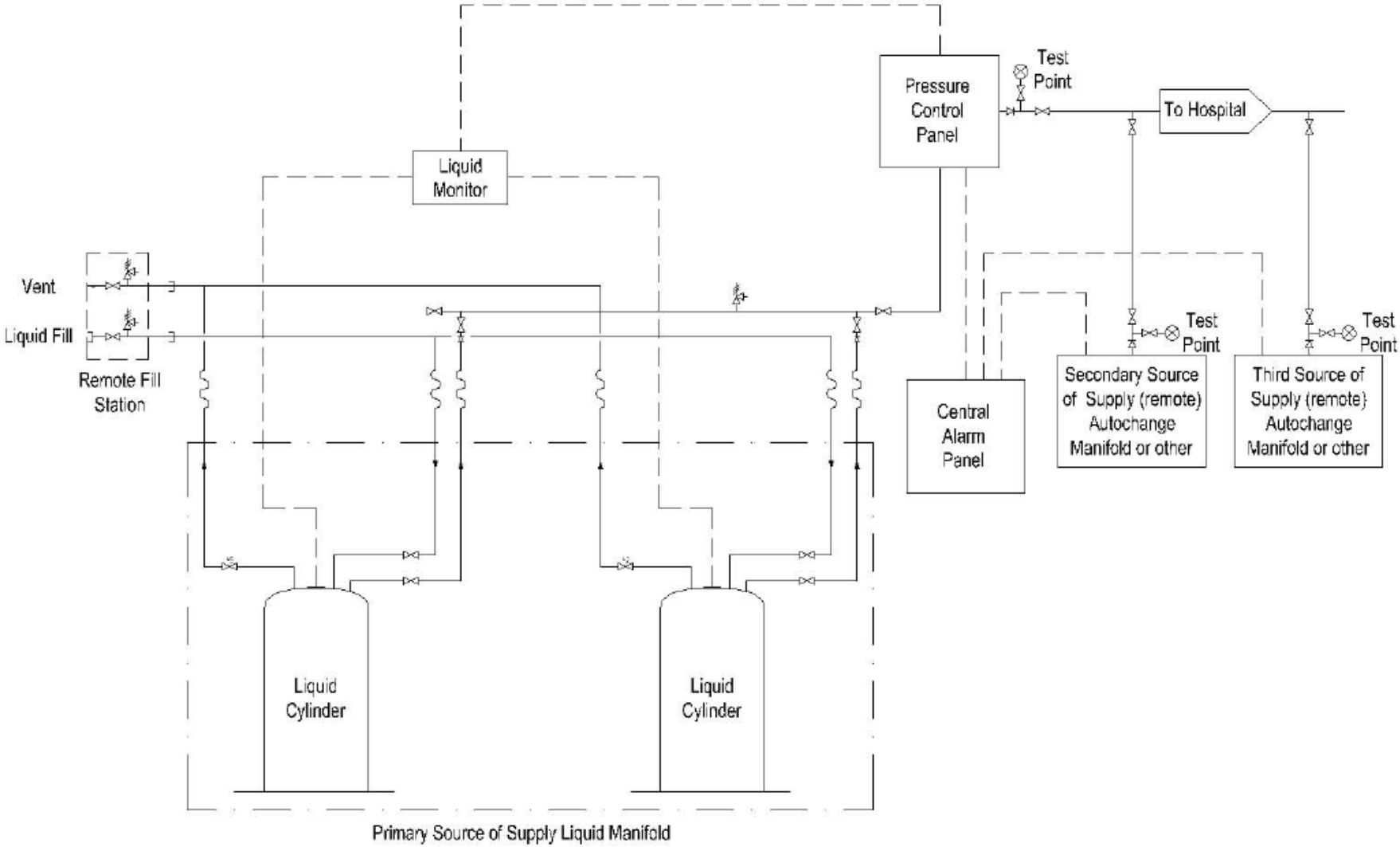


Figure 21: Typical primary liquid cylinder manifold installation with remote secondary supply source compressed gas cylinder manifold and remote third source supply

Compressed gas cylinder manifolds

6.77 The simplest supply system to provide medical oxygen to a hospital pipeline system utilises compressed gas cylinders, connected together on an auto-changeover manifold. As the demand increases, the number of cylinders fitted to the manifold can be increased to meet the hospital's requirements. The third or reserve supply for this system will usually be a manual changeover compressed gas cylinder manifold, which comes on line automatically (via a non-return valve) in the event of primary manifold failure.

6.78 For a full description of manifold supply systems, see Section 5.

Secondary supply systems

6.79 Where the primary supply system is a VIE, the secondary supply system can be either:

- another VIE; or
- a liquid cylinder manifold; or
- a fully-automatic compressed gas cylinder manifold.

6.80 Where the primary supply system is a liquid cylinder system, the secondary supply system should be a fully automatic changeover gas cylinder manifold that comes into operation automatically.

6.81 There should be a system of backflow prevention to protect either system venting through the other in the event of a single fault in either system.

6.82 Where the secondary supply is fed from compressed gas cylinders, the size of the changeover manifold and the number of cylinders stored on site should be based on the gas supplier's ability to guarantee a delivery service within a defined period.

6.83 Where a liquid oxygen system is used for the secondary supply, the system design should allow any liquid oxygen that has boiled off to be fed to the pipeline system to utilise product.

6.84 Where the feed from the VIE compound to the hospital extends a long distance, or is exposed to potential mechanical damage, particular importance should be given to siting the secondary supply system remotely from the main VIE compound with a separate supply to the hospital pipeline system. In all instances where pipelines cannot be inspected throughout their length, twin pipelines in separate ducts and suitably valved to permit pressure testing whilst maintaining the service should be provided.

6.85 Where the secondary supply is sited remotely, consideration should also be given to the set point of the secondary supply output regulator to ensure that the pipeline dynamic pressure is maintained at a minimum level of 420 kPa. Where a proposal is raised to consider the remote siting of the secondary supply the risk assessment, in consultation with the suppliers, must consider the changes

from a proved but simple control system that would be required to maintain a control link between primary and secondary panels and the requirement of the secondary supply economiser circuit, unless both primary and secondary VIEs on remote sites are served by a common panel or a back-up service is available on each site.

6.86 When the vessels are located on separate sites, a backflow prevention device must be fitted on each leg feeding into the pipeline system. This will prevent loss of product, either from the other vessel or from the hospital pipeline, in the event of failure of or damage to a VIE unit or its feed into the hospital pipeline. The backflow protection should be sited in a secure location where it is not liable to mechanical damage and be as close to the hospital curtilage as possible.

Emergency supply provision

6.87 In the event of total plant and/or main pipeline failure, an emergency supply of oxygen should be available for patient use.

6.88 The emergency supply system should be activated automatically when the primary and secondary system is empty or fails to supply or when the hospital pipeline pressure falls below 375 kPa. It must have the provision to prevent the automatic backflow of medical oxygen into the remainder of the pipeline system should the pipeline fail upstream of the connection.

6.89 A variety of sources are available for the provision of emergency oxygen, and these are detailed in paragraphs 6.96 – 6.105.

6.90 Under most conditions, compressed gas cylinders are the appropriate method of providing an emergency supply source.

6.91 The size and design of the emergency supply system should allow for cylinders to be changed whilst maintaining the emergency supply.

6.92 Where the emergency supply serves the hospital distribution system, the set point of the regulator should be 375 kPa to ensure that the plant low pressure alarm normally set at 385 kPa is activated thus providing warning of plant failure.

Emergency / maintenance inlet ports

6.93 Emergency / maintenance inlet ports are covered in Section 13. In some instances, installation of a fixed manifold system will obviate the need for fitting an emergency inlet port.

6.94 In smaller installations, fitting an emergency inlet port may be dispensed with if the risk analysis indicates that adequate supplies can be maintained via the NIST connectors of AVSUs supplying critical care areas.

6.95 When planning emergency provision for a complete system, vulnerability of the primary and secondary supplies will be a critical factor in determining both the type and the means of supply.

Fixed automatic/manual manifold systems

6.96 Where two VIE units on the same plinth are in use, the emergency supply system should comprise a fully automatic cylinder manifold permanently connected to (one of) the main oxygen riser(s) in the hospital, or directly into a ring-main system. It must be able to feed a riser automatically (without back-feeding to any damaged upstream section) on failure of both primary and secondary plant, or the MGPS upstream of the entry into the hospital. Such an arrangement is particularly suited to situations in which the main feed from the VIE installation to the hospital pipeline is vulnerable to mechanical damage, for example when buried under a roadway. The location and size of the manifold should be determined by the risk assessment and according to the dependency of the patients.

6.97 When two separately sited VIE units are used to provide the hospital supply, the need for emergency manifold provision should be assessed against the likelihood of failure of both VIE systems and their respective feeds into the hospital pipeline.

6.98 Where it can be shown through risk assessment that one or both units are fed into the hospital pipeline in a manner such that the probability of disruption of one or both of the feeds is negligible, the option to waive the fitting of further (manifold) supplies can be considered.

Local manifold provision (critical care areas)

6.99 To offer additional protection against the possibility of a pipeline failure within the hospital, further (manual or automatic) manifolds can be permanently connected, via non-return valves, downstream of AVSUs controlling high-dependency areas. Such units should come on line automatically on failure of the main supply to an AVSU. A further non-return valve must also be added upstream of the AVSU to prevent back-feeding into a failed main supply system.

6.100 The positioning of these manifolds is very important to ensure that the critical care/high dependency areas defined in the risk assessment process have adequate stocks of medical oxygen available in the event of a system failure. However, the risk analysis for the complete system may indicate that the probability of use of such a manifold system is negligible, or that the circumstances causing the system failure would in any event require the evacuation of the area.

6.101 Availability of accommodation, staff and manual handling issues would also need to be considered during the risk assessment process. Where space limitations prevent the installation of such manifolds, the implications of providing discrete cylinder/regulator combinations must be considered.

Gas feed via an AVSU (or terminal unit)

6.102 Oxygen supply to the downstream side of an AVSU (with the valve closed) may be achieved using an “emergency supply kit” consisting of two cylinder regulators and associated supply hoses with gas-specific connectors.

6.103 Such an arrangement may be used to support high-dependency departments, albeit the unit will usually be of limited capacity by comparison to a fixed automatic manifold system.

6.104 Storage, maintenance, testing, security and deployment arrangements for the emergency supply kits must be documented in the MGPS operational policy.

Discrete cylinder supplies

6.105 For non-critical care areas where there are no high-dependency patients, it may be appropriate to use individual cylinders as the reserve source of supply. Cylinders fitted with integral valves and having a product-specific terminal unit outlet are suitable for this purpose. The difficulties associated with storing, testing, maintaining, distributing and connecting large numbers of such equipment must not be underestimated. (Such protocols should be referenced in the MGPS operational policy).

Alarm systems

6.106 Installations of the following type should be fitted with alarm systems to provide visual and audible warnings at the plant (each site) and in a 24 hour manned station with slave panels as required for the following conditions. Variations to supply mode are:

- dual VIE vessels on a common site or separate sites feeding into a single control panel; or
- dual VIE vessels on separate sites each with independent control panels;
- single VIE vessel supported by a liquid cylinder secondary supply; or
- single VIE vessel supported by a fully automatic compressed gas cylinder manifold.

The following displays should be presented at the plant and in a 24-hour-staffed position.

Status/fault condition	Indication	Legend
Normal operation System available for use	Green	Normal
Primary supply system's operational stock empty Primary supply system's reserve stock in use	Yellow	Refill liquid
Primary supply system's reserve stock empty Secondary supply system in use	Yellow	Refill liquid immediately
Secondary supply system empty Emergency system in use	Yellow	Emergency supply in use
Pipeline pressure high or low	Red	Pressure fault

Table 26: Oxygen plant alarm conditions

6.107 It is not considered advisable that a single VIE in a remote location has no local back-up – refer to paragraph 6.85. Where the third source of supply is a liquid cylinder or fully automatic cylinder manifold serving separate or singular part(s) of the pipeline system the alarm displayed at the liquid cylinder or manifold and the 24 hour manned station will be independent of the primary and secondary sources of supply but similar to the alarm conditions 1, 2 & 4 laid out in paragraph 6.106 and Table 26. Where the assessment process considered that an additional emergency service manifold is advisable in event of maintenance requirements, alarm condition 3 would apply.

At the primary vessel and a 24-hour-manned position		
Status/fault condition	**Indication**	**Legend**
Normal operation System available for use	Green	Normal
Primary supply system's operational stock empty Primary supply system reserve stock in use	Yellow	Refill liquid
Primary supply system's reserve stock empty Secondary supply system in use	Yellow	Refill liquid immediately
Secondary supply system low	Yellow	Secondary stock low
Pipeline pressure high or low	Red	Pressure fault

Table 27: Oxygen central plant alarm conditions (primary supply)

6.108 When the primary system operational stock has been exhausted and the vessel contents reach the reserve stock level, the first alarm condition will be indicated by a yellow alarm and the legend "refill liquid" illuminated.

6.109 When the primary system reserve stock is empty and the secondary supply system is in operation, the second alarm condition will be indicated by a yellow alarm and the legend "refill liquid immediately" illuminated. This alarm condition continues until the primary supply system is refilled.

6.110 When the secondary supply system is low, the third alarm condition will be indicated by a yellow alarm and the legend "secondary stock low" illuminated. This alarm condition continues until the secondary supply system is refilled or the cylinders are replaced.

6.111 Should the primary supply of medical oxygen to the hospital pipeline fail due to lack of contents or mechanical failure of any of the components, or should a serious leak occur, the pipeline pressure will fall. When the plant output pipeline pressure falls below 385 kPa, the condition will be indicated by the "pressure fault" alarm.

6.112 If the regulator controlling the pipeline pressure should fail "open", the pipeline pressure will rise. This condition will be indicated by the "pressure fault" alarm when the pressure rises above 500 kPa.

At the secondary vessel/liquid cylinder supply/cylinder manifold and a 24-hour-staffed position		
Status/fault condition	**Indication**	**Legend**
Normal operation System available for use	Green	Normal
Secondary supply system's operational stock empty Secondary supply system's reserve stock in use	Yellow	Refill liquid / change cylinders
Secondary supply system's reserve stock empty Emergency supply system in use	Yellow	Emergency supply in use
Pipeline pressure high or low	Red	Pressure fault

Table 28: Oxygen central plant alarm conditions (secondary supply)

6.113 With a correctly installed and commissioned system where the three sources of supply are serving the full hospital distribution system, in the event of a loss of primary and secondary pressure the plant low pressure alarm condition of 385 kPa will be activated with the third source of supply continuing to supply the hospital at 375 kPa. With primary and secondary sources empty, all alarms on both plant and the 24 hour manned station will be activated. In a fault condition the degree of alarm should assist in identifying the problem. The third source should be clearly identified on the alarm panel as the oxygen emergency supply and recognised of having limited capacity. The Operational Policy document emergency procedures should normally ensure corrective action is taken at the first stages of alarm to ensure continuity of supply by arranging a liquid delivery or identify and rectify a fault condition.

6.114 Where the emergency supply is installed on individual zones of the pipeline system, the "emergency supply in use" alarm must be displayed within the pipeline zone area. A separate "emergency supply low" alarm should also be installed on each zone.

6.115 Where more than one VIE is used and the operational and reserve stock is distributed between multiple vessels, a lit "normal" display indicates that the vessel is available for use.

6.116 In the event that the primary (or secondary) vessel should become empty (or suffer from any other fault condition), the "normal" display should be extinguished, indicating that the vessel is not available for use.

6.117 Alarm conditions should be transmitted to the central alarm system.

6.118 Where relays are used, they should be energised relays that de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA. Alternatively, Volt-free, normally closed contacts rated at 50 V d.c. and 50 mA should be provided for transmission of the conditions to the alarm system.

6.119 Typical alarm trigger points are shown in Figures 12 – 17.

Determining system size through risk assessment

Introduction

6.120 The 2001 edition of Scottish Health Technical Memorandum 2022 defined a (fixed) VIE primary vessel capacity of 14 days' oxygen supply but did not define capacity for a liquid cylinder system. This section addresses the risk factors associated with the supply of oxygen on a hospital site and, with the aid of defined risk criteria, offers guidance on the sizing of VIE, liquid cylinder and compressed gas cylinder manifold installations for any specified location.

6.121 The risk assessment should take into account all issues concerning the safety and continuity of the medical oxygen supply. It is suggested that identified risk factors and criteria be evaluated using both qualitative and quantitative measures, and that all results be recorded in a logical manner that will support the decisions being made. The record of the risk assessment will also act as a reference document when the system is reviewed.

6.123 Additional local factors and requirements identified by the project team will also need to be considered when carrying out the risk assessment to take account of site-specific issues concerning how the product is stored, distributed and used.

6.124 Any risk control procedures identified by the risk assessment process which are designed to minimise any identified risks must be recorded and incorporated into the relevant hospital standard operating procedures (SOP) or work instructions (WI).

6.125 When sizing the vessels and cylinder manifolds to provide adequate storage of medical oxygen on site, the stock should be distributed between the three sources of supply as defined in BS EN 737-3: 2000 / BS EN 1SO 7396-1: 2007 + A2: 2010; that is, the medical oxygen supply system should normally consist of:

- a primary supply;
- a secondary supply;
- emergency third or reserve supply.

6.126 The capacity of the primary and secondary supply system will consist of:

- operational stock;
- reserve stock.

6.127 The operational stock is the volume of product that the gas supplier uses to manage deliveries to the hospital, and its exhaustion signals the point at which the vessel should be refilled under normal conditions.

6.128 The reserve stock is the volume of product that is used to provide additional stock, to take account of fluctuations in demand, or when the supplier fails to make a scheduled delivery.

6.129 The system should be designed so that the primary and secondary supply system stocks are kept separate from each other. Under no circumstances can the primary supply system operational stock be stored in the secondary supply system vessel.

6.130 However, where it is not possible to install a single large VIE vessel for the primary supply (such as where planning permission restrictions prevent the use of a single large vessel), it may be appropriate to hold all or some of the primary supply system reserve stock in the secondary supply vessel. Under these circumstances the primary supply vessel should retain a minimum level when changing over to the secondary supply system. The volume retained in the primary supply vessel should equate to the secondary supply system reserve stock. This should provide adequate stock on site to enable the gas supplier to resupply product to the primary vessel in the event of failure of the secondary supply. This level should be determined by the risk assessment process but should be at least one day's usable stock.

Review of risk assessment

6.131 The documented risk assessment should be reviewed after the installation is complete, prior to commissioning, to assess whether any parameters or circumstances have changed since the initial assessment. The risk assessment must also be reviewed at least annually (or when there is any significant change to the medical oxygen supply system or usage pattern) to ensure that the details are current. At this review, all changes should be considered that might have an effect on the safety of the system or the security of supply.

Sizing plant – general

VIE installations

6.132 The operational and reserve stock for each supply system should normally be held in the same vessel. Where planning restrictions prevent the use of a single large vessel on site, it may be appropriate to utilise multiple vessels to provide adequate stocks on site.

6.133 When sizing VIE systems for the primary or secondary supply, the vessel size will be determined by adding the operational and reserve stock together and allowing for the level of unusable stock left in the vessel when the designed flow rate cannot be maintained.

Liquid cylinder installations

6.134 For liquid cylinder installations, the primary system should be made up of a number of liquid cylinders connected together by a manifold. The secondary system will comprise an automatic compressed gas cylinder manifold system.

6.135 Each liquid cylinder will have a maximum design flow rate for continuous use. The number of liquid cylinders required for an installation may be governed by either the maximum storage capacity required on site or the flow rate required to meet the hospital's maximum demand.

6.136 When determining the number and size of liquid cylinders required for either a primary or a secondary supply to a VIE, an allowance has to be made for the unusable capacity of each cylinder when connected to the manifold system.

Compressed gas cylinder manifold systems

6.137 Where the hospital does not warrant a liquid oxygen system, an automatic cylinder manifold should be considered. This should be sited to facilitate future extension of the manifold banks.

6.138 The reserve supply will normally comprise a manually operated manifold system, connected such that it will come on line automatically (via a non-return valve) in the event of failure of the primary and secondary supply.

6.139 For sizing compressed gas cylinder systems, the size of the manifold will normally be determined by the ability of the hospital to provide adequately trained staff to change over cylinders quickly enough to meet the demand.

The risk assessment process

Risk assessment for management responsibilities

6.140 The risk assessment criteria, when considering management responsibilities for the medical liquid oxygen system, need to include the following:

- the need to document and agree responsibilities for the monitoring of the medical liquid oxygen VIE, and the need to establish a back-up procedure with the gas supplier to ensure that adequate stocks will be maintained in the event of a failure of the fitted telemetry system;
- the hospital should set up procedures to ensure that the VIE system is monitored at regular intervals for any deviation from normal operation (such as safety valves lifting, major leaks, or failure of either the telemetry or alarm system);
- the implications of any decisions to not fit telemetry or to utilise a vessel, or vessels, that do not provide adequate operational and reserve stocks. These decisions should be taken at an appropriate level of management, should be documented, and their implications should be considered as part of the risk assessment;
- consideration of the resources needed to maintain adequate supplies of medical oxygen either under normal, or emergency, conditions. When evaluating these requirements, consideration should be given to the risks that the healthcare organisation would face in the event of supply failure causing disruption of clinical services;
- consideration of the operational management consequences of using different suppliers to supply medical oxygen to different supply systems supporting the same pipeline installation. Any contracts involving different suppliers should clearly state the obligations and limitations of liabilities.

6.141 Where manifolds are used, adequately trained staff should be available, whenever required, to ensure continuity of supply. Consideration also needs to

be given to the manual handling issues concerned with changing cylinders on the manifold and arrangements to store adequate stocks to meet demands.

6.142 Consideration needs to be given to the type of clinical activities carried out in each area of the hospital and the ability to provide emergency back-up to individual areas used for critical care, or within high dependency units.

Initial risk assessment for siting of plant

6.143 The initial risk assessment should consider the requirements to ensure a continuous supply of medical gas to the patient.

6.144 The initial risk assessment criteria related to the complete installation should include:

- the size and location of each source of supply (for example the volume held as operational and reserve stock for each source of supply, located on one site or two independent sites);
- the associated risks with siting tanks at either the same or separate locations (for example physical space availability, accessibility for delivery and maintenance requirements, accessibility to the pipeline system [to tie-in points etc], alarm systems and cabling, pipeline routing and protection);
- the need to site the reserve sources of supply local to the point of use to protect against pipeline failure where high-dependency patients are located;
- safety requirements for the storage of oxygen on site, including compliance with the safety distances specified in BCGA CP19;
- the location and extent of the medical oxygen pipeline system;
- the vulnerability of the hospital pipeline to mechanical damage and whether underground sections of the pipeline system comply with the requirements of this Scottish Health Technical Memorandum and whether the pipeline is capable of being inspected throughout its entire length or pressure tested (whilst maintaining the supply), or otherwise can be tested;
- the space available for the liquid oxygen installation, or cylinder manifold, and the available access for the delivery vehicle;
- the vulnerability of the site to external damage;
- the possibility of interference with the supply system or other security issues.

Risk assessment for sizing of operational stock

6.145 The risk assessment criteria for the sizing of the operational stock should include:

- the average daily demand at the end of the contract period. Any changes to the predicted growth of demand will need to be considered, and changes made to the vessel size or delivery frequency at the appropriate time within the contract period. It may be beneficial to set a daily demand rate at which changes to vessel size or delivery frequency will be considered;

- a review of vehicular access to the VIE, timing of the deliveries, any restrictions due to local planning requirements, and the effect of these factors on the delivery frequency;
- an environmental impact assessment.

Risk assessment for sizing of reserve stock

6.146 The risk assessment criteria for the sizing of the reserve stock should include:

- the average daily demand at the end of the contract period. Any changes to the predicted growth of demand will need to be considered, and changes made to the vessel size or delivery frequency at the appropriate time within the contract period. It may be beneficial to set a daily demand rate at which changes to vessel size or delivery frequency will be considered;
- the delivery frequency guaranteed by the gas supplier that can be provided at short notice should the primary supply system fail;
- the minimum response time from when the primary supply system fails to when the delivery vehicle could be on site to refill the secondary supply VIE, or to provide replacement compressed gas cylinders for the manifold.

Risk assessment for the provision of emergency supply systems

6.147 The risk assessment criteria concerning emergency supply systems should include:

- the need for installation of independent emergency supplies to zones on the medical gas pipeline supplying critical care areas or wards or departments that are remote or vulnerable to interruption;
- the positioning of the manifold to ensure ease of changeover of cylinders with respect to access and manual handling issues;
- the storage of cylinders associated with the emergency manifold to ensure compliance with the appropriate codes of practice and local hospital requirements;
- training requirements for both the relevant clinical and operational staff to ensure correct operation of the emergency supply system.

Stock calculations

Calculation of operational stock for primary and secondary supplies

6.148 The capacity of the operational stock of primary and secondary supply systems should be agreed with the gas supplier and based on the following parameters:

- the current average medical oxygen daily demand, plus any natural growth over the contract period;
- any additional planned growth (above any natural growth) in the usage pattern within the contract period;

- the agreed delivery frequency.

6.149 The current average daily demand can be calculated by dividing the current annual consumption by 365 days.

6.150 The operational stock should be based on an average daily demand predicted for the end of the contract period calculated by:

Average daily demand = Current daily demand + Planned growth + Natural growth.

6.151 The operational stock is calculated as:

Operational stock = Average daily demand x Agreed delivery period.

6.152 If there is significant growth in average daily demand within the contract period, either the vessel should be resized or the agreed delivery frequency should be reviewed to reduce the delivery period and maintain the operational stock level.

6.153 The delivery period for the primary supply will be based on the gas supplier's normal delivery frequency.

6.154 The delivery period for the secondary supply will be based on emergency conditions when the primary supply is not available. Under these circumstances, special delivery response times must be agreed with the gas supplier.

6.155 The supply agreement should commit the supplier to manage the operational stock, based on an agreed delivery frequency and the minimum stock level to be maintained in the vessel.

Calculation of primary reserve stock

6.156 Table 29 provides a matrix for the calculation of primary reserve stock based upon distance from gas supplier and fitting of telemetry.

Kilometres from gas supply depot	No telemetry (no of days' stock)	Telemetry fitted (no of days' stock)
Up to 75	5	3
75-150	6	4
150-300	7	5
Over 300	8	6

Table 29: Requirement for remote indication for stock levels

Calculation of secondary reserve stock

6.157 The minimum level for reserve stock for the secondary supply should allow for circumstances in which the primary supply system is not available for use.

6.158 This secondary supply system reserve stock level will be dependent on:

- the proximity of the supplier's distribution depot;

- the response time that the gas supplier needs to make a delivery under these conditions;
- the delivery frequency that can be sustained under the conditions when the primary supply is unavailable for use.

Calculation of capacity of emergency supply systems (VIE and cylinder manifolds)

6.159 Where an existing hospital VIE acts as an emergency third source of supply to a new hospital installation, the minimum supply available to both hospitals should be in accordance with the suggested stock levels detailed in Table 29, above. The number of cylinders stored locally to the emergency supply system manifold and the number of connections on the manifold(s) should be determined by risk assessment.

6.160 When determining these requirements, the risk assessment needs to consider:

- the maximum demand from the high dependency patients who may be supplied from the pipeline zone that the emergency supply system protects;
- the maximum duration for which the emergency state is likely to last;
- the proximity of the supplier of the compressed cylinders to the hospital;
- the ability of the hospital to connect cylinders to the manifold.

6.161 Consideration needs to be given to the logistics of storing and handling the number of cylinders needed to provide adequate supplies until the primary/secondary supply systems or the hospital pipeline can be re-established.

Oxygen concentrator installations (PSA plant)

General

6.162 Oxygen concentrators or pressure swing adsorber (PSA) systems may be alternatives to the more traditional supply systems (the terms ‘oxygen concentrator’ and ‘PSA’ are interchangeable). Typical installations where PSA systems should be considered are those sites having no access to reliable liquid supplies, such as remote or off-shore locations, or where the safety criteria for a bulk liquid vessel cannot be met (for example, very restricted sites). Otherwise, PSA systems should only be installed when an investment appraisal shows them to be economical.

6.163 When installed, a PSA system will deliver product gas via the “oxygen” pipeline system.

6.164 Oxygen concentrators operate by adsorbing, under pressure, other gases in the atmosphere onto materials which have specific physico-chemical properties, thus freeing the oxygen which is stored and transmitting it for use. The adsorbents are known as artificial zeolites, more commonly referred to as molecular sieves. The sieve units are arranged in pairs, one adsorbing whilst

the other regenerates. The waste product, essentially nitrogen, is discharged to atmosphere during regeneration of the adsorbents. In some systems, the use of vacuum to remove the nitrogen increases the efficiency of the regeneration/adsorption process. Regeneration requires the use of a small proportion of the product gas.

6.165 The PSA process has reached a high level of technical sophistication and is capable of producing oxygen with a concentration of about 95%. (For the UK the minimum level, below which the emergency/reserve manifold will come into operation, is 94%.) The remainder is mainly argon with some nitrogen. The highest concentration is not likely to exceed 97/98%, except when the emergency/reserve manifold is in use, when it will be 100% if these are from a gas supplier.

6.166 The major components of a PSA system and their layout are shown in Figure 22. The typical major components of the system are the compressors, receiver(s), dryers, molecular sieves, vacuum pumps, filters and regulators. Other components are identical to those used for medical air and vacuum plant, which are described fully in the appropriate sections. A suitable operating and indicating system is also required, as specified below. Package supply systems, which should be specified to meet the requirements given in this memorandum, are available from manufacturers.

Note 19: Reference should be made to BS7634: 1993 / ISO 10083: 1992 for further guidance.

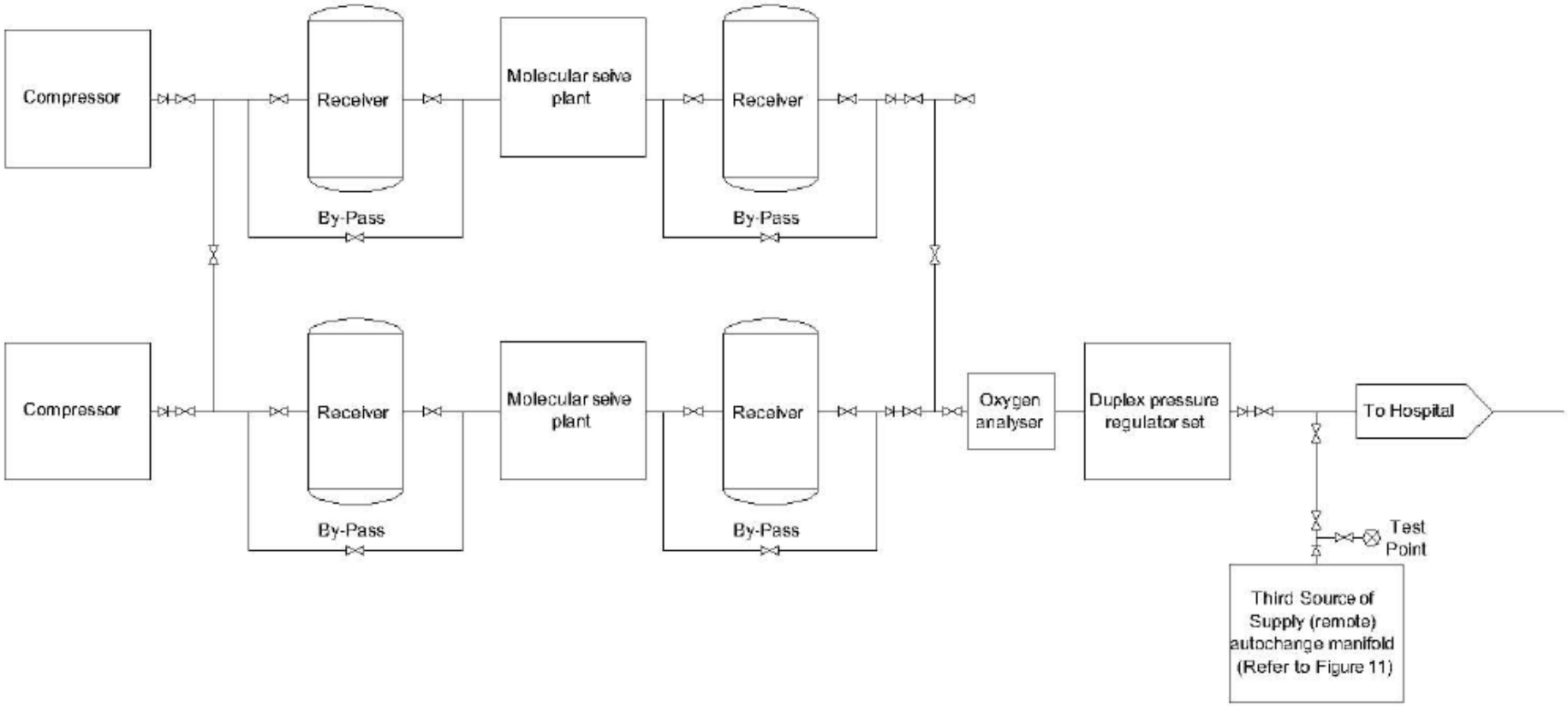


Figure 22: Schematic diagram of a typical PSA installation

Siting

6.167 The plant should have all-round access for maintenance purposes, and allowance should be made for changing major components.

6.168 The siting of the plant should allow for adequate flows of air for three different purposes:

- air intake to the compressors;
- cooling of the compressed air by the after-coolers;
- cooling of the compressors.

6.169 Each compressor may require ducting to ensure an adequate flow of cool air. The manufacturer should be consulted over the range of operating temperatures for which the system is designed. In extreme circumstances, refrigeration of the cooling air may need to be provided.

6.170 Air-inlet filters should be fitted either to the compressor inlet or at a suitable point in any ductwork. The filters should comply with BS ISO 5011: 2000 and be either dry medium filters or grade CA paper element filters.

Plant configuration

6.171 The plant should comprise:

- a duplex compressor – if more than two compressors are installed, the plant should provide the design flow with one compressor out of service;
- duplexed air treatment/molecular sieve devices, that is, two sets of filters and a pair of molecular sieves (one adsorbing whilst the other regenerates) and one vacuum pump (if required by the manufacturer).

Note 20: All duplexed components should be capable of independent operation.

Compressors and vacuum pumps

6.172 The compressors for the PSA systems may be any of the type recommended for compressed air systems. It is also possible to provide a combined medical air PSA plant. Generally, the compressed air requirement per litre of product gas is of the order 4:1; as a result the compressor plant will be on longer than that typically seen in hospitals.

6.173 A vacuum pump may be required as part of the system. The vacuum pump, if provided, is utilised during the adsorption/regeneration process. Vacuum pumps may be of any type as for the piped medical vacuum system. It will not generally be practicable to use water-sealed pumps or the medical vacuum plant.

Compressor and vacuum pump noise

6.174 The noise level produced by the compressors will increase with the capacity of the supply system. The maximum free-field noise level for un-silenced

compressed air plant, at 1m from the plant, varies with the type and power of the plant but should not normally exceed the following values:

Reciprocating	Screw	Vane	Power
85 dBA	76 dBA	76 dBA	7.5kW
89 dBA	78 dBA	76 dBA	7.6-15kW
93 dBA	80 dBA	79 dBA	15.1-22kW
97 dBA	92 dBA	90 dBA	22.1-60kW

Table 30: Compressor and vacuum pump noise ratings

6.175 In noise-sensitive areas, an acoustic enclosure should be included in the purchase specification for all compressors. Such an enclosure should produce a reduction of at least 10 dBA in the free-field noise level at 1m.

Molecular sieves

6.176 Duplex molecular sieves should be provided in pairs to permit continuous generation of oxygen. One of the pairs of duplex sieves will be in the adsorbing stage, whilst the other regenerates.

Dryers

6.177 Air dryers of the desiccant type are usually integrated within the molecular sieves and therefore do not regenerate independently. Refrigerant dryers may also be included.

Oxygen monitoring system

6.178 The plant should include a calibrated paramagnetic oxygen monitoring system comprising oxygen analyser, oxygen concentration indicator, oxygen flow monitor and oxygen concentration/flow recorder. Connections for calibration cylinders should also be provided. In the event of the concentration falling below 94%, the monitoring system should isolate the PSA system from the pipeline distribution system so that the emergency/reserve manifold operates. Additionally, an independent monitoring system should be provided to isolate the plant when the concentration falls below 94%. The second system need not be provided with a flow indicator or recorder.

Operating and indicating system

6.179 The operating and indicating system should perform the following functions, as appropriate:

- overall plant control and indication;
- individual compressor starting;
- individual vacuum pump starting (where fitted);
- control of dryers (where installed as a separate component);
- control of molecular sieves;
- plant status monitoring and indication;

- optional indication of the plant alarm status (this function may be considered to be part of the alarm system).

6.180 Provided that the individual compressor starters are housed in a separate compartment, these functions may be carried out by separate units or may be installed in a common panel and located on the plant or on the plantroom wall.

6.181 Control panels containing pneumatic components should have vents to permit release of pressure in the event of component failure. All functions and indicators should be appropriately identified and should have a design life of at least five years. The operating system should be capable of automatically restarting after reinstatement of the power supply.

6.182 All components of the PSA supply system should be connected to the essential electrical supply. The control system should ensure that compressors restart in sequence to avoid overloading the essential power supply.

Plant control unit

6.183 The plant control unit should have a separate power supply for each compressor and vacuum pump, controlled by a separate sub-circuit. The design should be such that no single component failure in the control unit will result in loss of plant output.

6.184 The unit should allow either manual selection of duty/stand-by for each of the compressors or have an automatic sequence selection with a means for manual override. The unit should ensure that two or more compressors do not start simultaneously when power is applied.

6.185 A warning notice that complies with BS5499-5: 2002 should be affixed which indicates the presence of low voltage.

6.186 A further warning notice indicating that the plant starts automatically should also be affixed near or on the plant.

6.187 Each compressor should have a selector switch which, when turned to the “on” position, allows the maximum and minimum pressure switches on the receiver to control the “on” and “off” loading of that compressor. An alternative “auto” position of the selector switch may allow automatic selection of the compressors.

Plant control indication

6.188 There should be indicators for each compressor as follows:

- green “mains supply on”;
- green “compressor called for”, which indicates that the compressor motor is electrically energised;
- an indicator of the pressure produced by the compressor.

Compressor and vacuum starter units

6.189 There should be individual starter units for each compressor and vacuum pump, which should include the features recommended for medical air compressor plants and vacuum plants respectively.

Molecular sieve control unit

6.190 The molecular sieve control unit may be mounted on the molecular sieve columns or may be located with the plant control unit. There should be separate power supplies for the “duty” and “stand-by” sieve assemblies, taken from the same phase.

6.191 The vacuum pump, if provided, forms part of the molecular sieve system.

6.192 The molecular sieve control unit should contain the following:

- a duty selector switch;
- an on/auto selector switch;
- individually-fused, separate cycling systems for each sieve pair;
- a system to control regeneration of the sieves in relation to pipeline demand;
- oxygen concentration, dryness and pressure sensors;
- an automatic changeover to the stand-by molecular sieve system, in the event of failure of the duty unit by oxygen concentration, dryness or pressure. This requires:
  - electrical and pneumatic isolation of the “duty” sub-assembly so that it is taken off-stream;
  - electrical and pneumatic energisation of the “stand-by” sub-assembly so that it is brought on-stream;
  - activation of the appropriate fault indicator and associated Volt-free contacts;
  - the sub-assembly to remain in this mode of operation until the fault has been rectified;
- green function indicators for each dryer sub-assembly to indicate:
  - molecular sieve 1 selected;
  - molecular sieve 2 selected;
  - selected molecular sieve – “normal”;
  - selected molecular sieve – “failed” (this fault indicator should remain until manually reset by means of a reset button);
- closure of all inlet, outlet, exhaust and purge valves.

Plant status monitoring

6.193 A monitoring system must be provided to detect the following faults in the air compressor system:

- plant faults (for each compressor):
  - control circuit failed;
  - overload tripped;
  - after-cooler temperature high;
  - compressor temperature high;
  - compressor run-up time too long;
  - activation of other safety devices supplied by the manufacturers.
- plant faults (for each molecular sieve unit):
  - control circuit failed;
  - “vacuum pump called for”;
  - overload tripped;
  - activation of any of the safety devices supplied by the manufacturer;
  - oxygen concentration failure;
  - pressure fault.
- plant emergency:
  - oxygen concentration failed at below 94% concentration;
  - receiver pressure 0.5 bar (gauge pressure) below the stand-by cut in pressure;
  - dryness above 67 ppm (–46°C at atmospheric pressure).
- pressure fault (cylinder reserve):
  - pressure in either bank below 50% (of normal cylinder pressure).
- pressure fault (pipeline):
  - low pipeline pressure;
  - high pipeline pressure.

Plant status indicator unit

6.194 In addition to the plant control indication, there should be a plant status indicator panel, which may be mounted on the plantroom wall or adjacent to either the compressor starter unit or the plant control unit. It should have a warning notice that complies with BS5499-5: 2002 to indicate the presence of low voltage.

6.195 There should be indicators for each compressor to show the following conditions:

a) green “mains supply on”;
b) yellow “control circuit failed”;
c) yellow “overload tripped”;
d) yellow “after-cooler temperature high”;
e) yellow “compressor temperature high”;
f) yellow for each individual safety device provided by the manufacturers;
g) yellow “compressor failure”.

6.196 There should be indicators for each molecular sieve dryer system to show the following:

a) green “mains supply on”;
b) yellow “oxygen concentration fault”;
c) yellow “pressure fault”;
d) yellow “dryness fault”.

When the stand-by dryer is in operation, conditions (b) and (c) in paragraph 6.195 should be transmitted as a plant emergency either to the alarm system or to the plant alarm signal status unit.

Alarm signal status unit

6.197 An alarm signal status unit should be provided as part of the control system. It should display the following conditions:

Indication	Legends
a. Green “normal”	Normal conditions
b. Yellow “plant fault”	Conditions (b)-(f) (see paragraph 6.195)
c. Yellow “plant emergency”	Conditions (b) or (c), or see conditions (g) (see paragraph 6.195)
d. Yellow “emergency supply low”	Emergency supply bank(s) low (<50%)
e. Red “pipeline pressure fault”	Pressure fault
f. Red “pipeline concentration below 94% O_2”	Oxygen concentration fault
Conditions (b) to (e) should be transmitted to the central alarm system.	

Table 31: Alarm signal status unit

6.198 Where relays are used, they should be normally energised relays, which de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA.

6.199 Alternatively, Volt-free, normally closed contacts rated at 5 V d.c. and 50 mA should be provided for transmission of conditions (b) to (e) to the alarm system.

6.200 The panel can be incorporated into the plant indicator unit, or be a separate unit within the plantroom. If mounted separately, the cabling should be monitored for open/short circuit. In the event of such a cabling fault, a red “system fault” lamp

should be illuminated on the alarm signal status unit, together with the appropriate alarm condition.

6.201 The alarm signal status unit should be supplied from all individual plant control units, or from a separate common supply.

Plant management

6.202 Connections should be provided that allow monitoring (but not control) of the plant operation. For example:

a) compressor – “on”, “off”, “on-load”, “unloaded”;

b) molecular sieves – “on” or “off”.

6.203 These connections should be used to provide input to the hospital building and energy management systems (BEMS).

7. Medical compressed air systems

General

7.1 Medical compressed air can be derived from compressor systems or by mixing gaseous oxygen and nitrogen from cryogenic liquid supply sources. Air produced by this latter method is referred to as synthetic air.

Compressor systems

7.2 Medical and surgical air can be provided from a single combined system or from separate plants. The choice ultimately depends on the relative consumption.

7.3 In the case of surgical air, consumption is at a high flow at a high pressure (up to 350 litres/min) but for relatively short periods of time (minutes); also, very small numbers of terminal units are in simultaneous use, typically fewer than five. Air for respirable purposes, however, is used at much lower flows (typically less than 80 litres/min) but, particularly in the case of patient ventilation, use can be continuous. Moreover, in the case of medical air there are considerably greater numbers of terminal units in use simultaneously. The installation of separate plants therefore can result in lower running costs. Requirements for separate surgical air systems are given in Section 8.

7.4 Some plant configurations are shown in Figures 23–26: reference should also be made to Tables 5 & 7 in Section 2:

- Figure 23 shows a typical medical air plant with fully automatic emergency reserve manifold;
- Figure 24 shows a combined medical and surgical air plant with emergency reserve manifolds. A combined system would be suitable for a small to medium hospital where separate plant could not be economically justified. In this case, a minimum of three compressors, each capable of supplying the total load should be installed plus automatic air cylinder manifold systems to support both the medical and surgical air;
- Figure 25 shows an option for combined plant with separate dryer and regulator arrangements;
- Figure 26 shows an option for combined plant with common dryer and separate regulator arrangements.

7.5 Other plant configurations are possible depending upon the specific design requirements e.g. for larger hospitals:

- two or three separate plants could be justified each serving a particular area;
- consider surgical air plant acting as an emergency back-up to the medical air plant;

- with synthetic air, however, careful planning is required to take into account the emergency back-up required, the use of nitrogen for surgical use, safety and cost in comparison to the conventional means of supply.

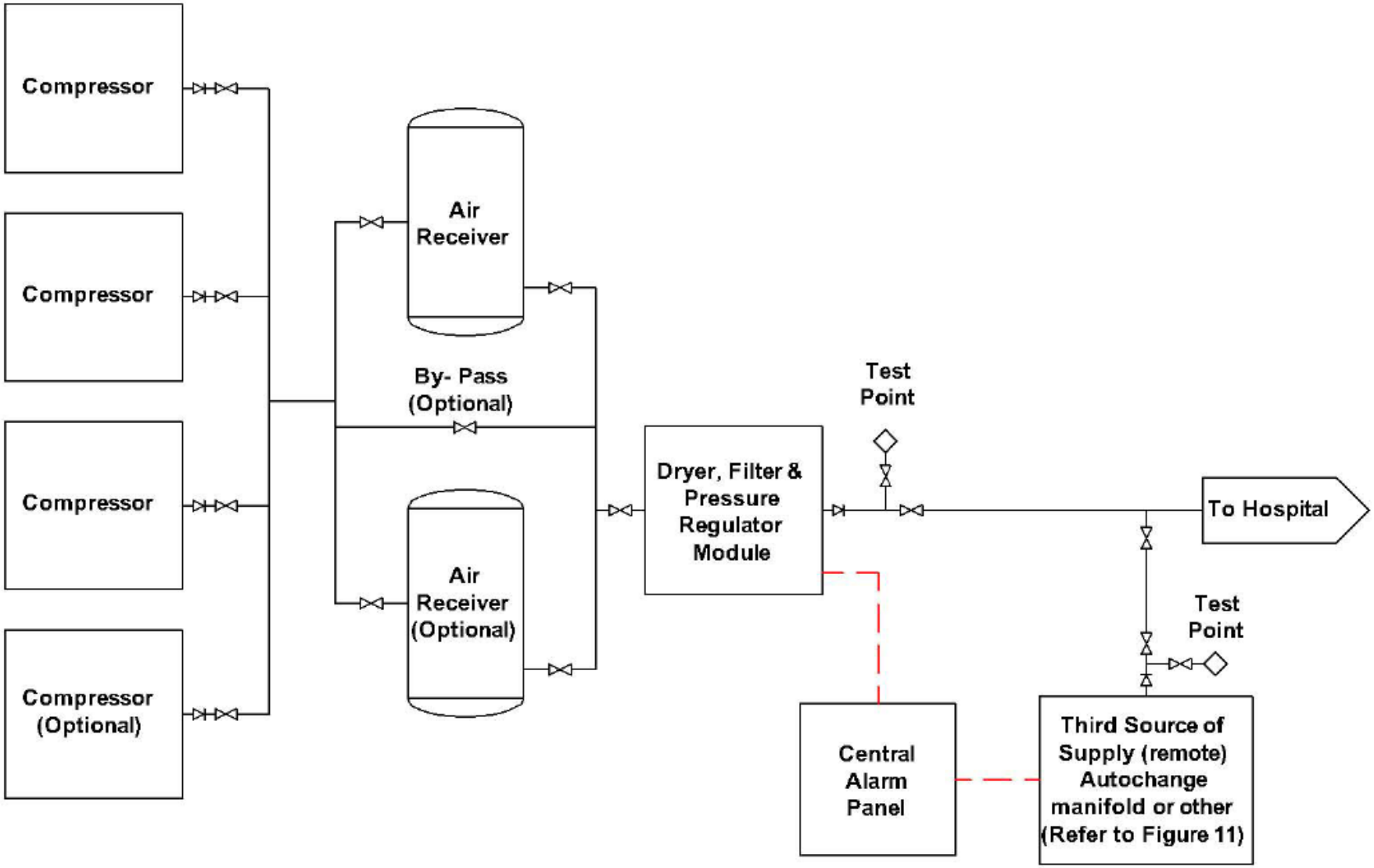


Figure 23: Typical medical air 400 kPa plant and automatic emergency reserve manifold

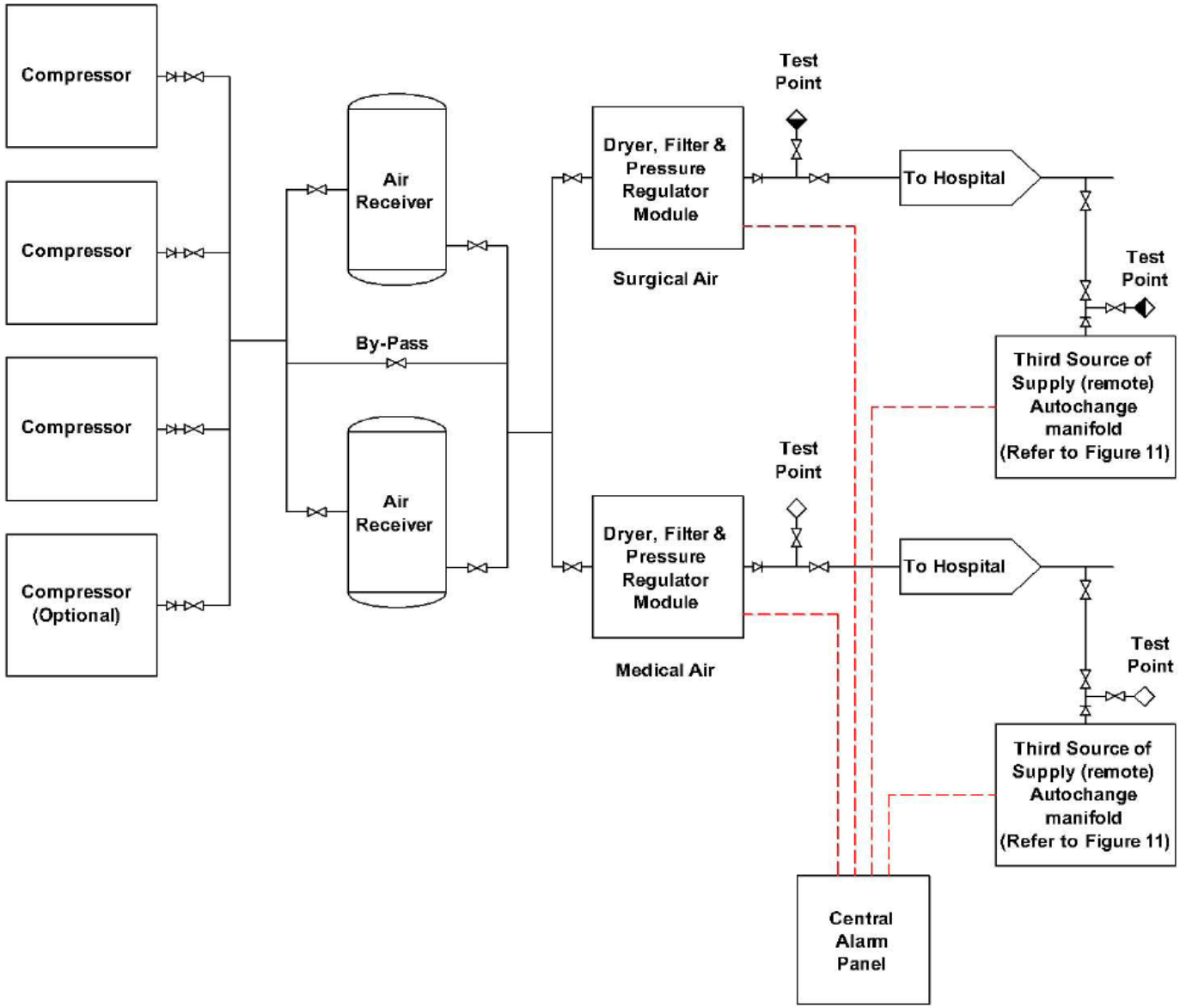


Figure 24: Typical duplex combined medical air 400 kPa and surgical air 700 kPa plant with emergency reserve manifolds

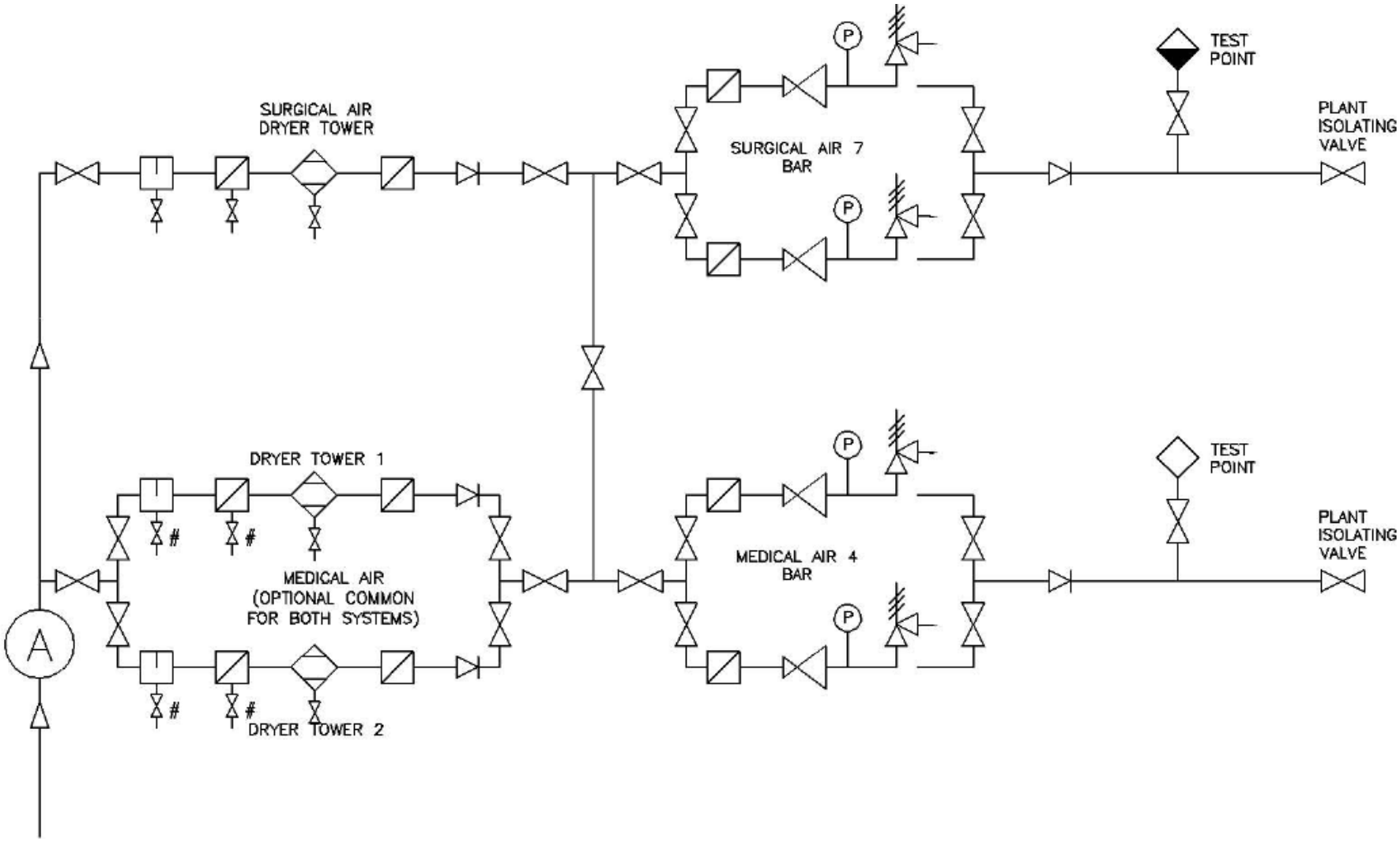


Figure 25: Option 1; medical air 400 kPa and surgical air 700 kPa with separate dryer and regulator arrangements

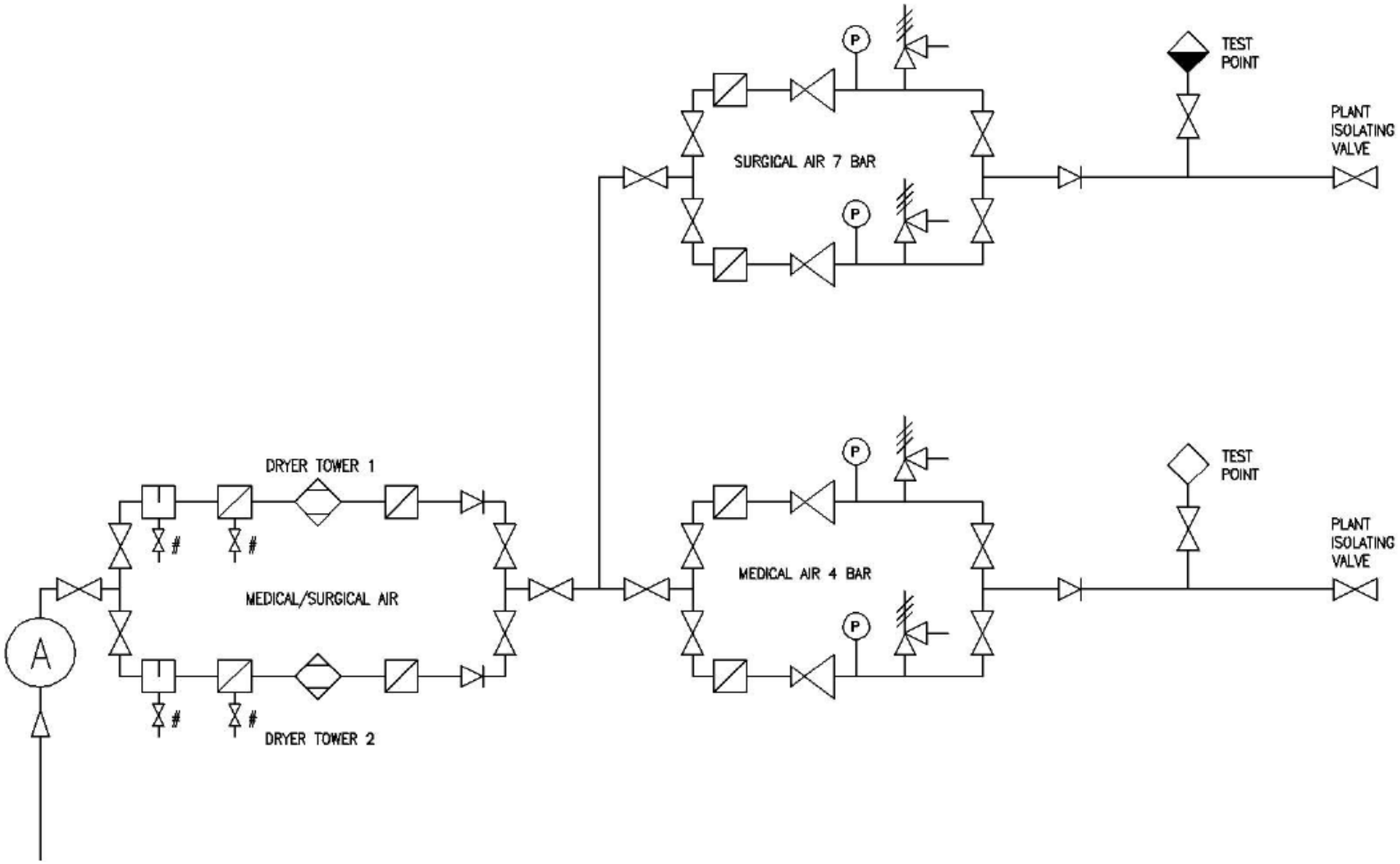


Figure 26: Option 2; medical air 400 kPa and surgical air700 kPa common dryer and separate regulator arrangements

Quality

7.6 The European Pharmacopoeia (Ph. Eur.) specifies maximum impurity levels for carbon monoxide. It may be necessary to make provision to control the levels of contaminants and to monitor the supply to ensure conformance with the specification. European Commission directive 2001/83/EC specifies that medicinal products should be manufactured to the approved standard.

Siting

7.7 The plant should have all-round access for maintenance purposes, and allowance should be made for changing major components.

7.8 The siting of the plant should allow for adequate flows of air for three different purposes:

- air intake to the compressors;
- cooling of the compressed air by the after-coolers;
- cooling of the compressors.

Compressor noise

7.9 The noise level produced by the compressors will increase with the capacity of the supply system. The maximum free-field noise level for un-silenced compressed air plant, at 1m from the plant, varies with the type and power of the plant but should not normally exceed the following values:

Reciprocating	Screw	Vane	Power
85 dBA	76 dBA	76 dBA	0-7.5kW
89 dBA	78 dBA	76 dBA	7.6-15kW
93 dBA	80 dBA	79 dBA	15.1-22kW
97 dBA	92 dBA	90 dBA	22.1-60kW

Table 32: Compressor noise levels

7.10 In noise-sensitive areas, an acoustic enclosure should be included in the purchase specification for all compressors. Such an enclosure should produce a reduction of at least 10 dBA in the free-field noise level at 1m.

Air intake

7.11 The position of an air intake can have a considerable effect on delivered air quality, particularly with respect to levels of carbon monoxide. The air intake for a compressor should be located to minimise contamination from internal combustion engine exhausts and the discharge from vacuum systems, AGSS and ventilation systems or other sources of contaminants. Air intakes should be ducted where necessary to avoid contamination; a minimum height of 5m above ground level should ensure a reasonable quality of intake air. Where this cannot be achieved, additional filtration and/or air treatment may be necessary. If the siting of the compressor, regardless of the air intake location, is considered

subject to a risk of aspirating toxic fumes and smoke as a result of a fire, an automatic shutdown system, linked to local smoke detectors, can be installed. If such a system is planned, it is essential that an automatic emergency supply manifold system is sited well away from the fire-risk area and is arranged to come on-line automatically in the event of plant shutdown.

7.12 Care is needed when extending compressor air intakes. Manufacturers' data should be consulted to ensure that intake flow, and hence compressor performance, are not adversely affected by excessive lengths of intake ducting. Choice of intake material is also important. Often, intakes are constructed from solvent-welded PVC. In a fire, toxic materials from the burning intake could be drawn into the air compressor and distributed throughout the system. In addition, there is a risk that inadequate solvent drying time before use of the intake will result in toxic solvent fumes being drawn into the system. Corrosion-resistant ducting (for example stainless-steel flue liner) is a suitable material.

7.13 Air-inlet filters should be fitted immediately upstream of the compressor. In exceptional circumstances, additional screens, filters and silencers may be required. The filters should comply with BS ISO 5011: 2000 and be either dry medium filters or grade CA paper element filters.

Compressor types

7.14 There are many different types of compressor currently available, the most common types being:

- reciprocating piston compressors;
- rotary vane compressors;
- rotary screw compressors.

7.15 The compressors may be of any type, provided they are suitable for continuous running on load and for high frequency start/stop operation. When selecting compressors the opportunity to maximise energy efficiency should be taken e.g. consideration should be given to the variable speed/ inverter drive motors which are increasingly being used in hospitals particularly on heating systems. In medical compressed air applications, this would reduce the stop/start frequency by maintaining a constant pressure within close limits and it is feasible to consider the eventual removal of the receiver. Research is being carried out into the use of variable speed drives with particularly successful applications in AGSS and Dental Vacuum and the removal of the energy wasteful constant volume exhauster. Now that the range of rotary screw compressors has been expanded particularly to the lower kW sizes, they have generally taken over from the reciprocating compressor in medical air applications. If reciprocating compressors are used, they may be either of the single or of the two-stage type, although for a 400 kPa system a single-stage compressor is usually satisfactory.

Compressor lubrication

7.16 Compressors may be oil-lubricated, provided that suitable arrangements are made to ensure that the air quality specification given in Table 42 is fulfilled (refer to Section 15).

7.17 Rotary screw compressors can be sealed by oil or purified water (reverse osmosis) with cooling by air or water. Water would provide lower operating temperatures with increased efficiency. However, water does introduce another external risk factor to ensuring the service provision. Thus the normal medical application is oil-sealed or air-cooled. Where there is a requirement for ducted intake air, this can be separate from the compressor cooling air. Reciprocating compressors may be oil-lubricated, carbon ring, PTFE ring or diaphragm-sealed type. However, the pulsating frequency of the piston and noise generated would normally require an acoustic enclosure.

7.18 Alternatively, oil-free compressors are available and may be beneficial in reducing filtration requirements.

7.19 Oil-free reciprocating and rotary screw compressors are not necessarily oil-less. Additionally the atmospheric air can carry oil vapours and contaminants and should not necessarily imply a reduction in filtration requirements. Oil-sealed rotary screw compressors have the added advantage of noise reduction, smooth air delivery and are more suited to a variable speed drive.

7.20 There is a danger that PTFE rings and lubricating oils could decompose at high temperatures to form toxic products. It is a requirement of paragraph 7.70 to monitor compressor temperature and to close down the compressor on fault condition. BS EN ISO 15001: 2010 specifies the requirements for selecting materials used in medical supply equipment.

7.21 On start-up, when oil is used as the sealant, moisture condensing at high pressure forms an emulsion with the oil. Once operating temperature is reached, water is readily separated. Because it is impossible to match the varying demand with plant capacity, it may be necessary to include oil heaters to avoid emulsification. If it is intended to omit oil heaters, manufacturers should be asked to confirm the suitability of the compressor for intermittent operation. Oil-lubricated compressors, however, are considered to be satisfactory.

7.22 Where oil-lubricated compressors are used, suitable means of separating oil from condensate is essential.

7.23 Once a compressor installation has been selected:

- the plant should include at least two compressors, but additional compressors may be included in accordance with Table 10;
- the individual compressors should be arranged so that they will supply the system simultaneously if necessary;
- the relative magnitude of the capital and running costs should be evaluated at the time of purchase. Too much emphasis has been placed on low

capital cost at the expense of reliability and high power costs. The running costs should be calculated at realistic levels of usage;

- the control system for the compressor plant should include an “hours-run” counter and should be constructed in accordance with the guidelines given below;
- the efficiency of plant, expressed as the volume of air delivered to the pipeline distribution system (after losses in the drying system and filtration system) per kilowatt-hour (kWh), should be stated by the supplier of the system. The testing procedure should evaluate this efficiency by testing the power consumption over a suitable period of time at 100%, 10% and 0% of the system design flow. A minimum efficiency of 5 m^3/kWh at 100% and 10% is required. The power consumption at zero flow should be less than 1% of that at 100% design flow.

After-coolers

7.24 After-coolers (and inter-coolers) usually form part of the compressor sub-assembly. After-coolers should be fitted to all medical air compressor systems. These will normally be air-cooled, and may need ducting with forced ventilation to ensure an adequate supply of cooling air.

Receivers

7.25 Air receivers should comply with BS EN 286-1: 1998 + A2: 2005 for all vessels up to 10,000 bar litres, and should be supplied with test certificates. The minimum water capacity of the receivers should be 50% of the compressor output in 1 minute, stated in terms of free air delivered at normal working pressure. Receivers should also be fitted with an automatic drain. Electrically operated automatic drains have been found to be more reliable.

7.26 To facilitate the statutory inspection, there should be either two suitably valved air receivers or, for a single receiver, a by-pass arrangement (for use in manual operating mode only) in order to avoid interruption to the supply. Alternatively the tertiary supply manifold can be used. A by-pass arrangement should only apply if rotary screw compressors are provided. Alternatively the tertiary supply manifold can be used provided an adequate supply of cylinders are available and constant monitoring is applied.

7.27 For systems that have a design flow exceeding 500 litres/min, two receivers should be provided with valve arrangements to permit isolation of one or the other for inspection purposes.

Air treatment and filtration

General

7.28 Contaminants can enter the compressed air system from three sources: the atmosphere, the compressor and the pipeline distribution system. Each potential source must be taken into account when specifying the type and location of air treatment equipment. Filtration equipment may include pre-filters,

coalescing filters, adsorption equipment, carbon filters, particulate filters, bacterial filters and any other additional filtration equipment necessary to ensure the quality of the product.

Solid contaminants

7.29 Particles in the environment cover a wide range of sizes, but approximately 80% are less than 0.2µm and are therefore not removed by the intake filter to the compressor.

7.30 Although particles smaller than 40µm are unlikely to cause mechanical damage, a 5µm intake filter is preferred to avoid blockage of internal air/oil separators.

7.31 Filters are specified in terms of performance tests – a sodium flame test, a DOP (dispersed oil particulate) test etc.

Water

7.32 Water is always a contaminant in a compressed air system, regardless of the type and location of the compressor plant, since the air drawn into the compressor intake is never completely free of water vapour. The amount can vary from 2.5 g/m^3 to over 40 g/m^3 depending on the climatic conditions. The after-cooler and receiver remove some of this, but about 20 g/m^3 is likely to remain in the compressed air unless removed by dryers.

7.33 A water content not exceeding 67 vpm (parts per million by volume – equivalent to dew-point –46°C at atmospheric pressure) is specified for medical air pipeline systems. Only desiccant dryers can usually achieve this. A variety of desiccant types are available. Silica gel, although a desiccant, can easily fracture and powder and is not used in medical compressed air applications. Activated alumina is the common type employed. Molecular sieve desiccants employing zeolites can also be used, but on occasions it has been found that this material has produced air with an increased oxygen content, in the order of 24%. Refrigerant dryers can perform satisfactorily down to a pressure dew-point of +3°C (atmospheric dew-point –20°C) and are therefore not recommended as the sole form of drying.

Oil

7.34 With oil-lubricated compressors, it is inevitable that the compressed air will contain oil. Even with oil-free compressors (non-lubricated), complete freedom from oil and oil vapour cannot be positively guaranteed, as hydrocarbon vapours may be drawn into the compressor. Oil levels in the air supply must be controlled to 0.1 mg/m^3 with means of monitoring on a routine basis.

7.35 Oil will exist in the system in three forms: bulk liquid, oil aerosol and oil vapour. Provided that the oil lubricant is appropriate and the after-cooler properly designed, the amount of oil present as vapour should be small and is unlikely to exceed 0.5 mg/m^3.

7.36 The amount of oil that is present as bulk liquid and aerosol is more difficult to predict. With modern, well-maintained oil-lubricated compressors, it is unlikely

to exceed 5 mg/m^3 due to the high-efficiency oil/air separator. A pre-filter/ separator will remove the bulk contaminants which should reduce the remaining oil content to 0.5 mg/m³, particle removal down to 1 micron and a DOP penetration of less than 0.03%. The coalescing filter should further reduce the remaining oil content to 0.01 mg/m³, particle removal down to 0.01 micron and a DOP penetration of less than 0.0001%. The preferred practice is to retain the pre and coalescing filter as separate assemblies.

7.37 Oil-contaminated compressor condensate is classified as a trade effluent by virtue of Chapter 14 of the Public Health (Drainage of Trade Premises) Act 1937. An oil condensate separator should therefore be installed.

7.38 Under Scottish environmental legislation, it is illegal to make a discharge of trade effluent to “controlled waters” via a surface water drain without the consent of the Scottish Environment Protection Agency (SEPA).

7.39 Similarly, the Water Authority enforces the limit of oil condensate discharged into the public foul sewer. Prior consent to discharge is mandatory.

7.40 Condensate from oil-free compressors may be discharged to drain.

7.41 Any condensate produced from the compressor/ dryer system must be regarded as trade effluent and is therefore not suitable for discharge to any surface water system draining to any surface water sewer, water-course or soak away; this may not apply if a suitable oil / water separator is installed. Maximum oil content limits range from region to region, from 25 mg/litre up to 500 mg/litre; the water authority should be consulted.

Dryer and filter assembly

7.42 Each dryer and filter assembly should be rated for continuous use at the system demand flow.

Dryer controls

7.43 The dryer control system should ensure that regeneration is operated in proportion to the compressed air usage. The effectiveness of the control system will become apparent when the efficiency of the compressor system is tested at 10% and 0% of the system design flow. Evidence of the reliability and performance of a dryer system should be sought from manufacturers, since these items are critical to the overall performance of the compressor system. The dryer control system should include a dew-point hygrometer and display with a minimum accuracy of ±3°C in a range from –20°C to –60°C atmospheric dew-point, with a set point of –46°C. It should be arranged that in the event of open circuit, a “plant emergency” alarm be initiated.

Dust filters

7.44 There should be a dust filter downstream of the dryers to remove particles down to 1 µm, with a DOP penetration of less than 0.03%, when tested in accordance with BS EN ISO 3549: 2002.

Activated carbon filter

7.45 Duplex activated carbon filters should be installed upstream of the final bacteria filter for odour removal.

Bacteria filters

7.46 Duplex bacteria filters should be fitted upstream of the final pressure regulator with appropriate isolating valves. The filters should provide particle removal to 0.01 mg/m^3 and a DOP penetration of less than 0.0001%.

Pressure control

7.47 The pressure control should maintain the nominal pipeline pressure within limits given in Section 4. Duplex line pressure regulators should be provided with suitable isolating valves. The regulators should be of the non-relieving type.

Safety valves

7.48 Safety valves should be provided in accordance with the requirements given below. All safety valves should conform to BS EN ISO 4126-1: 2004. A safety valve of the certified discharge capacity stated should be fitted in each of the following positions:

- on the delivery pipe of each compressor and upstream of any isolating valve, non-return valve or after-cooler, capable of discharging the total throughput of the compressor;
- on each air receiver and dryer tower, capable of discharging the sum of the throughput of all the compressors. It is not necessary to provide safety valves on the dryer columns where the system is already protected by a safety valve on the receiver and the downstream equipment, that is, if the dryer column is already sufficiently protected;
- immediately downstream of each pressure regulator, capable of discharging the system demand flow.

7.49 All safety valves should be of the closed-bonnet type and connected to suitably sized pipework to allow safe discharge, not necessarily to the outside.

Traps, valves and non-return valves

Automatic drainage traps

7.50 Electrically or mechanically operated automatic drainage traps should be provided on the after-coolers, receiver, separators and coalescing filters. The discharge from these drainage traps should be piped to a suitable gully via an oil/water separator. Co-ordination with building work is required for this provision. A manual by-pass valve should be fitted to each after-cooler and receiver automatic drainage trap to permit a trap efficiency check. Automatic drainage should be fitted to all pre-filter / separators and coalescing filters. Electrically-operated automatic drains have been found to be more reliable.

7.51 Drainage and tundishes are usually provided under the building contract. Separators should be provided under the air compressor contract. Provision of oil/water separators should be supplied by the plant manufacturer and matched to suit the combined plant output.

Non-return valves

7.52 Non-return valves are required to prevent backflow of the air supply in certain situations. These valves should be located as follows:

- between the compressor and the receiver, but downstream of any flexible connector;
- downstream of the dust filter on the dryer;
- upstream of the emergency cylinder reserve connection in the pipeline connecting the plant to the pipeline distribution system, to prevent back-feeding this plant;
- upstream of any inlet point that may be used to feed the system in an emergency;
- downstream of the emergency cylinder manifold regulators.

Isolating valves

7.53 Isolating valves should be provided downstream of non-return valves and upstream of, for example, the connection of the emergency reserve manifold. Isolating valves should be provided in order to facilitate maintenance or replacement of plant items.

7.54 Manually-operated ball isolation valves should be located in the positions shown in Figures 23 – 26 to allow isolation of components such as receivers, dryers, automatic drains, pressure regulators and filters. There should also be a valve on the compressed air plant, downstream of the plant non-return valve and the connection of the cylinder manifold supply.

Pressure indicators

7.55 Pressure indicators should comply with BS EN 837-1:1998 or have an equivalent performance if electronic indicators are used. Calibration should be in bar or kPa. All gauges should have a minimum scale length of 90mm, and the working range should not exceed 65% of the full-scale range except on differential pressure gauges. Pressure indicators should be connected by means of gauge cocks.

7.56 Pressure indicators should be located:

- on the plant control unit indicating receiver pressure;
- on each receiver;
- downstream of each pressure regulator;
- on each dryer tower;

- on the plant pipework, upstream of the plant isolating valve.

7.57 Differential pressure indicators should be provided across each:

- pre-filter / separator;
- coalescing filter;
- dust filter;
- activated carbon odour filter;
- bacteria filter.

7.58 Except for pressure gauges, all control and measuring devices should be connected directly to the pipework via a minimum leak device (to allow removal for servicing) and not isolated by valves.

Operating and indicating system

7.59 The operating and indicating system should perform the following functions:

- overall plant control and indication;
- individual compressor starting;
- control of dryers;
- plant status monitoring.

All pressure switches mounted internally or externally which may require adjustment when 'live' should be designed and operated at extra low voltage.

7.60 Provided that the individual compressor starters are housed in a separate compartment, these functions may be carried out by separate units or may be installed in a common panel and located on the plant or on the plantroom wall. Control panels containing pneumatic components should have vents to permit release of pressure in the event of component failure. All indicators should be appropriately identified and should have a design life of at least five years.

7.61 The operating system of each compressor should be capable of automatically restarting after reinstatement of the power supply.

7.62 All components of the medical air supply system should be connected to the essential electrical supply. The control system should ensure that compressors restart in sequence to avoid overloading the power supply.

Plant control unit

7.63 The plant control unit should have a separate power supply for each compressor, controlled by a separate sub-circuit. Generally, system resilience can be increased through the specification and design of the electrical services by having separate supplies for designated components, for example, two out of four compressors or vacuum pumps being supplied by a separate electrical system / distribution board.

7.64 The unit should:

- allow either a manual selection of duty/stand-by for each of the compressors or preferably have an automatic sequence selection with a means for manual override;
- incorporate an automatic standby control in the event of a printed circuit board failure;
- be capable of manual operation of the compressors in the event of the main and standby central control panel functions failing;
- ensure that two or more compressors do not start simultaneously when power is supplied;
- for each compressor starter unit or if remote from the compressor, incorporate an independent manual start which will permit the compressor to work under load and fitted with an emergency stop.

7.65 A warning notice that complies with BS5499-5: 2002 should be affixed which indicates the presence of low voltage.

Plant control indication

7.66 There should be indicators for each compressor as follows:

- green “mains supply on”;
- green “compressor called for”, which indicates that the compressor motor is electrically energised;
- an indicator of the pressure produced by the compressor.

Compressor starter units

7.67 There should be individual starter units for each compressor which operate a single designated compressor. The starters should be provided with safety interlocks, as specified by the compressor manufacturers, which should inhibit plant operation until manually reset by means of a button. The starters should allow automatic restart after an interruption to the power supply. Each starter unit should contain the following:

- an isolator interlocked with the covers;
- either HRC (high rupturing capacity) fuses to BS88 or suitable circuit breakers to BS EN 60947-2: 2006 + A1: 2009 and/or BS EN 60898-1: 2003 + A1: 2004;
- an industrial grade ammeter to BS EN 60051-1:1999, IEC 60051-1:1997 (digital ammeters of similar accuracy to those compliant with BS EN 60051-1: 1999, IEC 60051-1: 1997 may be used);
- a “total hours” counter if not included in the plant control unit;
- a green “mains supply on” indicator if mounted separately from the plant control unit.

Dryer control unit

7.68 The dryer control unit may be mounted on the dryers or may be located with the plant control unit. There should be separate power supplies for the duty and stand-by dryer assemblies taken from the same phase.

7.69 The dryer control unit should contain the following:

- a duty dryer selector switch;
- a service function – to enable selection of continuous/normal running;
- individually fused, separate cycling systems for each dryer;
- a system to control regeneration of the dryers in relation to pipeline demand;
- a hygrometer and display with a minimum accuracy of ±3°C in a range from –20°C to –60°C (set to –46°C atmospheric dew-point) and a pressure sensor;
- an automatic changeover to the stand-by dryer system in the event of failure of the duty unit by either dryness or pressure. This requires:
  - electrical and pneumatic isolation of the duty sub-assembly so that it is taken off- stream;
  - electrical and pneumatic energisation of the stand-by sub-assembly so that it is brought on-stream;
  - activation of the appropriate fault indicator and associated Volt-free contacts;
- the sub-assembly to remain in this mode of operation until the fault has been rectified;
- green function indicators for each dryer sub- assembly to indicate:
  - dryer 1 selected;
  - dryer 2 selected;
  - selected dryer – “normal”;
  - selected dryer – “failed” indicated by an orange or amber light (this fault indicator should remain until manually reset by means of a reset button).With a duty fault condition existing, the standby dryer will function in the normal alternate drying / regeneration mode.
- a fail-safe system which on failure of the power supply causes the following:
  - closure of the exhaust and purge valves;
  - opening of the inlet and outlet valves.

Plant status monitoring

7.70 A monitoring system should be provided to detect the following faults in the air compressor system:

- plant faults (for each compressor):
  - control circuit failed;
  - motor tripped;
  - after-cooler temperature high;
  - compressor temperature high;
  - compressor failed to go on load.
  - activation of other safety devices supplied by the manufacturers;
- plant faults (for each dryer unit):
  - dryer failure;
  - pressure fault;
- plant emergency:
  - receiver pressure 0.5 bar below the stand- by cut-in pressure;
  - receiver pressure 0.5 bar above cut-out pressure;
  - dryness above –46°C at atmospheric pressure;
- pressure fault (cylinder reserve):
  - as the reserve manifold is a fully automatic cylinder manifold, the full set of standard alarm conditions should apply to the central alarm system.
- pressure fault (pipeline):
  - low pipeline pressure;
  - high pipeline pressure.

Where surgical and medical air are supplied from a standard compressor plant with duplex dryer / filtration unit, each service should be provided with a duplex regulator set. Each set should be fitted in parallel to the other service, each monitored by a high and low line pressure switch. The central alarm panel need only indicate a plant combined line pressure fault, identifying of the service by investigation.

Plant status indicator unit

7.71 In addition to the plant control indication, there should be a plant status indicator panel that may be mounted on the plantroom wall or adjacent to either the compressor starter unit or the plant control unit. It should have a warning notice that complies with BS5499-5: 2002 to indicate the presence of low Voltage.

7.72 There should be indicators for each compressor to show the following conditions:

a) green “mains supply on”;

b) yellow “control circuit failed”;

c) yellow “overload tripped”;

d) yellow “after-cooler temperature high”;

e) yellow “compressor temperature high”;

f) yellow for each individual safety device provided by the manufacturers;

g) yellow “compressor failure”.

7.73 There should be indicators for each dryer system to show the following:

a) green “mains supply on”;

b) yellow “dryness fault”;

c) yellow “pressure fault”.

Alarm signal status unit

7.74 An alarm signal status unit should be provided as part of the control system. It should display the following conditions:

a) green “normal” (normal);

b) yellow “plant fault” conditions ((b)–(g) in paragraph 7.72);

c) yellow “plant emergency” (low reservoir pressure/high moisture: that is, condition (b) in paragraph 7.72);

d) yellow “reserve low” (emergency/reserve banks low (<50%));

e) red “pipeline pressure fault” (pressure fault).

7.75 Conditions (b) to (e) in paragraph 7.74 should be transmitted to the central alarm system. Where relays are used, they should be normally energised relays that de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA.

7.76 Volt-free, normally closed contacts rated at 50 V d.c. and 50 mA should be provided for transmission of conditions (b) to (e) in paragraph 7.74 to the alarm system.

7.77 The panel can be incorporated into the plant indicator unit or be a separate unit within the plantroom. If mounted separately, the cabling should be monitored for open/short circuit. In the event of such a cabling fault, a red “system fault” lamp should be illuminated on the alarm signal status unit together with the appropriate alarm condition.

7.78 The alarm signal status unit should be supplied from all individual plant control units or from a separate common supply.

Plant management

7.79 Connections should be provided which allow monitoring of plant alarm conditions (b) to (e) in paragraph 7.74 and pump running for each “compressor”. These connections should be Volt-free contacts normally closed for each

condition having a minimum rating of 50 V d.c. and 50 mA. The building management system should not be used to control the plant.

Synthetic air

7.80 This section provides technical details of the process and systems required to generate medical air from mixing gaseous oxygen and nitrogen, derived from cryogenic supplies.

7.81 For the purposes of the Medicines Act 1968, it is considered that the synthetic air is manufactured on-site, for use on that site only, in exactly the same way as for medical air derived from compressor plant. The production of synthetic air implies a manufacturing process, and as such, the process should be subjected to the same safety requirements of any pharmaceutical process. This should include, for example, a HAZOP (HAZard and OPerability) analysis and other safety analyses that may be necessary.

7.82 Synthetic air is generated by mixing gaseous oxygen and nitrogen in a blender or mixing panel at pre-set pressures to ensure that the resultant mixture is always correct. Continuous on-line monitoring of oxygen concentration is provided to check the mixture; the system shuts down automatically if the oxygen concentration varies from the specified value.

7.83 If one mixing system shuts down, the pipeline is supplied from the secondary mixing system to ensure continuity of supply.

7.84 The feasibility study should provide more information on the details of the monitoring and alarm systems required, as well as operational information.

7.85 The VIE system supplying the medical oxygen may be used to supply the synthetic air system, depending on the system demands.

7.86 Nitrogen supplied to the synthetic air system may also be used to provide the power source for surgical tools instead of surgical air at 700 kPa.

7.87 An electrical power supply is required in order, for example, to operate solenoid valves and monitoring instrumentation. Therefore the system should be connected to the essential power supply and via an uninterruptible power supply (UPS) with at least four hours' capacity; this should ensure continuity of supply in the event of power failure.

System description

7.88 The gaseous oxygen and nitrogen are derived from bulk liquid supplies contained in a VIE – asset out in the "Liquid oxygen systems" text within Section 6.

7.89 The oxygen for synthetic air may be taken from the VIE supplying the medical oxygen system or it may be from a dedicated VIE. It would normally be more cost-effective for the oxygen to be taken from the main VIE, although this would obviously depend on the existing VIE capacity, the demand, space constraints etc. The feasibility study should provide more detailed information on whether it

is likely to be more cost-effective to provide a totally separate VIE system or to use the existing medical oxygen VIE. The feasibility study should include a cost comparison against other methods of supply. Unlike the renting of liquid vessels, there can be a high capital cost for the ancillary mixing equipment which may not come under the rental agreement.

7.90 For both the oxygen and nitrogen it is necessary to have a secondary supply system to ensure continuity of supply; the system demands are such that this should be derived from a second – normally smaller – VIE.

7.91 This secondary oxygen supply can also serve the hospital's medical oxygen system.

7.92 Since four VIEs will be required, the space requirements will need special consideration when planning the installation of a synthetic air system.

7.93 The system comprises:

- storage vessels – one main vessel and one secondary supply vessel for both oxygen and nitrogen;
- vaporisers for both oxygen and nitrogen;
- medical oxygen flow control – where used to supply medical oxygen systems;
- surgical nitrogen flow control – where required;
- a control panel for the nitrogen and oxygen supplies to the mixing panels;
- duplicate air mixing panels;
- buffer vessels – each mixer has a buffer vessel to smooth fluctuations in demand;
- a warning and alarm system;
- duplicate oxygen analysers on each mixer.

7.94 A typical system is shown in Figure 27 overleaf which supplies synthetic air with a third source of supply for medical air (remote), surgical nitrogen and oxygen with a third source of supply for oxygen (remote).

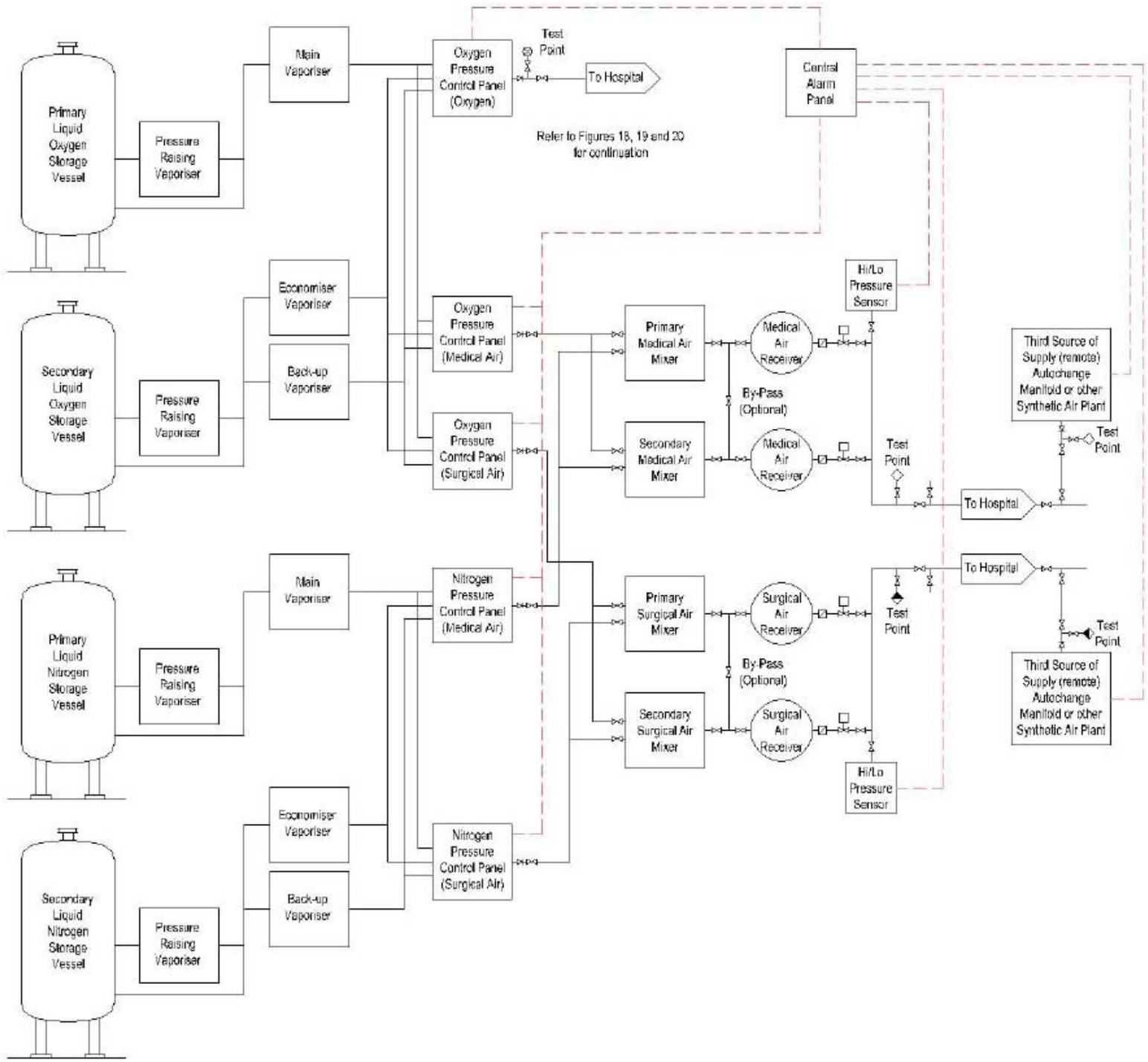


Figure 27: Synthetic air plant

Storage vessels

Vessel summary

7.95 The following vessels are required:

- one main oxygen vessel;
- one secondary oxygen vessel with at least 24 hours' capacity;
- one main nitrogen vessel;
- one secondary nitrogen vessel with at least 24 hours' capacity.

Vessel operating pressure

7.96 The following operating pressures are required:

- main vessels: 12.5 bar;
- back-up vessels: 12.5–14 bar.

Main vessel capacity

7.97 The main vessel should normally be sized on the basis of two weeks' supply. This should be calculated as 14 x the average daily usage. This should provide adequate storage and a cost-effective vessel-filling regime. The gas supplier should, however, be consulted as there may be other factors, such as geographical location, space etc, which need to be taken into account when sizing the main vessels.

Back-up vessel capacity

7.98 The stand-by vessel should have 24 hours' capacity at any time; that is, it should be sized on the basis of twice the average daily usage. This will ensure that there is always 24 hours' supply available.

7.99 In addition to the normal instrumentation as set out in the "Liquid oxygen systems" text within Section 6, the vessels should be fitted with a telemetry system to monitor continuously the vessel contents.

7.100 This information should be transmitted direct to the gas supplier and also the hospital. The exact details of how much information, and where it should be received, will depend on each hospital site.

7.101 The main vessel low level alarm is activated at 25% full; the back-up low level alarm is activated at 50% full.

7.102 The safety relief valves and bursting discs should be sized in accordance with BCGA CP19.

7.103 The liquid from the vessels should be supplied to the process at a nominal pressure of 12.5 bar.

Vaporisation

7.104 The main and stand-by vessels should have dedicated vaporisers designed for continuous capacity and 24-hour capacity respectively at 1.5 x the required flows to ensure that the vaporisers are not overdrawn.

7.105 This may be achieved in each case by either a single set of vaporisers or by vaporisers operated on timed or manual changeover.

7.106 It is preferable for the vaporisers to operate on a timed changeover as this avoids the need for hospital staff to manually operate the changeover valves.

7.107 The timed changeover will require a 110 V or 240 V supply; this should be on the emergency supply and a UPS should also be provided, with at least 4 hours' capacity.

7.108 Each vaporiser or set of vaporisers must have a safety relief valve.

Medical oxygen flow control

7.109 A control panel (similar in principle to a C11 panel) should be provided – the only difference is that the secondary supply is taken from a low-pressure liquid source.

Surgical nitrogen flow control

7.110 A control panel to regulate the gaseous nitrogen to between 7.5 and 9.5 bar, depending on the system design, should be provided.

7.111 The pipeline distribution system should be designed in exactly the same way as for surgical air 700 kPa systems, as described in Section 8.

Control panel for the nitrogen and oxygen supplies to the mixing panels

7.112 The control panel should be sized to provide pressure-regulated flows as appropriate for the mixing system; this would typically be up to 200 Nm^3/hr (normal cubic metres per hour).

7.113 The stand-by supply regulation cuts in when the main line pressure falls to 11 bar; there is no regulation on the main supply line.

7.114 A non-return valve should be installed in both the nitrogen and oxygen supply lines within the mixer to prevent cross-contamination.

7.115 A non-return valve should also be installed on both the main oxygen supply and the stand-by oxygen supply to the mixer to prevent the medical oxygen line becoming contaminated with nitrogen.

Air mixing panels

7.116 A range of sizes of mixing panels is available with, typically, nominal capacities of 50, 100 and 200 Nm^3/hr.

7.117 A regulated supply of nitrogen and oxygen is blended in a mixing valve. The differential pressure at the inlet to the mixing panel is critical and should not exceed 0.5 bar. A pressure-switch-operated solenoid valve opens and shuts on a 0.5 bar differential.

7.118 The main mixer solenoid valve opens when the line pressure falls to 4.2 bar; the stand-by mixer solenoid valve will open if the line pressure continues to fall to 4.0 bar.

7.119 Two independent paramagnetic oxygen analysers are provided on each mixer to give continuous on-line measurements.

7.120 If the oxygen concentration falls outside 20–22% as measured by either analyser, the mixer solenoid valve is held closed and the mixer is shut down. In addition, a signal is relayed downstream to close the solenoid valve on the buffer vessel associated with that mixer.

Buffer vessels

7.121 Each mixer has associated with it a buffer vessel to smooth fluctuations in demand.

7.122 In the event that the oxygen concentration differs from the specification (that is, 20–22%), the solenoid valve downstream of the buffer vessel will also close, preventing air from the buffer vessel from entering the distribution system.

7.123 The buffer vessel, together with appropriate means of safety relief, should be sized to match each mixing panel to provide stable operation.

Alarm signal status unit

7.124 The same alarm conditions for liquid oxygen should also be transmitted and displayed for the liquid nitrogen system. The following conditions should be displayed for the mixing panels:

a) green “normal” (normal);
b) yellow “plant fault” (low gas pressure to any mixer);
c) yellow “plant emergency” (analysis out of specification on any mixer);
d) yellow “reserve low” (operating on final mixing panel/buffer vessel only);
e) red “pressure fault” (pressure fault).

7.125 Conditions (b) to (e) of paragraph 7.124 should be transmitted to the central alarm system. Where relays are used, they should be normally energised relays that de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA.

7.126 Volt-free, normally closed contacts rated at 50 V d.c. and 50 mA should be provided for transmission of conditions (b) to (e) of paragraph 7.124 to the alarm system.

7.127 The panel can be incorporated into the mixing panel control unit or be a separate unit within the plantroom. If mounted separately, the cabling should be monitored for open/short circuit. If such a cabling fault occurs, a red “system fault” lamp should be illuminated on the alarm signal status unit together with the appropriate alarm condition.

Emergency supply provision

7.128 A risk assessment should be carried out to establish the vulnerability of the main supply system of both oxygen and nitrogen. Further information is given in Section 2 on sources of supply and in Section 6.

Additional use of medical air systems

7.129 It is possible to use medical/surgical air as a power source for pendant control and braking systems.

7.130 These additions must not compromise either the medical air system or operation of connected equipment. They must be connected via a non-return valve and flow-limiting device, and be capable of isolation by means of an AVSU labelled to identify the equipment controlled.

7.131 Medical air systems must not be used for applications referred to in paragraph 2.6.

8. Surgical air systems

General

8.1 Surgical air at 700 kPa is only used as the power source for surgical tools. These tools typically require high flows – up to 350 litres/min – at 700 kPa at the point of use. Where nitrogen is available on site, it may be used as an alternative source of supply.

8.2 Supply systems for surgical compressed air may be a cylinder manifold system, a dedicated 700 kPa compressor system or a compressor system capable of supplying both the 700 kPa and the 400 kPa supplies. In practice, the decision about which compressor system to install needs careful consideration because of the flow rates required and total usage (see Section 7).

8.3 A compressor system will be required for large operating department complexes specialising in orthopaedic and/or neurosurgery that require the use of pneumatically-powered surgical tools. An automatic reserve manifold located in separate accommodation should be provided. A typical system is shown in Figure 28 overleaf.

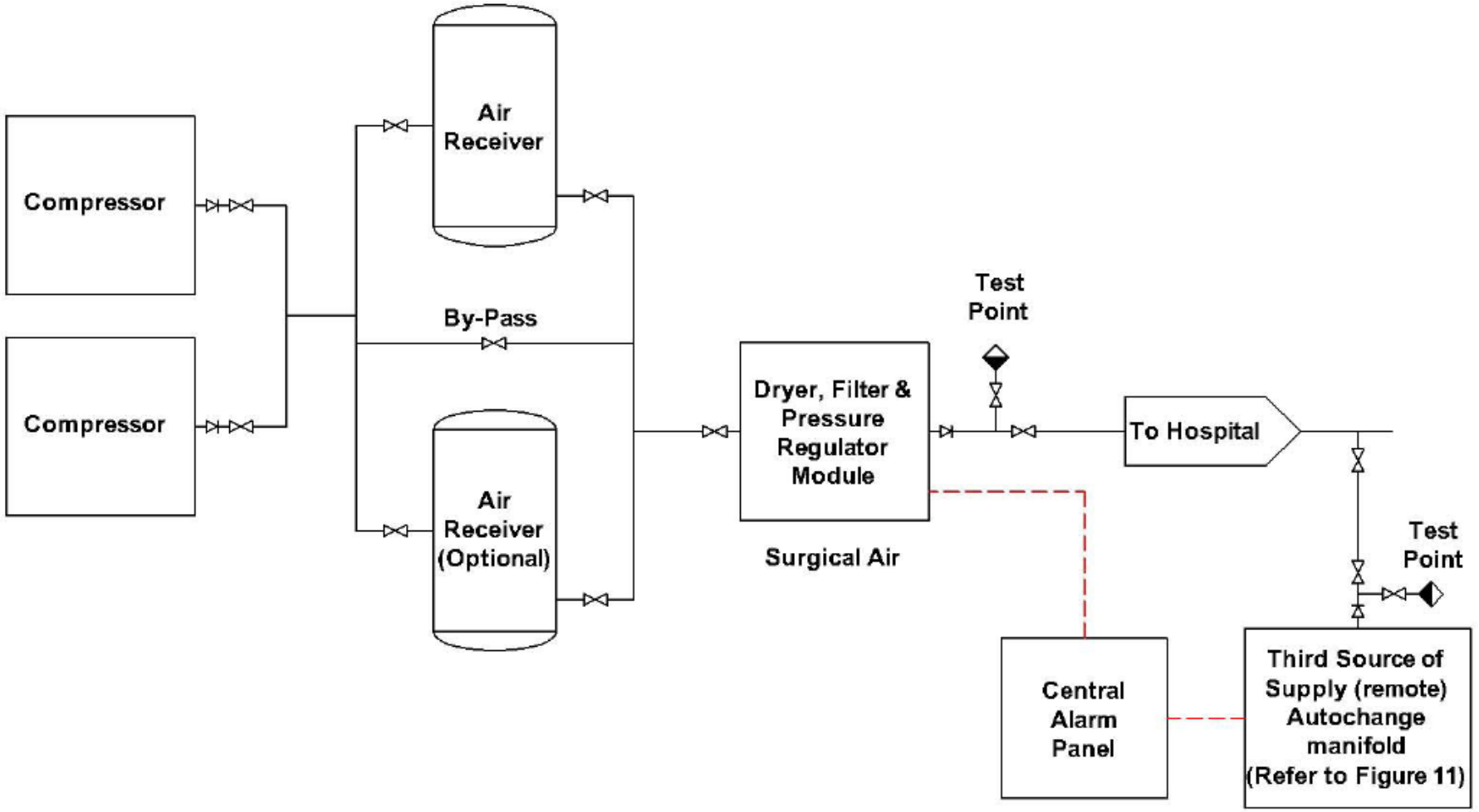


Figure 28: Typical surgical air plant and automatic emergency reserve manifold

8.4 It is possible to use nitrogen instead of air as the power source for surgical tools. This may be derived from either a liquid source or cylinders. In either case, the terminal units must be different from the existing medical air 700 kPa terminal units. A NIST connector is already specified for nitrogen and should be used.

8.5 The pressure control equipment should comprise duplex regulating valves with upstream and downstream isolating valves, pressure gauges and pressure relief valves.

8.6 Whatever supply system is installed, the overall system should be designed to provide a minimum of 700 kPa at the front of each terminal unit at a flow of 350 litres/min.

Note 21: Systems designed to meet requirements of earlier editions of Scottish Health Technical Memorandum 2022 may not provide 350 litres/min at 700 kPa. Information on upgrading surgical air systems in given in Appendix J.

8.7 The maximum pressure at the terminal unit under “no flow” conditions should not exceed 980 kPa.

8.8 Cylinders of medical air or nitrogen stored locally should always be available for use in an emergency.

8.9 Vessels should be selected as follows:

Design flow (Litres/min)	Vessel size	Compressor output (litres/min)
< 500	1 x 200% design flow	0.33 x design flow
500 - 2000	2 x 66.6% design flow	0.66 x design flow
2001 - 3500	2 x 50% design flow	0.66 x design flow
> 3500	3 x 33.3% design flow	0.50 x design flow

Table 33: Air receiver vessel selection

Extension of surgical air systems into dental departments

8.10 The preferred option for dental surgeries is a dedicated compressor system often purchased as Group 3 equipment. However, some surgical air systems, where pipelines are reasonably located, have been extended into the surgeries. When such extensions are made, a duplex regulator set incorporating upstream and downstream isolating valves, safety relief valves, pressure gauges and flow restrictor to provide 50/60 litres/min per chair per regulator should be fitted, located in a suitable plantroom secure from unauthorised access with gauges visible to the eye. Monitoring of low and high pressure by an area alarm panel should be in place. There should be no need to include a non-return valve or back feed protection. The following must be taken into account:

- the extra demand on the existing system must not compromise patient safety or operation of either the existing system or its extension. In

particular, the ability of an existing emergency supply system to cope with potentially very high demands must be carefully assessed;

- the Authorised Person (MGPS) with responsibility for the existing surgical air system will automatically assume responsibility for the whole of the dental compressed air and vacuum system. Both the Authorised Person (MGPS) and Quality Controller (MGPS) must appreciate that extending a surgical air system into a dental unit for dental instrument use will introduce “non-standard” pipework terminations, for example crimped or compression-fitted connectors, in addition to non-degreased components. Failure of these “non-standard” components could lead to a serious de-pressurisation of the existing surgical air system and, if provided from the same source, the associated medical air system. Under no circumstances should the surgical air system at original or reduced pressure be extended into a dental laboratory;
- a test point should be available at each chair;
- if the medical air is derived from a plant that supplies surgical air, the medical air supply should have a separate manifold reserve supply when space and system design makes this practicable.

9. Medical vacuum systems

General

9.1 The medical vacuum pipeline system provides immediate and reliable suction for medical needs, particularly in surgical accommodation.

9.2 The medical vacuum pipeline system consists of the vacuum supply system, the distribution pipework and terminal units. The performance of the pipeline system is dependent on the correct specification and installation of its component parts. This chapter describes the requirements of the vacuum supply system.

9.3 The medical vacuum pipeline system should be designed to maintain a vacuum of at least 300 mmHg (40 kPa) at each terminal unit during the system design flow tests.

9.4 To ensure continuity of supply, the vacuum plant should be connected to the essential electrical power supply.

9.5 The capacity of the vacuum supply system should be calculated in accordance with the design and diversified flow data provided in Table 21.

9.6 With the exception of the vacuum discharge to atmosphere, the pipeline distribution system for vacuum has traditionally been constructed of copper. PVC pipework can be considered where cost-effective. Pressure testing of PVC pipework should be carried out at 150 kPa. Pressure testing of copper pipework should be carried out at 500 kPa.

9.7 The major components of a medical vacuum system and their layout are shown in Figure 29 overleaf. A suitable operating and indicating system with alarms is also required. The location of the components should allow adequate space for access for maintenance. Packaged supply systems are available from manufacturers that should be specified to meet the requirements given in this memorandum.

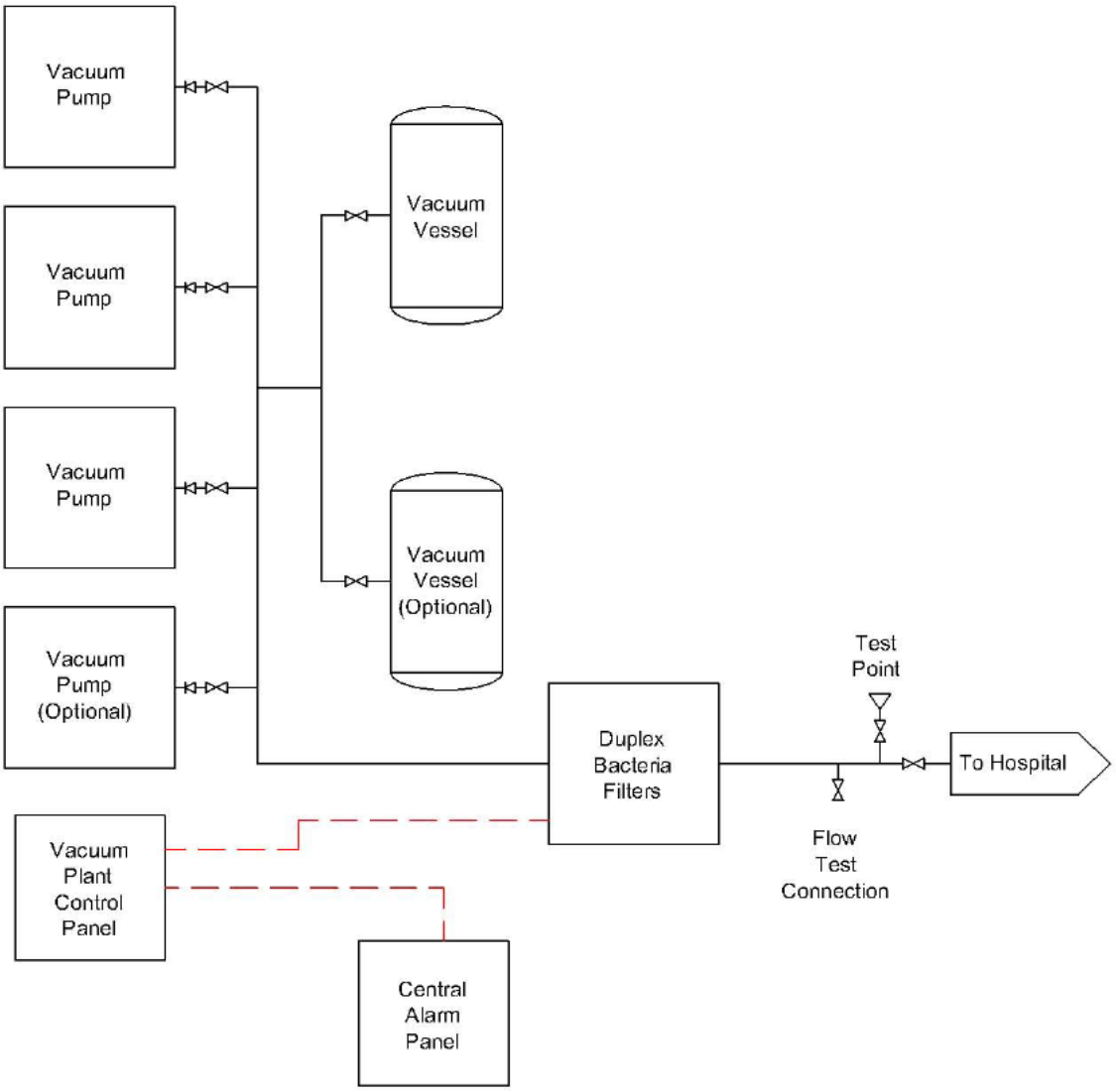


Figure 29: Typical medical vacuum plant

9.8 The plant should consist of at least three identical pumps, a vacuum reservoir(vessel) with by-pass facilities, duplex bacteria filters with drainage traps, appropriate non-return valves, isolating valves, gauges and pressure switches, an operating and indicating system, an exhaust system and a flow test connection. For capacities in excess of 500 litres/min, two vessels that can be independently isolated should be installed.

Note 22: The third means of supply for a vacuum installation will comprise of portable suction equipment and/or the third vacuum pump of a triplex pump system.

Siting

9.9 The plant should have all-round access for maintenance purposes, and allowance should be made for changing major components.

9.10 The siting of the plant should allow for adequate flows of air to cool the pumps. The manufacturers should be consulted over the range of operating

temperatures for which the supply system is designed. In extreme cases, refrigerator cooling may be required.

Pump noise

9.11 The noise level produced by the pumps will increase with the capacity of the supply system. For larger systems this can result in an unacceptable noise level at the pump. The maximum free-field noise level at 1m from the un-silenced pump should not exceed the following values for individual pumps:

Power (kW)	Noise level (dBA)
5	75
5.1 -15	82
15	89

Table 34: Vacuum pump noise levels

9.12 A suitable acoustic enclosure may be required in the purchase specification for all pumps with a free-field noise level at 1m of 80 dBA or over. An enclosure should produce a reduction of at least 10 dBA in the free-field noise level at 1m. Vacuum pumps should be mounted on anti-vibration mounts, where necessary, to minimise transfer of noise and vibration to the building structure.

Vacuum plant exhaust

9.13 The position of the termination point should be carefully chosen to be clear of windows, ventilation intakes and the intake of air compressors and other equipment, since for oil-lubricated pumps the vacuum exhaust is likely to be polluted with oil fumes.

9.14 Noise from the exhaust should be considered and a silencer fitted if necessary.

9.15 The construction should conform to the following criteria:

- the exhaust should be sized to give a back pressure at system design flow which is matched to the pump performance;
- the termination point should be turned down and provided with protection to reduce the effect of wind pressure and prevent the ingress of rain, snow, insects or animals;
- weatherproof notices should be fixed at the discharge point(s) with the legend “medical vacuum discharge point – do not obstruct”;
- the exhaust pipe should be provided with a drainage valve and transparent collection jar at its lowest point;
- a silencer should be fitted in the exhaust pipe from each pump. This may be integral with the pump unit.

Efficiency

9.16 The pump should be capable of producing a higher vacuum than that required in the pipeline, so that the resistance of the bacteria filter and back pressure in the exhaust system can be overcome.

9.17 The capacity of the vacuum pump should be specified in terms of the free air aspirated (FAA) in litres/min when the pump is operating at a vacuum of 475 mmHg (63 kPa) and at 450 mmHg (60 kPa) at the plant pipeline connection.

Vacuum pumps

9.18 Any type of pump apart from water-sealed pumps can be used.

9.19 Pumps should normally be oil-lubricated. Vapours from the lubricating oil are unlikely to be a significant component of the exhaust gases if correctly maintained. “Dry running” rotary vane pumps are available at increased capital cost and with lower efficiency than oil-lubricated pumps of comparable performance.

9.20 At least three pumps should be provided. The actual number is at the discretion of the plant manufacturer to ensure optimum cost benefit of the system. All pumps should be designed for high frequency stop/start or continuous operation. The opportunity to maximise energy conservation should be taken into consideration. Variable speed / frequency inverter drive motors are being increasingly used in industry with consumption being electronically controlled to give rapid response to any output change and avoiding the energy wasteful start/stop frequency within the present wider pressure change corridor. Dental centralised systems and AGSS are obvious applications for such systems but could equally apply to medical vacuum systems with the larger capacity pipe sizing in many instances avoiding the need for a reservoir.

9.21 All systems should comprise pumps and motors of identical type that are suitable for continuous running and stop/start operation.

9.22 Pump motors should comply with the Model Engineering Specification C51 – ‘Electrical requirements for specified equipment’ with the addition of Class F insulation and Class B temperature rise.

Vacuum reservoirs

9.23 In conventional pump control a vacuum reservoir should be provided so that the duty pump does not run continuously for low loads. The reservoir should be manufactured in accordance with BS EN 286-1:1998 + A2: 2005, with test certificates provided to the user. The minimum test pressure should be 400 kPa / 4 bar. For variable speed applications seek advice from the manufacturer.

9.24 The water capacity of the reservoir should be equal to the plant design flow at 450 mmHg (60 kPa) in terms of free air aspirated in one minute with the pump operating at 475 mmHg(63 kPa).

9.25 Provision should be made for draining the reservoir under vacuum conditions. By-pass facilities should be provided so that the reservoir can be drained and inspected without interruption to the vacuum supply. The reservoir should be fitted with suitable lifting lugs and feet.

9.26 If multiple reservoirs are provided, they should be arranged in parallel.

Bacteria filters

9.27 The bacteria filters and drainage trap should comprise two identical sub-assemblies with manually-operated isolating valves, arranged to allow either sub-assembly to be on stream. Each sub-assembly should contain a bacteria filter rated at the plant capacity.

9.28 The bacteria filter should be marked with the legend “bio-hazard”, together with a description of a safe procedure for changing and disposing of the filters and emptying the drainage trap. Refer to Part B of this SHTM – Appendix D.

9.29 The bacteria filters should have a filter efficiency, when tested by the sodium flame test in accordance with BS3928:1969, of greater than 99.995% at the system design flow.

9.30 The pressure drop across a clean filter at the system design flow should not exceed 25 mmHg (3 kPa) at a vacuum of 475 mmHg (63 kPa).

9.31 The drainage trap may be integral with the bacteria filter and should be fitted with a transparent bowl to collect liquid. The bowl should be suitable for steam sterilization at 134°C.

9.32 Although there is no firm evidence that has demonstrated the need for bacteria filters, it is recommended that such devices are included as precautionary measures.

Pressure control

9.33 The cut-in setting for the vacuum pumps should be adjusted to allow for the pressure drop across the pipeline distribution system and the bacteria filters. The cut-in may be expected at about 500 mmHg (67 kPa).

9.34 The cut-out setting should be at an appropriate point on the performance curve of the pump, which minimises stop/start operation but is at a vacuum which is economically attained by the pump. This cut-out setting may be expected at about 650 mmHg (87 kPa).

Valves

9.35 Non-return valves should be fitted, when necessary, at the inlet and outlet of each pump to prevent backflow when a common discharge pipe is used. (Some vacuum pumps include integral non-return valves).

9.36 Manually operated valves should be arranged in the positions shown in Figure 29 to allow isolation of components such as pumps, reservoirs, by-pass pipework, drainage traps and bacteria filters.

Pressure regulation of vacuum system

9.37 A minimum vacuum level of 300 mmHg (40 kPa) is required at the connection point of each terminal unit with a flow of 40 litres/min whilst the system is operating at system design flow.

9.38 This performance is tested by the procedures carried out in accordance with Section15.

9.39 A maximum pressure drop of 100 mmHg (13 kPa) is allowed across the terminal unit at a free air flow of 40 litres/min to provide a minimum pressure of 300 mmHg at a pipeline pressure of 400 mmHg. At lower negative pressures, the volumetric flow would increase by expansion and be represented by a larger pressure drop across the terminal unit. Such tests must be qualified by the pipeline pressure at the time of test. The minimum pressure permitted at the front of the furthest terminal unit on each branch line should be 300 mmHg (40 kPa) at a flow of 40 litres/min. When the system is subjected to the total design flow, the minimum dynamic pipeline pressure from the plant should be 450 mmHg (60 kPa).

Vacuum indicators

9.40 Vacuum indicators should comply with BS EN 837-1:1998 or have an equivalent performance if electronic indicators are used. Calibration should be 0–760 mmHg (0–101 kPa). All gauges should be a minimum scale length of 90mm.

9.41 Vacuum indicators should be located on:

- the plant control unit indicating the vacuum in the pipeline (that is, on the pipeline side of the bacteria filter);
- each reservoir.

9.42 A differential vacuum indicator (to indicate filter blockage rather than quantitative pressure drop) should be located across the bacteria filter and have a service isolation valve.

Electrical supply

9.43 The electrical supply to the medical vacuum plant should be connected to the essential electrical supply. The control system should ensure that pumps restart in sequence to avoid overloading the power supply.

Pump operating and indicating system

General description

9.44 The operating and indicating system should perform the following functions:

- overall plant control and indication;
- individual pump starting;
- plant status monitoring and indication;
- alarm signal status unit.

9.45 Provided that the individual pump starters are housed in a separate compartment, the operating and indicating system may be housed in separate units or may be installed in a common panel and located on the plant or on the plantroom wall.

9.46 Pneumatic components should have ventilation. All functions should be appropriately identified. Indicators should have a design life of at least five years. The operating system should be capable of automatically restarting after reinstatement of the power supply.

Plant control unit

9.47 The control unit should have a separate power supply for each pump controlled by a separate sub-circuit. It should be manufactured and installed in accordance with IEE regulations, and the design should be such that no single component failure in the control unit will result in loss of plant output.

9.48 The unit should allow either manual selection of duty/stand-by for each of the pumps or have an automatic sequence selection with a means for manual override. The control unit should ensure that two or more pumps do not start simultaneously when power is applied.

9.49 A warning notice which complies with BS5499-5: 2002 should be affixed which indicates the presence of low voltage.

9.50 For testing purposes, each pump should have a selector switch which when turned to the “on” position allows the pump to run continuously.

Plant control indication

9.51 There should be indicators for each pump as follows:

- green “mains supply on”;
- green “pump operating”, which indicates that the pump motor is electrically energised;
- green “pump operating”, which indicates that the pump is drawing vacuum;
- an analogue or digital gauge registering the vacuum level within the pipeline.

Pump starter units

9.52 There should be individual starter units, each one operating a single designated pump. The starters should be provided with safety interlocks as specified by the

pump manufacturers, which should inhibit plant operation until manually reset by means of a button. The starters should allow automatic restart after an interruption to the power supply. Each starter unit should contain the following:

- an isolator interlocked with the covers;
- an emergency stop;
- either HRC fuses to BS88 or suitable circuit breakers to BS EN 60947-2: 2006 + A1: 2009 and/or BS EN 60898-1: 2003 + A1: 2004;
- starter;
- an industrial grade ammeter to BS EN 60051-1: 1999, IEC 60051-1:1997 or an electronic digital instrument of comparable, or higher, standard;
- a total hours run counter, if not included in the plant control unit;
- a green “mains supply on” indicator, if mounted separately from the plant control unit.

Plant status monitoring

9.53 A monitoring system must be provided to detect the following faults in the vacuum supply system:

- plant faults for each pump:
  - control circuit failed;
  - motor tripped;
  - pump failed to go on load;
  - activation of other safety devices supplied by the manufacturers;
- plant emergency – receiver vacuum has fallen, for example, by 50 mmHg below the cut-in setting for the pump;
- pressure fault (pipeline) – pipeline vacuum less than 360 mmHg.

Plant status indicator unit

9.54 In addition to the plant control indication, there should be a plant status indicator panel that may be mounted on the plantroom wall or adjacent to either the pump starter unit or the plant control unit. It should have a warning notice that complies with BS5499-1: 2002 to indicate the presence of low voltage.

9.55 There should be indicators for each pump to show the following conditions:

a) green “mains supply on”;
b) yellow “control circuit failed”;
c) yellow “motor tripped”;
d) yellow for each individual safety device provided by the manufacturers;
e) yellow “pump failure”.

Alarm signal status unit

9.56 The following indication of plant conditions should be provided:

a) green “normal” (indicator normal);

b) yellow “plant fault” conditions (b)–(d); see paragraph 9.55;

c) yellow “plant emergency” condition (e); see paragraph 9.55;

d) red “pipeline pressure fault” (pressure fault).

9.57 Conditions (b) to (d) of paragraph 9.56 should be transmitted to the central alarm system. Where relays are used, they should be normally energised relays, which de-energise under fault conditions, with contacts having a minimum rating of 50 V d.c. and 50 mA.

9.58 Volt-free, normally closed contacts rated at 50 V d.c. and 50 mA should be provided for transmission of conditions (b) to (d) of paragraph 9.56 to the alarm system.

9.59 The panel can be incorporated into the plant status indicator unit or be a separate unit within the plantroom. If mounted separately, the cabling should be monitored for open/short circuit. In the event of such a cabling fault, a red “system fault” lamp should be illuminated on the alarm system status unit together with the appropriate alarm condition.

Plant management

9.60 Connections should be provided which allow monitoring (but not control) of plant alarm conditions (b) to (d) of paragraph 9.56 and pump running for each vacuum pump. These connections should be normally closed, volt-free contacts for each condition having a minimum rating of 50 V d.c. and 50 mA.

9.61 Plant should be operated in accordance with the manufacturer’s instructions and be covered by a sound, effective planned preventative maintenance (PPM) policy.

10. Anaesthetic gas scavenging disposal systems

Terminology

10.1 An active system, as specified in either BS6834: 1987 or BS EN ISO 7396-2: 2007 is one in which a high air flow generated by an electrically driven pump is used to exhaust air through the system's fixed pipework. This in turn entrains waste gases from the patient, or patient ventilator, via a transfer hose and receiving system.

10.2 The transfer and receiving system form part of the anaesthetic/breathing system.

10.3 The receiving system is designed to match the variable flow in the breathing system to the constant flow of the disposal system and ensure that very low induced flows are imposed (0.5 litres/min in the case of BS6834:1987 and 0.05 litres/min in the case of BS EN ISO 7396-2: 2007).

10.4 In the UK, only systems complying with the BS or EN Standards above are considered appropriate for scavenging waste anaesthetic gases from accommodation in which general anaesthesia is taking place.

10.5 Active scavenging for dental installations is an entirely different concept. An active system is one in which there is a flow generated through the patient's nasal mask and this carries away the waste gases exhaled by the patient. This flow is in the order of 45 litres/min and is achieved by connection of the mask (via a suitable flow-limiting adaptor or terminal screw adjustment) to an active scavenging system (BS/EN) wall terminal unit. Alternatively, a Group 3 local active unit is available designed for dental purposes. Consideration should be given to providing additional room ventilation i.e. high level supply and low level extract.

General

10.6 Anaesthetic gases are considered to be substances hazardous to health for the purposes of the Control of Substances Hazardous to Health Regulations 2002 (COSHH), except where they are administered to a patient in the course of medical treatment.

10.7 Detailed guidance on compliance with COSHH is given in the Department of Health's (1996) 'Advice on the implementation of the Health & Safety Commission's occupational exposure standards for anaesthetic agents'. Further guidance is given in by the Health & Safety Executive's (1996) 'Anaesthetic agents: controlling exposure under COSHH'.

10.8 The COSHH regulations set out very specific duties that apply to anaesthetic gases, and employers have a legal obligation to ensure that these duties are discharged. It is therefore the responsibility of the general manager or chief

executive to implement the requirements of the COSHH regulations with respect to anaesthetic gases. This subject is covered in Part B.

10.9 For new installations, an assessment should be made of the transfer and receiving equipment currently in use and intended for use with the new installation. Where the transfer and receiving equipment has been designed to BS6834:1987, the disposal system design should be to BS6834:1987. Where the transfer and receiving equipment in use has been designed to BS EN 740:1999, the disposal system should be designed to BS EN ISO 7396-2: 2007. Where a mixture of equipment is in use, the system should be designed to BS6834:1987. Where both types of equipment are required to be used on the same disposal system, a restrictor should be provided for the BS EN 740:1999 equipment to restrict the flow to its design flow rate. The system should be installed in all operating departments and other areas, as required, in accordance with the levels of provision given in Table 11.

Note 23: BS6834: 1987 covered all aspects of the anaesthetic gas scavenging systems. BS EN 737-2: 1998 and BS EN 737-4: 1998have now been replaced with BS EN ISO 7396-2: 2007 and BS EN ISO 9170-2: 2008 respectively.

10.10 A typical system schematic is illustrated in Figure 30a and 30b and shows the terminology used.

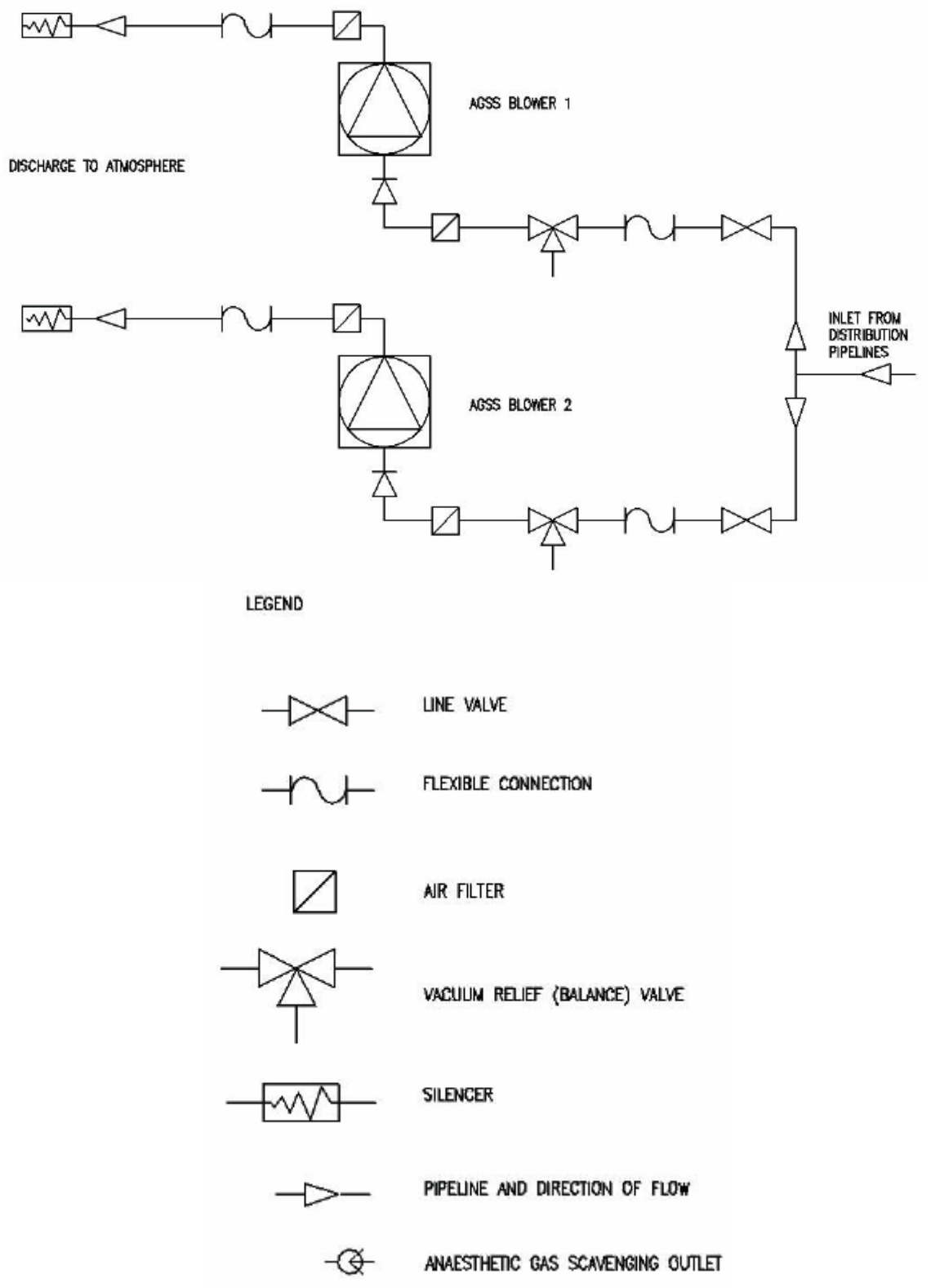


Figure 30a: AGSS Plant schematic (duplex blowers shown)

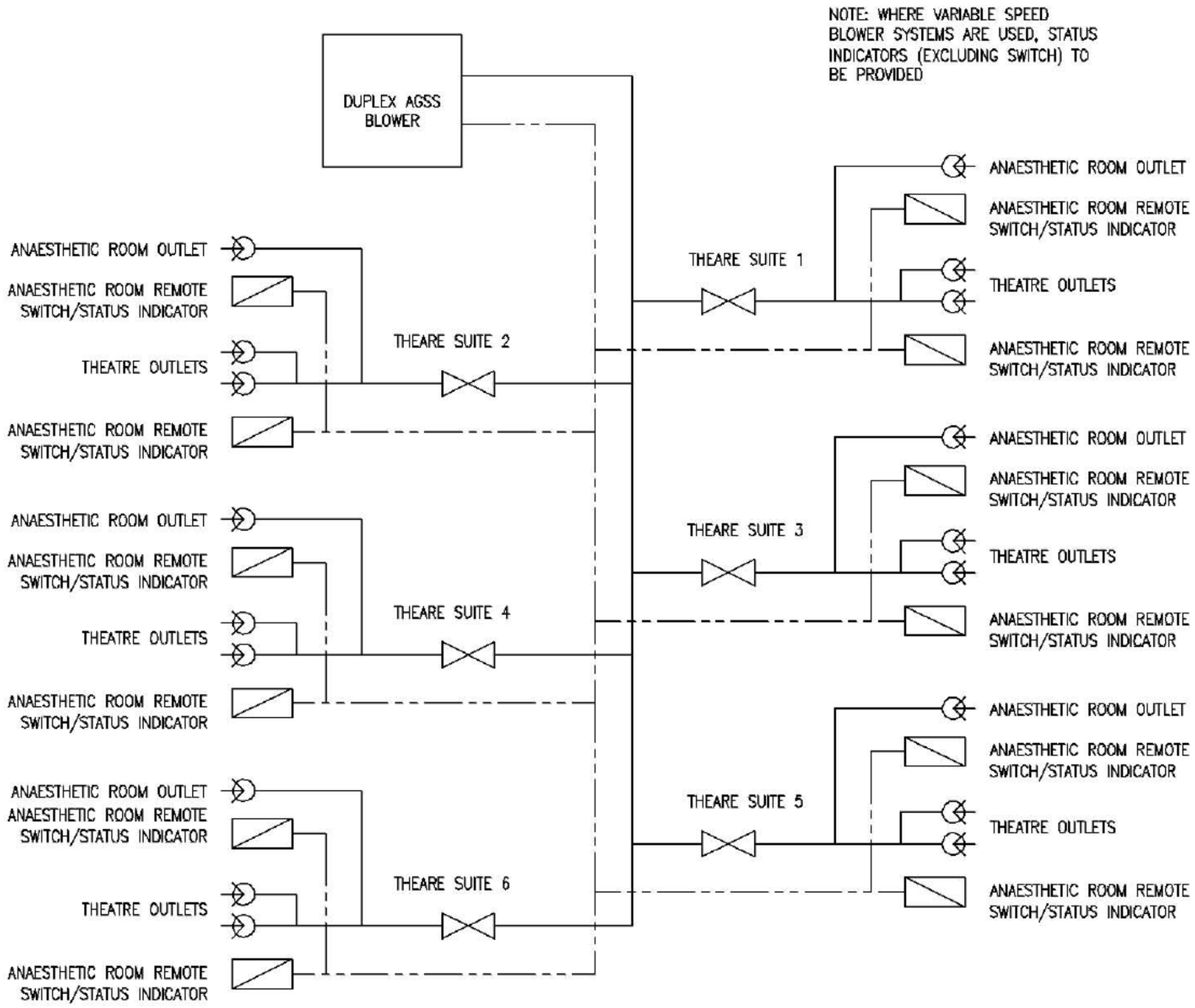


Figure 30b: Pipeline schematic, including remote AGSS switching

10.11 The internal components and pipework of AGS disposal systems are in contact with a patient's expired breath. Even though there is considerable dilution by virtue of the receiving system that forms part of the anaesthetic equipment, there is, however, potential for bacteriological contamination. The materials should be reasonably resistant to corrosion and should withstand cleaning, disinfection or sterilization as appropriate.

10.12 The fixed pipework may be of copper or other suitable material such as PVC. Where copper pipework is installed at the same time as the MGPS, it is desirable to use degreased pipework to the same specification as that used for the MGPS (see Section13) in order to avoid confusion. Pipeline pressure testing and loss allowances should be in accordance with the requirements for medical vacuum pipeline pressure tests.

10.13 Where PVC pipes larger than 38mm diameter pass through a fire compartment, they should be protected with metal sleeves extending for 1m either side of the compartment in accordance with the Building (Scotland) Amendment Regulations 2006. The recommendations of Firecode and Scottish Health Technical Memorandum 81 should be followed.

Selecting the number of disposal system pumps

10.14 The number of disposal system pumps selected for operating theatre suites should be determined through consideration of a number of factors including: the number of theatres concerned; the layout of the department; the degree of difficulty associated with the pipework installation; a cost comparison between systems; together with an evaluation of the impact and level of disruption likely to be realised in the event of a fault condition occurring which could result in the loss or partial loss of the system. The following selections could be considered:

- An individual pump per theatre suite will not maintain the system under a fault condition. Spare pumps can be carried in store, however, the disruption factor and outage time must be taken into consideration.
- A duplex pump set will ensure continuity of supply in the event of a single fault condition. When applied in conjunction with other control measures, such as the mechanical ventilation system providing the specified number of air changes for the room, the exposure to anaesthetic agents should be maintained below the prescribed occupational exposure standards in compliance with the COSHH requirements being achieved.
- When specifying a simplex or duplex pump set providing AGS to a number of areas, consideration must be given to future maintenance requirements which will require all rooms with an AGS outlet on the system to be accessed almost simultaneously for the purposes of carrying out a system performance test either as a ppm activity or following modification of the system.

Note 24: Anaesthetic gas scavenging systems when installed, commissioned and operated should maintain the service in normal use and on a single fault condition. To ensure continued service under a fault condition as required by European Standards, a minimum of a duplex pump plant assembly would be required. The single pump arrangement with a replacement pump in store would not meet the requirement for maintaining the service under a single fault condition. The impact and level of disruption to service in the event of simplex plant failure should be carefully evaluated when finalizing the plant selection.

10.15 Historically a fixed volume exhauster was installed which generated noise, at times unacceptable depending on location and was not energy efficient. With respect to patient safety, the air admittance valve imposed a further risk factor and in most instances staff failed to switch off the system when not in use, resulting in 24/7 exhauster operation and premature replacement of plant. In order to avoid such problems, variable speed/ frequency inverter vacuum pumps should be considered as a first option. As described in other sections of SHTM 02–01 the electronic control will give optimum efficiency with virtual instantaneous response to any output demand. If required the controller will automatically engage the standby pump within preset parameters, however, normally the duty pump would be sized for the design flow taking account of the appropriate diversity factors.

10.16 With variable speed control, tight pipeline pressure loss tolerances, pipe sizing and a terminal unit with variable screw adjustment, the system can be designed to meet the performance requirements of both BS6834: 1987 and BS EN ISO 7396-2: 2007. Protection of the system should include a safety relief valve set to suit system requirements.

10.17 The number of operating theatres and departments served by any one system should be estimated by plant location to departments. Eventually separate switching at each terminal unit should not be a requirement, however, it remains a requirement of BS6834, therefore switching should remain for the present even though the variable speed motor will adjust or automatically closedown at no demand. Further consideration should be given to the location of the plant control indication which rather than individually located at each plant control switch, can be incorporated within the area alarm panel.

Flow and diversity

10.18 Although more than one AGS terminal unit may be installed in an operating room or anaesthetic room for convenience, it may be assumed that only one terminal unit in each room will be in use at any given time. The AGS terminal unit in the anaesthetic room and operating room, however, may on rare occasions be in use simultaneously; therefore, the plant is sized for two AGS terminal units for each operating suite.

10.19 The performance criteria for the disposal system are specified in the relevant British, European and International Standards in terms of the extract flows at specified resistance. The disposal system should meet the requirements set out in the table

	Disposal system standard			
	Pressure drop		Flow rate	
	BS6834: 1987	BS EN ISO 7396-2: 2007	BS6834: 1987	BS EN ISO 7396-2: 2007
Maximum	1 kPa	1 kPa	130 Litres/min	80 Litres/min
Minimum	4 kPa	2 kPa	80 Litres/min	50 Litres/min
Maximum static pressure	20 kPa(-ve)	15 kPa(-ve)		

Table 35: Disposal system pressure and flow rates

Notes applicable to Table 35: a) Since the preparation of BS6834:1987, developments in anaesthesiology have resulted in reduced flows being used. Depending on local circumstances, it may be possible to commission systems for different flows in accordance with BS EN ISO 7396-2: 2007.

b) Details of the test flows should be recorded in the commissioning documentation.

c) The pump inlet should include a vacuum indicator for commissioning and servicing purposes.

Discharge outlet

10.20 Careful consideration should be given to the siting of the discharge from the disposal system. It should preferably be sited at roof level, well away from ventilation inlets, opening windows and other apertures, to prevent pollution re-entering the building. Signage should be provided in accordance with Appendix K.

Plant control indication

10.21 There should be indicators to show the following conditions:

- green “mains on”;
- green “air flow” normal;
- yellow “duty pump failed” (plant fault) – applies to duplex plant only;
- red “system failed” (plant emergency).

10.22 Indicator panels should be installed in operating rooms and at other locations where gas scavenging is available.

10.23 The “air flow normal” indication should be initiated by either a pressure switch or air flow detection device at the pump when vacuum is established within the pipeline.

11. Other medical gas pipeline installations

General

11.1 It is possible to extend medical gas system design concepts to other gases used from cylinders and still maintain the elements of gas specificity that are essential requirements together with all other relevant safety considerations.

Helium/oxygen mixture

11.2 Helium/oxygen mixture is used by patients with respiratory or airway obstruction and to relieve symptoms and signs associated with respiratory distress. It can be administered by means of face mask and cannula, a demand valve with face-mask with cannula attached, a nebuliser, or by a ventilator.

11.3 Its main use will be in Accident & Emergency (A&E), supplied from portable cylinders with integral control valve and regulator, and in critical care areas.

11.4 When provided by means of a pipeline installation, all the elements of a manifold supply system for other medical gases should be installed.

11.5 The manifolds will be designed to operate at low pressure (10 bar), and connection to K-size cylinders will be made by means of a low-pressure flexible assembly to a terminal unit integral with the cylinder regulating valve. The connection to the manifold will be by means of a NIST connector.

11.6 The individual cylinders will include pressure transducers to monitor the pressure upstream of the integral control valve. (Cylinders do not necessarily discharge simultaneously.)

11.7 The manifold should be located close to the facility that it supplies.

Compressed Gas Cylinder Manifold Systems		
Primary supply	**Secondary supply**	**Tertiary supply (third source of supply)**
Duty bank of a fully automatic manifold. Number of cylinders based on system design.	Standby bank of a fully automatic manifold.	Manual emergency reserve manifold - to come on-line automatically via a non-return valve in the event of a single fault condition and to act as a reserve supply during maintenance / repair works Type and capacity of supply to be determined by risk assessment.

Table 36: Compressed gas cylinder manifold systems

Oxygen/carbon dioxide mixture

11.8 Oxygen/carbon dioxide mixture has been supplied by pipeline in at least one installation in the UK for anaesthetic purposes in cardiothoracic procedures.

11.9 There has been little interest shown in installing others and, therefore, this medical gas is no longer included within the scope of this Scottish Health Technical Memorandum.

Carbon dioxide

11.10 Carbon dioxide is now not generally used as a respiratory stimulant post-operatively. Pipelines have not been installed in the UK for respiratory applications. Its main use today is for insufflation during surgery, and to date there have been some installations in the UK.

11.11 When pipeline systems are installed for such purposes, the general requirements for other medical gas pipelines should be followed. The terminal unit should comprise a NIST connector with integral check valve contained in the surgeon's pendant. The level of provision of AVSUs should be provided as for other medical gas pipelines.

11.12 A semi-automatic manifold will normally be satisfactory and it should be installed "locally". A 2x4 VF-size manifold will provide adequate capacity. The safety valve discharge should be taken outside the department. The warning and alarm system indicator will normally be installed in the operating room control panel.

Nitric oxide

11.13 Treatment using nitric oxide is subject to specific Ph. Eur. requirements. Distribution of the gas by pipeline systems is not considered appropriate.

12. Warning and alarm systems

General

12.1 The provision of a warning and alarm system is essential to monitor the safe and efficient operation of an MGPS. There are three reasons for this monitoring:

- to indicate normal function of the pipeline system by means of visual indicators;
- to warn by visual and audible indication that routine replacement of cylinders or other engineering action is required;
- to inform the user by visual and audible emergency alarms that abnormal conditions have occurred which may require urgent action by the user. This alarm condition will require a rapid response by the various departmental staff.

12.2 To date, practice has been to have a “dedicated” medical gas warning and alarm system and this approach will remain in many situations. With the development of computer-based integrated patient/ management systems, nurse call and other alarm systems, however, there is considerable scope for including medical gas system information including text action prompts etc. Additionally, building management IT-based systems will play an increasing role in the operation and management of an MGPS.

Dedicated systems

12.3 The requirements of “dedicated” warning and alarm systems are covered in paragraphs 12.3 to 12.62 and a schematic diagram of a typical central system layout is shown in Figure 31. Warning and alarm systems are required for all medical gas and vacuum systems. A simplified system is required for AGSS, with the warning/indication panel located in the operating room or other area where AGSS is used.

12.4 Warning and alarm systems comprise pressure sensors, a central system providing information on all monitored functions, with repeater panels located where information is required to ensure the necessary action is taken. Area alarms should be provided to give warning to users downstream of the designated departmental AVSU (see Section 3).

12.5 Pressure sensors should be connected to the pipeline by means of a minimum leak device. Whenever possible, pressure sensors should be installed outwith the ceiling space e.g. within wall mounted AVSU panels, within individual AVSUs or within a dedicated panel or box. Where this cannot be achieved, ventilation of the space will be required.

12.6 All MGPS warning and alarm indicating panels should comply with the requirements of this Scottish Health Technical Memorandum, including all operating room panels.

Panel location

Central indicator panel

12.7 Warning and alarm conditions for all medical gas supply systems should be displayed on a central panel located in a position where there is continuous 24-hour occupation, such as the telephone switchboard room or the porters' lodge.

Repeater indicator panel

12.8 Repeater panels should be provided in other locations to display all or some of the information on the central alarm so that appropriate action can be taken to ensure the continuing operation of the system. Some warning system information may be appropriate for display in specific departments, for example cylinder manifold status information in a porters' room, and oxygen concentration in the pharmacy department when a PSA plant supplies the hospital pipeline installation. The inclusion of a repeater alarm panel within critical care areas (ITU, CCU, HDU, SCBU etc.) should be considered to advise staff of high / low pressure fault conditions and whether the emergency supply is in use.

Area warning and alarm panel

12.9 Area panels to display "high" and/or "low" gas pressure should be installed in the locations given in Section 3. The sensors for these panels should be located downstream of the designated AVSUs, normally the departmental AVSUs. It should not be possible to isolate the sensor with a separate shut-off valve and they should be connected to the pipeline by means of a minimum leak device.

System components

12.10 Warning and alarm systems include the following functional elements:

- interfaces/transmitters that convert the signal from the plant or manifold Volt-free alarm contacts into a form which can be transmitted via multiplexed cable (for example using pulse-width modulation). The transmitter may be a separate unit or may be incorporated:
  - in plant or into a manifold control panel;
  - into an indicator panel. Line-fault monitoring devices should be included in both cases;
- indicator panels which display the transmitted signals;
- interconnecting multiplex wiring which connects all interfaces/transmitters to all indicator panels.

System layout

Central plant alarm system

12.11 A typical system layout is shown in Figure 31, which shows initiating devices at remote locations such as the VIE compound, medical air and vacuum plantrooms, manifold rooms and emergency/reserve manifold rooms. The transmitters are normally located close to the initiating devices. Central / repeater alarm panels are typically located at the telephone exchange, the security room, the porters' room and the engineer's office to provide information requiring action by engineering and other support staff.

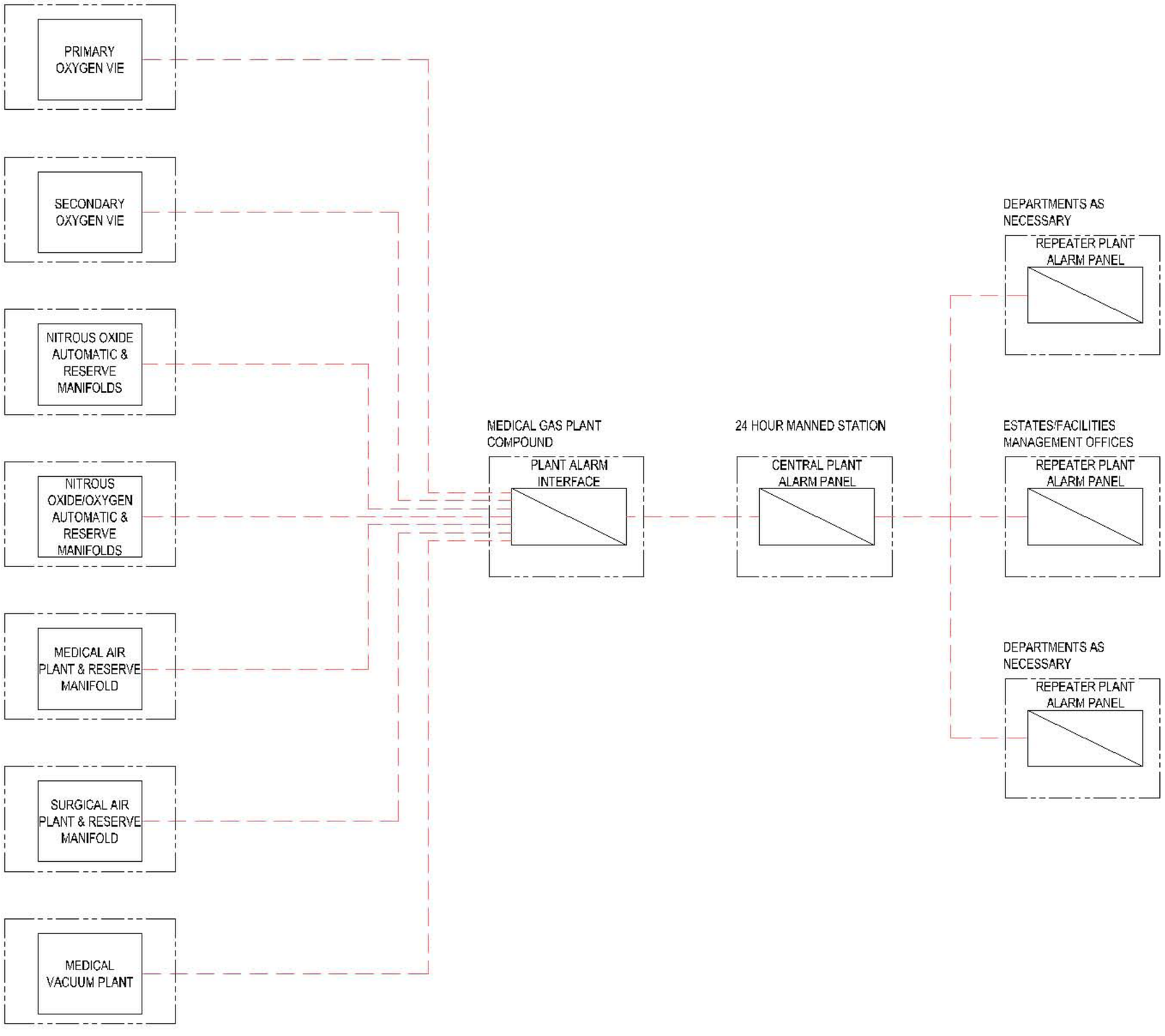


Figure 31: Central plant alarm

Area alarm systems

12.12 A typical layout of an area alarm system is shown in Figure 32 for illustration purposes. For each gas service there should be local pressure switches for low pressure; high pressure switches are also required when there is any combination of oxygen, nitrous oxide and medical / surgical air installed together. These conditions should be indicated on a locally-mounted indicator panel, with the facility to provide a common alarm condition for connection to other repeater alarm panels. In situations where the staff base is not in close proximity to the AVSU module / pressure switches, the area alarm panel should be located where it will be both audible and visible from the staff base. Area panels carry no indication of the warnings for cylinder replacement and plant functions that are given on central indicator panels.

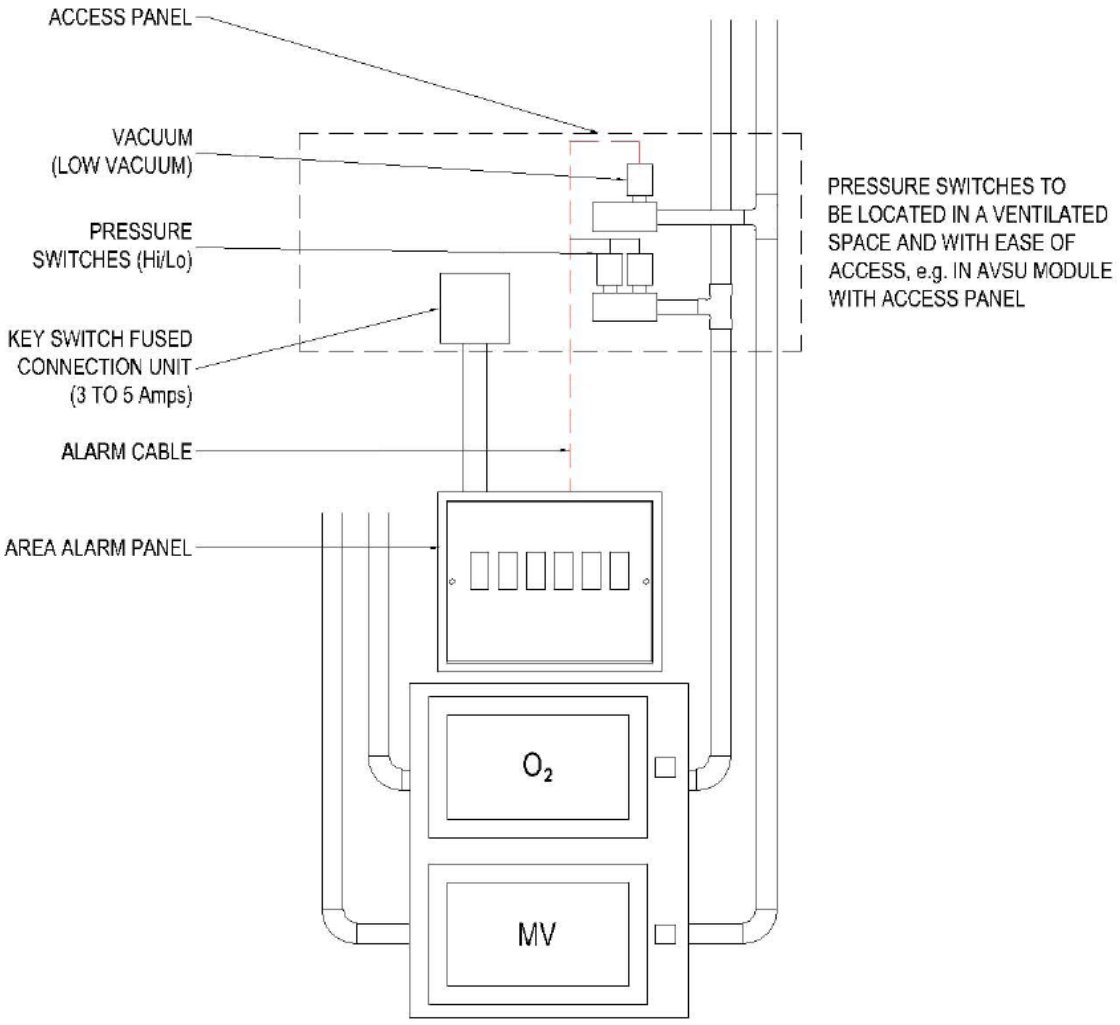


Figure 32: Area alarm panel arrangement (2-gas service shown)

General requirements

Labelling

12.13 All visual signal panels should be permanently labelled according to their function, including clear identification of the areas, rooms or departments served.

Visual signals

12.14 Flashing visual signals should have alternate “on” and “off” periods, each of equal duration between 0.25 and 0.50 seconds.

12.15 There should be two separately energised light sources for each signal, arranged so that the failure of one source does not affect the other.

12.16 The light sources should have a design life of at least five years of continuous operation.

Audible signals

12.17 All audible signal tones should be modulated equally at a rate of 4 Hz ±10% between two tones of 440 Hz ±10% and 880 Hz ±10%.

Automatic resetting

12.18 When a warning or alarm signal occurs and the system condition subsequently reverts to normal, the corresponding visual and audible signals should automatically reset to normal.

Temporary muting

12.19 Means must be provided on each panel for the user to mute the audible signal. The signal must re-sound after a nominal 15-minute period if the fault condition still exists. The process of muting and reinstatement of the signal should be repeated until the fault condition has been rectified. Operation of the mute on the central panel should be accompanied by change from flashing to steady illumination of the corresponding visual indicator irrespective of the number of alarm conditions displayed on the central and any repeater panels. Operation of the mute on area alarm or repeater panels should not be accompanied by a change from flashing to steady illumination.

Continuous muting

12.20 An internally-mounted switch should be provided to allow continuous muting during periods of maintenance. When the system condition returns to normal, the continuous muting should automatically reset to normal operation. When the continuous muting is in operation on any alarm condition, it should not prevent the operation of the audible signal on other alarm conditions when a fault condition arises.

Electrical wiring

12.21 All electrical wiring should be in accordance with IEE Regulations.

System integrity

12.22 If extra low voltage (ELV), maximum 50 V, is superimposed on the signal or communication circuit (for example by cross-connection), the system design should ensure that any damage to the system is limited to replaceable panel components and that such damage is indicated as a system fault.

12.23 The performance of the system should not be compromised by the use of multi-core cabling that carries ELV and communication signals in adjacent cores.

12.24 The system should be designed to reject spurious radio frequency (RF) or mains noise typically arising in hospitals, examples being diathermy equipment and current spikes caused by plant start-up etc.

Relay conditions

12.25 If relays are used to transmit alarm signals, the relays should be energised in their normally closed condition.

Mains power supply

12.26 The mains electricity supply should be derived from the essential power supply (that is, it must be on the emergency system).

Safety extra low voltage/functional extra low voltage power supply

12.27 The panel power may be designed either as a safety extra low voltage (SELV) system or as a functional extra low voltage (FELV) system, as defined in Part 4 of the IEE Wiring Regulations.

12.28 The ELV power supply may be housed either in the alarm panels or in a separate metal enclosure.

12.29 The power supply should be rated for the full load of the panel, with visual and auditory signals on all normal and alarm conditions.

Test facility

12.30 Each panel should be provided with a means to test all visual and audible signals on that panel. The power supply should be capable of sustaining all indicators and audible signals.

Warning and alarm system faults

General

12.31 A flashing red visual indicator and an audible signal should operate on all panels when any of the following conditions occur:

- line fault from the initiating device;
- communication fault or other wiring fault;
- mains power failure.

Line fault

12.32 The system should monitor the integrity of the lines between the initiating devices and the panel or transmitter units. The "alarm system fault" condition should be indicated on loss of integrity, for example open or short circuits, together with the visual alarm indicator(s) associated with the faulty wiring.

Communication/wiring fault

12.33 The system should indicate an alarm system fault in the event of loss of data transmission between panels and transmitters.

Mains power failure

12.34 Failure of mains power should be shown by a flashing red indicator and an audible signal, which should be powered from an internal battery. The audible signal may be muted and not automatically reinstate as required under normal power supply (see paragraph 12.19), but the visual indicator should continue to flash until either the fault has been rectified or the battery has discharged.

Stand-by battery

12.35 A battery should be provided with sufficient capacity to power the visual and audible "alarm system fault" signal for a minimum period of four hours. The battery should be sealed and exchangeable, and should automatically recharge within 72 hours.

Legend

12.36 The legend on this indicator should be "alarm system fault".

Indicator panel requirements for all systems

Indicators

12.37 Panels should be provided with all indicators for the gas services in local use.

12.38 The visual indicators should be arranged vertically in priority order, with the normal indicators at the top. The sequence of gas services should be, from left to right:

- medical oxygen (cryogenic and cylinders/ pressure swing adsorber (PSA) systems);
- nitrous oxide;
- nitrous oxide/oxygen mixture;

- medical air 400 kPa (compressor plant, cylinders and synthetic air);
- surgical air 700 kPa;
- medical vacuum plant;
- helium/oxygen mixture.

12.39 In addition to the gas service signal indicators, each panel must include:

- a green “power on” indicator without an audible signal;
- a red “alarm system fault” indicator with an audible signal.

Labelling

12.40 Panels should be labelled as follows:

- medical gas alarm;
- with the identification of the medical gas services indicated, and the areas and departments served.

Construction

12.41 The fascia panel should be removable to allow access to the rear of the fascia or to the panel for maintenance purposes.

12.42 Access to the interior of the panel should be tamper-proof.

12.43 It should be possible to replace the source of illumination without removing the legend.

12.44 Panels should have electrical sections with protection at least equal to IP4X as defined by BS EN 60529:1992.

12.45 Panels and their housings should be of adequate strength for their purposes and be manufactured from corrosion-resistant materials.

12.46 If gas services are brought into the panel, they should be housed in separate, enclosed compartments, which are vented to the outside.

12.47 There should be gas-tight seals where electrical services pass through any gas compartment.

Remote audible sounder

12.48 All panels should have provision for connection to a remote audible sounder.

Central indicator panel requirements

Displays

12.49 The central panel should display all signals for all MGPS which are generated by the warning and alarm system, as described in paragraphs 12.50–12.53, below.

Normal

12.50 The normal condition for all piped MGPS should be displayed as a steady green visual signal. The “normal” indicator should extinguish in warning and alarm conditions.

Warnings

12.51 Warning conditions appropriate to each MGPS should be displayed as a flashing yellow visual signal that may be accompanied by a mutable audible signal (see Table 37).

Emergency alarms

12.52 Emergency alarms are generated by loss of pipeline pressure or vacuum and are indicated by flashing red visual signals accompanied by mutable audible signals.

Alarm system fault

12.53 The “alarm system fault” condition should be displayed as a flashing red visual signal accompanied by a mutable audible signal.

Mute functions

12.54 The temporary mute should cancel the audible signal for about 15 minutes and change the visual indicators from flashing to continuous on all central and repeater panels.

12.55 Operation of the continuous mute should inhibit the 15-minute reinstatement of the audible alarm.

12.56 Operation of the mute should not inhibit the visual or audible indication of any subsequent alarm conditions.

Panel legend and display

12.57 Panel legend and display should be as shown in Table 37.

Repeater indicator panel requirements

Displays

12.58 The repeater indicator panel should always display “normal”, “emergency alarm” and “alarm system fault” conditions as given above. The repeater panel should display some or all of the warning conditions that are displayed on the central indicator panel. The extent of the display of warnings should be varied to suit local clinical requirements.

Mute functions

12.59 The temporary mute should cancel the audible signal for about 15 minutes whilst the visual indicator continues to flash. Operation of the temporary mute (on the central panel) should change the visual indicator to continuous illumination on the central and any repeater panels.

12.60 Operation of the continuous mute must inhibit the 15 minute reinstatement of the audible alarm.

12.61 Operation of the mute should not inhibit the visual or audible indication of any subsequent alarm conditions.

Panel legend and display

12.62 The panel legend and display should be as shown in Table 37.

Area alarm panel

Panel displays and legend

12.63 Area alarm panels should display the conditions listed in Table 38.

Mute functions

12.64 The temporary mute should cancel the audible signal for about 15 minutes whilst the visual indicator continues to flash.

12.65 Operation of the mute should not inhibit the visual or audible indication of any subsequent alarm conditions.

Integrated systems

12.66 The introduction of computer-based systems for a range of functions such as patient information, nurse call and other alarm conditions provides an opportunity to further include certain provisions of medical gas pipeline warning and alarm conditions. This concept is totally new and, at this stage, the applications have not been thoroughly evaluated or analysed. One of the advantages of the concept is that text prompts can be displayed on the computer display when changes in the status of the pipeline occur, and these prompts can advise staff of the need to take specific action.

12.67 The advantage of a computer-based system is that the advice given in the text message can be varied to take account of specific circumstances, changes in operating procedures and functional changes within individual departments. Such systems are likely to be of most use in in-patient ward accommodation; it may not be appropriate for central warning and alarm conditions or in individual operating rooms and other accommodation in which anaesthetic procedures are taking place.

12.68 It will be necessary to change the perception of users in that with this approach the “normal” conditions of the pipeline systems that are continuously displayed on alarm indicator panels will not exist – audible emissions and displayed messages generated by the computer-based system will be in response to changes from the “normal” situation. To ensure the long-term viability of the system, any supplier or installer of such a system must supply sufficient information about the system to allow modification, expansion or replacement of sections of the system by a third party. This must include source code for any software, passwords and details of any other security device, and details of any communication protocols. This information must be handed to the end-user before the system is accepted by the end-user.

Note 25: No further information can be given at this stage until further development and consultation takes place.

Supply system [1]	Alarm conditions	Legend	Colour	Audible system	Location [2]
Automatic manifold as primary and secondary source of supply	1. Duty bank empty: stand-by bank running	Change cylinders	Yellow	Yes	A B
	2. Stand-by bank below 10% capacity	Change cylinders immediately	Yellow	Yes	A B
Automatic manifold as reserve supply for liquid oxygen and compressed air plant	Manifold to be monitored. Refer to para. 5.15	Reserve low	Yellow	Yes	A B
Compressed cylinders on reserve manifold serving an automatic manifold	Reserve pressure below 68 bar (<14 bar for N_2O)	Reserve low	Yellow	Optional	A B
Medical air compressor and surgical air compressor	1. Plant fault	Plant fault	Yellow	Yes	A B
	2. Plant emergency	Plant emergency	Yellow	Yes	A B
Medical vacuum plant	1. Plant fault	Plant fault	Yellow	Yes	A B
	2. Plant emergency	Plant emergency	Yellow	Yes	A B
Oxygen concentrator	1. Plant fault	Plant fault	Yellow	Yes	A B
	2. Plant emergency	Plant emergency	Yellow	Yes	A B
Pressure fault (pipeline) high or low and oxygen concentration fault for PSA plant	For each gas service to indicate that the pressure in the distribution system has risen/fallen from the "normal" working pressure given in Section 4 and, for PSA plant, that O_2 concentration <94%	Pressure fault	Red	Yes	A B
Vacuum pressure (pipeline)	To indicate that vacuum in the pipeline distribution system has risen above the normal working pressure given in Section 4	Pressure fault	Red	Yes	A B

Table 37: Signals and displays for central alarm panels and repeater panels

Notes applicable to Table 37: 1. For liquid supply systems, see Section 6.

2. A = Central alarm panel – telephone room and/or porters' room, ie. with 24-hour occupancy.

   B = Facilities Management office reception.

3. Locations should include Critical Care Areas, (ITU, CCU, HDU, SCBU, A&E Resuscitation, etc.) can be considered as appropriate.

Alarm function	Legend	Colour	Auditory signal
For oxygen, nitrous oxide and medical air(1) to indicate that the pressure in the pipeline serving the department has risen above the normal value given in Section 4	High pressure	Red	Yes
For each gas service to indicate that the pressure in the pipeline serving the department has fallen below the normal value given in Section 4	Low pressure	Red	Yes
For vacuum to indicate that the pressure in the pipeline serving the department has risen above the normal value given in Section 4	Vacuum fault	Red	Yes

Table 38: Area alarm panel legend and display

Note 26: A high pressure alarm is only required when oxygen, nitrous oxide and medical air are installed together. Refer to Table 11 for location of area panels.

13. Pipeline installation

General

13.1 Generally, MGPS should be kept away from areas where they may be subject to any of the following:

- mechanical damage;
- chemical damage;
- excessive heat;
- splashing, dripping or permanent contact with oil, grease or bituminous compounds, electrical sparks etc.

13.2 Service ducts, ceiling spaces or voids containing pipelines that include valves etc. should have adequate ventilation to prevent gas build-up in the event of any leakage. Where piped medical gas services are installed of all welded, brazed or joint-free construction, it is generally not necessary to provide ventilation in service ducts, ceiling spaces or voids provided the piped systems are subjected to the rigorous testing imposed by this SHTM. Service ducts, ceiling spaces or voids containing mechanically connected valves or pressure switches will require ventilation in line with the requirements of BS8313:1997.

13.3 Exposed pipelines should not be installed in lift shafts, kitchens, laundries, boilerhouses, generator rooms, incinerator rooms, storage rooms designed to house combustible materials, or in any other fire-risk areas. Additionally, medical gas pipelines should not be installed in fire escape compartments (e.g. stair wells, fire exit lobbies). Where pipelines in hazardous areas are unavoidable, they should be enclosed in non-combustible, non-corrosive materials that have no electrolytic reaction with copper in order to prevent the possibility of the liberation of gases into the room in the event of pipeline failure. Medical gas pipelines should not be run in the same duct as flammable substances, oils, cryogenic or hot services such as steam, condensate, high or medium temperature hot water. Allowance may be made for steam and hot water services where they can be regularly inspected and are routed clear of the medical gas pipelines. Corrosion of copper pipe through chloride deposits from steam pipe leakage could result in the loss of the supply.

13.4 External pipe runs should be avoided when possible. Where external runs are necessary, they should be protected as follows:

- **on external vertical surfaces up to the maximum height of exposure to possible damage (for example vehicular movement):** by means of galvanised, profile-section steel of sufficient thickness to afford adequate protection. The protection should cover the entire space taken up by the pipeline(s), but stand off the surface such that the pipes can be inspected visually. The armour should be readily detachable to permit more detailed inspection;

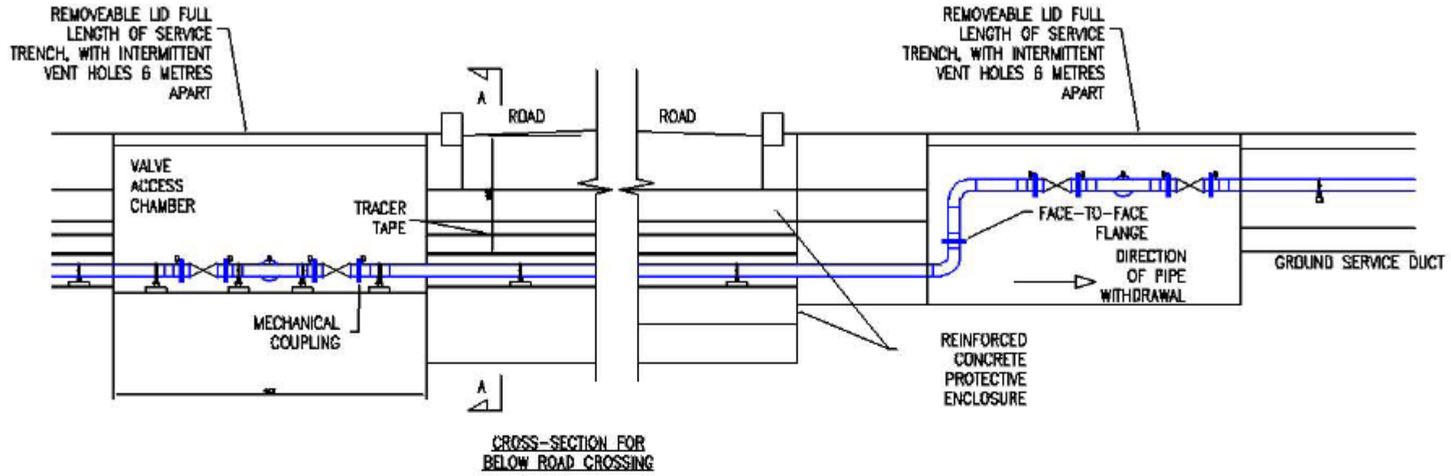
- **when crossing horizontal surfaces, roofs etc:** similar protection as detailed previously should be provided to withstand “stepping” damage using profiled section.

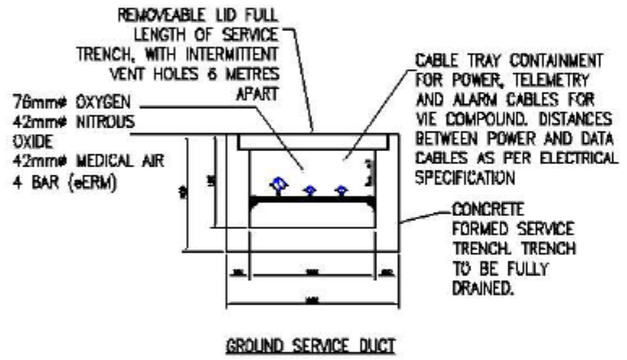
13.5 Pipework should be protected from lightning strikes by ensuring that they are run within a 60º cone beneath the lightning conductor, for example when run along parapet walls, or when penetrating parapet walls. When run across roof surfaces, a copper lightning conductor should be run on the top surface of the pipework cover providing physical protection, and should be bonded to it.

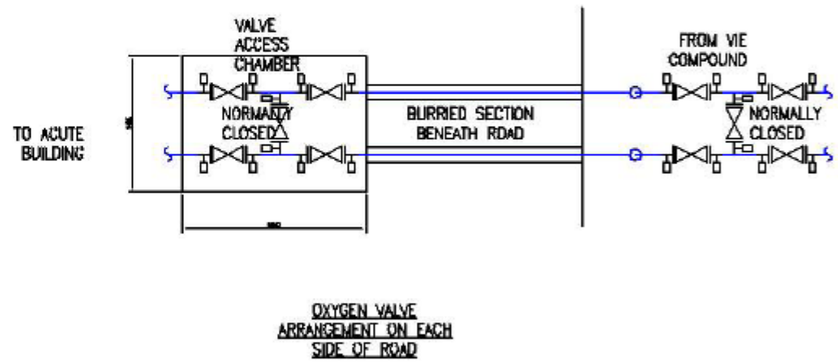
13.6 Internal pipelines should be suitably protected where there is a possibility of physical damage, for example from the passage of trolleys, tugs etc.

13.7 Wherever practicable, a clearance of at least 25mm should be maintained between each service and 150mm should be the separation distance between the medical gas pipeline and the outer surface of insulation of heating pipes, hot water service and steam pipelines to prevent heat transfer. Where pipelines cross over services and a clearance of 25mm cannot be maintained, they should be electrically bonded and wrap-insulated, in accordance with IEE Regulations. They should be bonded to the main earth at building entry and exit. Care is required when selecting pipeline routes to prevent the pipes coming into contact with electric cables and wiring, and to minimise the risk of electric shock in the event of a fault on adjacent cables (see Section 2).

13.8 Underground pipelines should be run in properly drained ducts not less than 450mm x 450mm which have removable covers to facilitate installation and subsequent inspection. Where it is not possible to provide removable covers, two pipes should be run in separate ducts / trenches with valves provided in a convenient location at either end. The valves should comprise LVAs with NIST connectors for the purposes of pressure and other tests. The separation distance between the two trenches should be not less than 2m where practicable (see Figure 33). The two pipes should each be sized for the design flow. One or more different gas pipelines can be run in each duct / trench. The route of the pipeline should be identified on the surface and should be clearly shown on site layout drawings. The possibility of installing a “ring-main” (see Figure 34) or double-end supply should also be considered for both air and oxygen within the curtilage of the building.







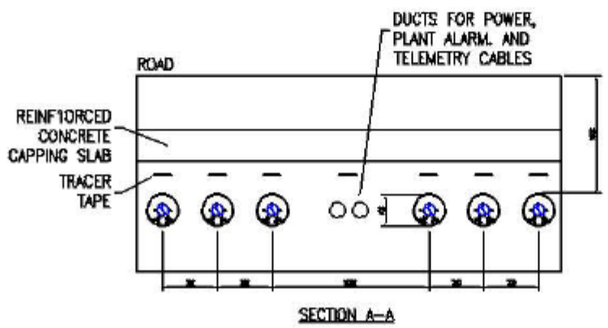


Figure 33: Miscellaneous pipe routing and protection arrangements

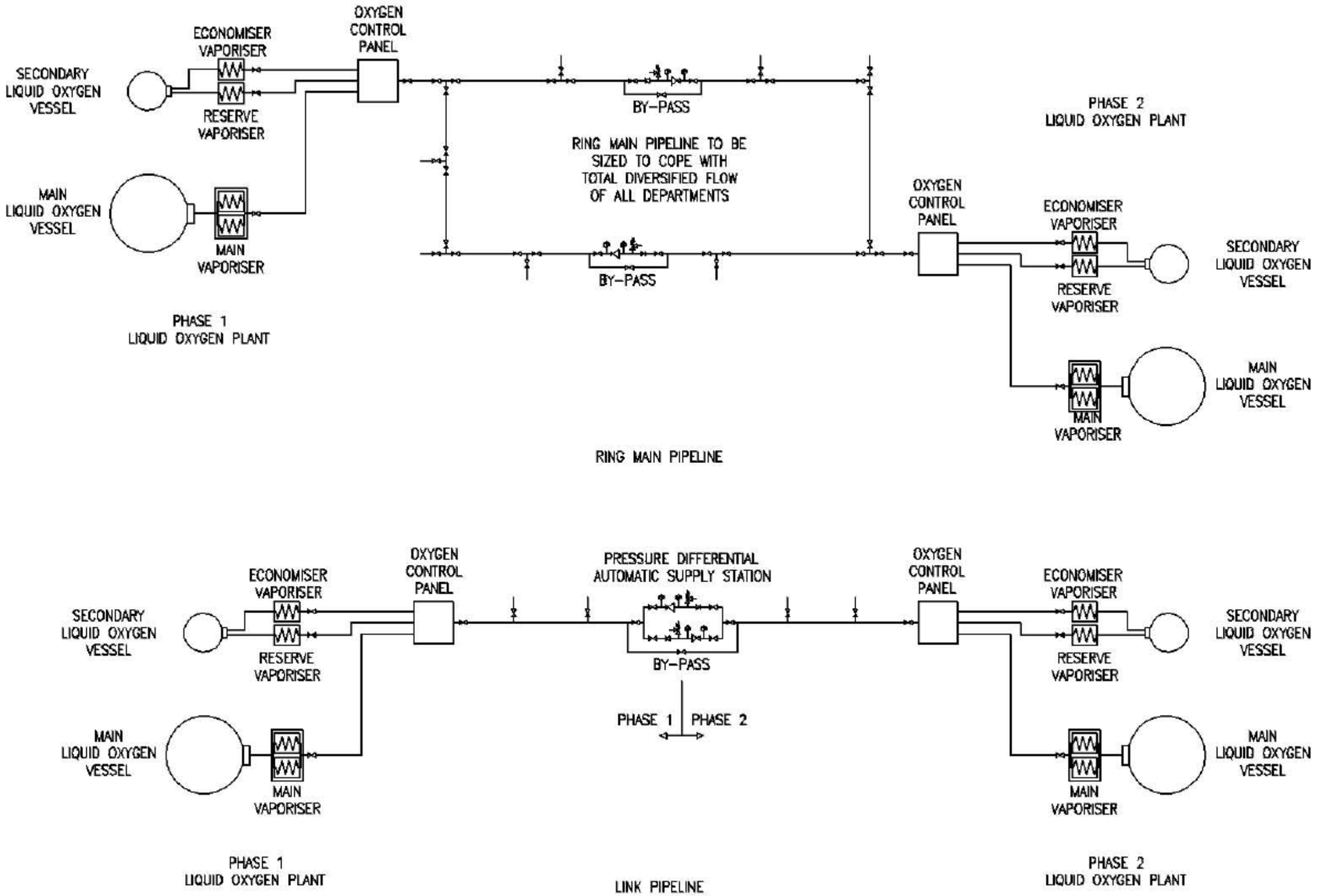


Figure 34: Typical ring main and link pipeline arrangement

13.9 Pipelines concealed within walls should have their route clearly shown on "as-fitted" drawings. Pipelines should not be encapsulated in floors, and any joints should be kept to the minimum practicable. Pipelines in stud or plasterboard walls or partitions are acceptable, but the pipeline should be protected from corrosion. If the enclosure of pipelines within plaster wall finishes is unavoidable, they should be wrapped in protective grease-free tape.

13.10 Pipelines need further protection in certain circumstances as follows:

- where pipes pass through walls, partitions or floors, they should be provided with sleeves of copper pipe (with fire stopping), which should extend at least 50mm from the surface of the wall, partition or floor. Since it is normal for other trades to seal the pipe sleeves at the penetration the medical gas contractor should ensure that the pipe sleeves are secured temporarily in place during the construction phase, e.g. by adhesive tape;
- where penetrations are exposed to general view, be provided with appropriate wall or ceiling plates;
- in radio-diagnostic procedure rooms etc., radio frequency (RF) screening wave guides may be required (the advice of the equipment manufacturer should be sought);
- corrosion of pipes can occur where they are in contact with timber that has been treated with fire-resistant or flame-retardant compounds, for example some timber used for roof trusses and floor joists.

13.11 This contact should be avoided by the use of impermeable non-metallic materials in the area where contact may occur. PVC spacers or adhesive PVC tape may be used for this purpose. If spacers are used they should not be liable to drop out due to shrinkage or subsequent movement of the pipe or timber.

13.12 Such precautions are not required where untreated timber is used or where the treated timber is effectively sealed with paint or varnish before the pipes are fixed to it.

Pipeline materials

Quality

13.13 The manufacturer should comply with BS EN ISO 9001: 2008 for pipes and for all materials including fittings, terminal units etc.

13.14 Where materials are obtained from suppliers from other countries, the suppliers should be registered in accordance with BS EN ISO 9001:2008.

Pipes

13.15 Material for pipes should be manufactured from phosphorus deoxidised, non-arsenical copper to BS EN 1412:1996 grade CW024A (Cu-DHP) in metric outside diameters and to:

- BS EN 13348: 2008 – R250 (half hard) for sizes up to 54mm; or

- BS EN 13348: 2008 – R220 (annealed) for larger sizes.

Pipe jointing fittings

13.16 In addition to the above, pipe jointing fittings should be end-feed capillary fittings to BS EN 1254-1:1998.

Other fittings

13.17 Other fittings (oxygen compatible) for connection to copper pipes (for example valve and control panel fittings) may be of copper, brass, gun-metal, bronze or stainless steel.

Cleaning

Pipes

13.18 All pipes must be cleaned and degreased for oxygen service and be free of particulate matter and toxic residues in accordance with BS EN 13348: 2008. They must be individually capped at both ends and delivered to site identified as medical gas pipes.

Pipe jointing fittings

13.19 All pipe jointing fittings and sub-assemblies of fittings for connection to pipes must be cleaned and degreased for oxygen service and be free of particulate matter and toxic residues. They must be individually sealed in bags or boxes and delivered to site identified as medical gas fittings.

13.20 Although it is not essential to use degreased pipelines and components for vacuum and AGSS installations, these are frequently installed by the contractor simultaneously with the medical gas pipelines. Degreased pipe and fittings should therefore be used for the vacuum and AGSS installations to avoid confusion. PVC pipework may also be used for vacuum and AGSS but is unlikely to be of benefit other than for exhaust discharges.

Note 27: Pipes should only be cut with wheel pipe cutters, not hacksaws, to prevent the ingress of copper particles.

Pipeline jointing

General

13.21 Except for mechanical joints, only copper-to-copper joints will be permitted on site, made with brazing filler rods that can be used without flux.

Note 28: Brazing is performed at a higher temperature than in the case of silver soldering with capillary fittings; the exterior of the pipe will therefore have considerably darker oxide deposits.

13.22 Copper joints to brass or gun-metal fittings will require the use of flux, with subsequent cleaning to remove the flux residues and oxide deposits.

13.23 Heating of the joint for brazing should be carried out with oxygen/acetylene, liquid petroleum gas/oxygen torches. Additional heating may be required for larger pipe sizes / fittings, for example, by means of a second torch.

Note 29: Oxygen / acetylene has an excellent safety record when used on site by the specialist MGPS contractor. This fuel-gas provides a narrow controlled flame with the higher flame temperature providing rapid heat transfer to the pipe and is generally the most suitable method for brazing pipelines in close proximity to other services and building fabric. In view of the unstable nature of the fuel-gas, brazing equipment must be in excellent condition with all component parts checked daily and subject to the correct lighting procedure prior to going on site. The control of cylinders on site should be governed by specific site procedures. The cylinders should be removed from site at the end of the working day. Oxygen / propane has a lower flame temperature and a wider spread of flame making it unsuitable for work in enclosed spaces or close to other unprotected services or building fabric. Small hand-held gas canisters, although limited in terms of their contents, can be useful for 15 / 22mm diameter pipe on a small project or break-in.

13.24 The techniques recommended cover all copper-to-copper joints and all copper-to-brass/gun-metal/ bronze joints in an MGPS, and are explained in more detail below.

13.25 The brazing technique should be used on all medical gas pipeline services.

Pipe preparation

13.26 Pipe ends should be cut square with the pipe axis, using sharp wheel cutters whenever possible, and be cleaned to get rid of any cuttings or burrs. Where a pipe shows a deformation or the pipe ‘cut’ shows a significant ragged burr, that pipe section and the pipe wheel cutters should be replaced. On no account should de-burring be attempted unless the burr is at the lower end of the pipe when in a vertical position, the likelihood by doing so when horizontal could leave deposits within the pipeline. All installation teams should carry spare wheel cutters.

13.27 Evidence of such burrs during examination of selected cut-out connections would be classed similarly to oxidation of pipelines and would result in additional joint removal for inspection until satisfied that a quality standard was being achieved. The use of a hacksaw for copper pipe should mean instant degrading of any certificate of competency of the individual and removal from site.

13.28 When brazing copper-to-copper joints:

- the brazed joints should be made using a silver-copper-phosphorus brazing alloy CP104 to BS EN ISO 17672: 2010. No flux should be used;
- ensure adequate protection of adjacent pipe runs and other services.

Note30: Brazing copper to brass/gun-metal/bronze is not performed on site. Manufacturers use copper-silver-zinc brazing alloy AG203 to BS EN ISO: 17672: 2010 with an appropriate flux. The flux residues created by the process are chemically removed and, if necessary, the complete assembly is cleaned and degreased for oxygen service. Where brass/gun-metal/bronze fittings are required to be installed they should be supplied complete with copper "tails" of adequate length to ensure that the brazing process does not damage the components.

Use of N_2 internal inert gas shield

13.29 Brazing should be carried out using oxygen-free nitrogen (OFN) as an internal inert gas shield to prevent the formation of oxides on the inside of the pipes and fittings. This method leaves a bright, clean bore. Some slight burnishing may occasionally be observed on sectioned joints. Purging is still required to remove the internal shield gas and the other particulate matter not associated with the brazing operation.

13.30 Oxygen-free nitrogen (OFN) should be supplied to the inside of the pre-assembled, unbrazed pipework through a pressure regulator and flow controller or flow-regulating device.

Application

13.31 OFN should be used as an internal inert gas shield for all positive pressure gases, vacuum and AGSS pipelines.

Note 31: During the first-fix (carcass) stage of pipeline installation, particularly when installing in confined locations such as medical supply units or running pipework within partitions, etc. to individual terminal unit drops, it is possible to inadvertently crossover a pipeline. This is usually discovered at an early stage and, so that the pipe section can be re-assigned and the fault can be corrected, it is essential to use the shield gas to maintain the cleanliness of the internal bore.

13.32 By agreement between the health facility management and the medical gas contractor, the use of a purge gas may be waived on joints such as break-ins to old pipeline systems, where pipe joints will not have been made in accordance with this technique.

13.33 It is recommended that the pipeline to be brazed should first be subject to a high flow of oxygen free nitrogen (OFN) to remove air, followed by a period of 'pickling' at a low flow prior to brazing whilst maintaining the flow.

13.34 Cleanliness of the pre-brazed joint is important. Prepared joints will pick up surface tarnish or moderate oxidation if left and can influence the quality of braze particularly when the permitted depth of braze is 3mm. Failure to braze within the day can be accepted, however any delay should not extend beyond the third day. The nitrogen purge must be maintained during the cool-down of the joint. Adjacent pipes should preferably be subjected to an OFN purge for the duration of the work and cooling period. If it is not possible to introduce OFN

into an adjacent pipe, e.g. pipeline with a live working gas, a heat resistant blanket(s) wrapped round the adjacent pipe(s) should be made available in proximity to the pipeline being brazed.

13.35 Pipe ends may be capped if desired to direct the flow of nitrogen into sections of the pipe or pipes to be brazed. Particular attention should be given to the gas shielding of T-joint fittings. It is essential that there is a leak-free connection between the pipework to be brazed and the OFN supply.

13.36 On completion, all pipes should be maintained under pressure following tests. The pressure to be maintained to ensure internal cleanliness should be agreed on site, however, 1 bar (max) (100 kPa) has been recognised as an accepted pressure.

13.37 Internal oxidation of pipes could mean replacement of pipe thus careful preparation is normally repaid. Purging on completion will remove dust particles or possibly the odd copper particle. It is not intended to remove oxides developed during the brazing stage.

Safety

13.38 If working for prolonged periods in very confined spaces, precautions must be taken to avoid excessive build-up of nitrogen by ventilating the space or by piping the shield gas safely out of the space. The oxygen content of the ambient air should be monitored when brazing in a confined space.

Control of cylinders

13.39 The contractor and the site engineer must keep a record of nitrogen cylinders held on a site. Nitrogen cylinders should be accounted for and removed from the site at the end of the contract, and must not become mixed up with medical gas cylinders.

Inspection of joints

13.40 Inspection of joints should be carried as a “rolling” procedure on a monthly basis as work progresses for each team performing the installation in accordance with the following procedure:

- the Contract Supervising Officer (CSO) or Authorised Person (AP), whoever is responsible for the inspections and validation, should identify a number of fittings to be cut out for examination in order to establish the quality of the finished joint. The exact number to be cut out will vary with the size of the installation: as a guide, a ratio of one fitting per 200 should be cut out; a minimum of ten for all systems should be cut out for examination (it is preferable to perform these checks before pressure-testing sections of pipeline). The actual removal of the joints should be witnessed by the CSO or AP (MGPS). It is generally not necessary to request cut-outs from vacuum and AGSS pipelines;

- the fittings cut out should be cut open (quartered longitudinally) and examined. If unacceptable joints are found, adjacent fittings should be cut out until the extent of any faulty workmanship has been established. This may require extensive removal of sections of the installation;
- In order to maintain a record of the inspected joints, consideration should be given to photographing the joint, recording the pipeline section the joint was removed from, the Competent Person (MGPS) who made and cut out the inspection joint and finally comments by the CSO or AP on their findings, e.g Passed or Failed and reasons for failure. This method of recording is more viable now with the availability of digital photography and electronic file storage systems, particularly on larger projects. The above will also act as a means to assess the competence of the individual Competent Person (MGPS) and act as a tool for the CPs employer to validate the CPs competency under the company's quality management system.

Internal cleanliness

13.41 The tube and fitting should be internally clean and free from oxides and particulate matter. Some heat burnishing may be apparent and is acceptable.

Penetration

13.42 Penetration of brazing alloy:

- due to tolerances of the capillary space on these pipes and fittings, full penetration of the brazing alloy may not occur and is not necessary;
- the minimum penetration at any point on the joint must be three times the wall thickness of the tube or 3mm, whichever is greater;
- the pipe should be fully inserted up to the shoulder of the fitting.

Note 32: These tests can be carried out on a sectional basis.

Jointing methods (mechanical)

13.43 It is not envisaged that mechanical joints, with the exception of NIST connections, will be required for new works. In exceptional situations, such as when brazing could impose an unacceptable risk or in situations when patients cannot be transferred to alternative accommodation, should mechanical connections be used. They may also be used for connecting pre-piped bedhead trunking and wall units to the pipeline distribution system. In which case they should be of the permanent swaged type, not contain elastomeric materials, and if located within ceiling voids, that void should be subject to adequate ventilation to prevent any gas accumulation in the event of any leakage.

13.44 Mechanical joints in keeping with paragraph 13.43 should only be viewed as a non-permanent emergency connection, with each connection number tagged and marked up on the record drawings with all remaining work fitted with brazed copper end caps. The installation should be made good as soon as possible in

accordance with paragraphs 13.29 – 13.35.Mechanical joints will in all instances be subject to, prior to fitting, approval by the Authorised Person and be located readily accessible for periodic inspection.

13.45 PTFE tape is not an acceptable sealing material on oxygen systems or elsewhere downstream of final filters on supply plants.

Note 33: PTFE tape, if applied, can enter the gas system and fragments can block terminal units and present a fire hazard with high-pressure oxygen. Also, when applied by hand, traces of oil and grease can contaminate the inside of the pipeline.

13.46 Liquid or gel-sealing media should be used only if they have been tested and proven safe when subjected to the tests specified in BS EN ISO 15001: 2010.

Capping

13.47 Sections of pipeline should be capped and pressurised with medical air as soon as they are completed so as to prevent the ingress of debris.

Pipeline supports

13.48 The pipeline should be adequately supported at sufficient intervals in accordance with Table 39, below, to prevent sagging or distortion. Supports for surface-mounted pipework should provide clearance to permit painting of the surface. Where it is essential for pipes to cross electric cables or conduit, they should be supported at intervals on either side of the crossing to prevent them from touching the cables or conduit. Supports should be of suitable metallic, non-ferrous material or suitably treated to minimise corrosion and prevent electrolytic reaction between pipes and supports. Supports for vertical drops to terminal units within medical supply units can be of a suitable non-metallic material.

Pipeline outside diameter (mm)	Maximum interval between supports (m)
Up to 15	1.5
22-28	2.0
35-54	2.5
>54	3.0

Table 39: Intervals between copper pipe supports (horizontal and vertical)

Note 34: Consideration should be given to additional supports near LVAs, elbows, etc. where the potential effects of inadvertently applied torque can result in severe pipeline distortion or fracture.

13.49 In situations where medical gas pipelines are required to span building movement joints, consideration should be given to the method by which pipelines are supported to prevent mechanical damage.

13.50 Pipelines need not be laid with falls. In the case of vacuum, the sub-atmospheric pressure will result in the evaporation of any moisture entering the system.

13.51 The connection of individual, or a number of vacuum terminal units into branches, should be taken into the top of the pipeline to avoid flooding other vertical pipe drops should liquid carry-over occur. Within trunking systems and medical supply units etc, vacuum pipes should connect into the underside of terminal units.

13.52 Each vacuum main riser should be provided with a drain leg consisting of a single full bore flanged valve up to pipe diameters of 42mm - pipe diameters in excess of 42mm can reduce to accommodate a 42mm valve followed by a pipe extension of similar bore to valve off a minimum length 0.5m extension terminating in a capped screwed connection. The extension should have a clear sight glass throughout its length or alternatively be fully transparent. Robust flexible hosing, providing it is of sufficient clarity and capable of withstanding 150 kPa positive pressure and 100 kPa negative pressure is a further alternative and has the advantage of being easily replaced. A double valve arrangement increases cost and has no advantage. It is not recommended that such a drain leg be cleaned in situ. This should be bagged and taken to a safe environment for cleaning, disinfection, sterilization or disposal as appropriate in accordance with the Hospitals' infection control / clinical waste procedures.

13.53 Competent persons carrying out work on vacuum or AGSS systems should be suitably clothed and protected in accordance with SHTM 02-01 Part B, Appendix D or as directed by the Infection Control Officer.

Identification of pipelines

13.54 Pipelines should be identified in accordance with BS EN 1710: 2005 + A1: 2008, and colour banding for the pipelines should be used. Colour band identification (see Figure 35) should be applied adjacent to valves and on either side of walls, obstructions such as ventilation ducted services when they obscure pipe run, junctions and change of direction. A label applied every 3m and bearing 6mm size letters should identify each gas. Self-adhesive plastic labels of approved manufacture may be used for this purpose. A band 150mm wide is usually adequate. All colour-coded tapes applied by the pipe manufacturers should be removed before the systems are identified, in accordance with this paragraph.

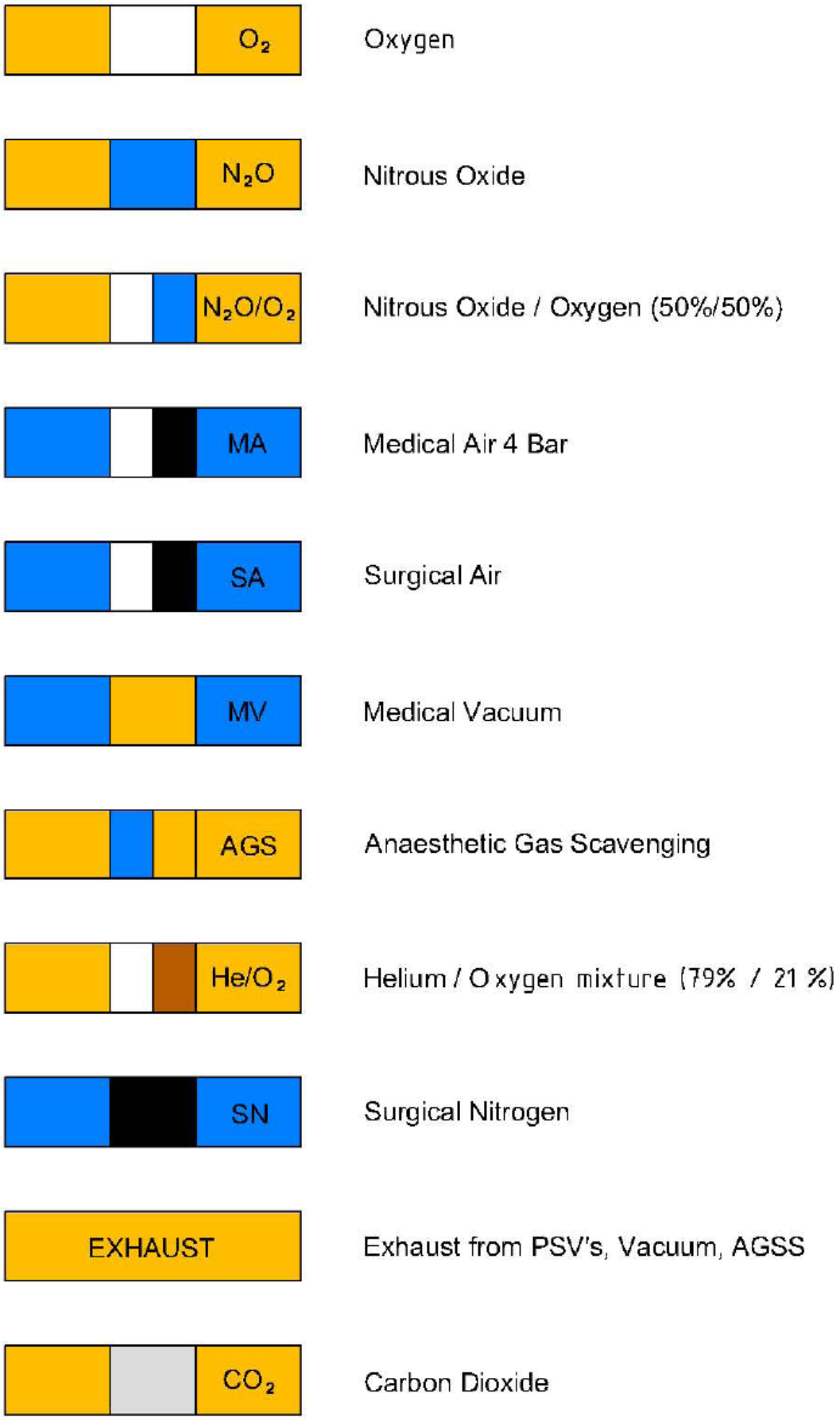


Figure 35: Pipeline identification colours

13.55 Care should be taken to maintain pipeline identification when periodical re-painting is undertaken. The direction of flow should be indicated. Where a pipeline is used as a link between two systems or is part of a ring main, direction flow arrows should indicate bi-directional flow. Alternatively, the pipeline can be labelled to indicate the purpose of the pipe, e.g. Ring Main or Link Pipeline.

Pipeline components

13.56 Pipeline components, which may be attached to an MGPS, include various types of terminal unit, AVSUs and other components such as emergency inlet ports and pressure control equipment.

Medical supply units

13.57 These should comply with BS EN ISO 11197: 2009. The construction should provide segregation of FELV electrical services by means of partitions or flexible conduit as appropriate. Access to “live” components should be via panels that are removable by means of tools only.

13.58 All rigid medical supply units should be piped in copper, which will avoid the higher pressure losses, leakage, probable volatile contaminants, regular inspections and replacement associated with flexible hoses. Exceptions will be motorised and multi-movement pendants which should be constructed in such a manner to ensure that the flexible hoses are not subjected to kinking or twisting.

13.59 The flexible hoses should be free from volatile or organic compounds and certificated to that effect by the pendant manufacturers or suppliers by QC tests conducted at manufacturers’ premises prior to pendant assembly.

13.60 Where the pendants incorporate flexible hose assemblies, the hoses should only be of sufficient length to provide connection to the fixed pipeline and terminal unit by means of the appropriate NIST connection in accordance with BS EN ISO 9170-1: 2008

13.61 Excess hose length is a contributory factor in surgical air system pressure drops across the pendant which may exceed this Scottish Health Technical Memorandum 02-01 and BS EN ISO 9170-1: 2008. Where Ultra-clean canopy systems are in place, consideration should be given for surgical air to be piped in copper within a custom built support utilising the canopy structure.

13.62 All equipment incorporating gases suspended from the ceiling structure or wall mounted should provide sufficient venting to allow the escape of gas to the room in the event of leakage/rupture of one or all of the medical gas services.

13.63 The recommended height for rigid pendants is 2,000mm above FFL. The maximum height for pendants capable of vertical movement should be 2,000 mm above FFL in the fully retracted position.

13.64 The use of medical air for pneumatically actuated pendants is covered in Section 3 Table 11, note 3.

Note 35: In cases where medical or surgical air terminal units are not required to be included in these pendants, an AVSU will still be required "locally" for emergency isolation and servicing of the air-braking mechanisms of some units.

The pendant manufacturer should advise the designer of the requirements for the particular pendant, i.e. the pressure required.

Flexible pendant fittings

13.65 These should comply with the requirements of BS EN ISO 9170-1: 2008 and BS EN 739: 1998. In particular, all loose assemblies should be provided with appropriate NIST connectors.

Bed-head trunking/walling systems

13.66 These fittings should generally be in accordance with BS EN ISO 11197: 2009. Separate compartments should be provided for electrical services, nurse call/radio, etc. and medical gas pipelines.

13.67 The medical gas compartment should be provided with ventilation by means of louvres, slots, etc. to prevent the accumulation of any gas in the event of leakage of the medical gas pipeline services. Unit construction should prevent the accumulation of gas in event of leakage from any of the medical gas system components. Ventilation by any other means, such as natural gaps in trunking sections, are not acceptable as such gaps are dependent on the quality of manufacture and/or fitting and can therefore not be relied upon to adequately vent off leaked gas.

13.68 In some departments, to engender a more domestic environment, medical gas and other bedhead services are installed within concealed recesses (or behind decorative panels, paintings etc). In such cases, adequate provision must be made for ventilation, and the required space to permit connection and disconnection of equipment should be considered. The covers should be clearly labelled to indicate that medical gas equipment is installed within/behind.

13.69 There are three possible installation procedures:

- the introduction of prefabricated units carrying services will require a technical specification, co-ordination of services and procedures. As a minimum to ensure the cleanliness and integrity of the medical gas pipeline systems is retained, brazed copper end-caps or temporary mechanical connections should be a requirement for all pipe terminations;
- providing the bedhead trunking or wall panel is accompanied by a test certificate, the joints can be subjected to a completed installation (2nd fix) pressure test;
- any temporary emergency connection should be removed at the earliest date when a permanent brazed connection should be made.

Note 36: After any such disconnection and reconnection, it will be necessary to carry out the full range of anti-confusion tests.

LVAs and AVSUs

13.70 All valves should be of the lever-ball type, having flanged O-ring seal connections which open and close with a 90º rotation: the handle should be in line with the pipeline when open.

LVAs

13.71 LVAs should be capable of being locked with the valve in the open or closed position. Means of physically isolating and blanking the pipeline both upstream and downstream of the valve should be provided. The means of isolation should be in the form of a spade that can be readily deployed. It should blank both the pipeline and the valve port and be visible when deployed. Each valve should be provided with a set of “through” and “blanking” spades; they should be coloured white and red respectively. The valve flange should include the thread, and the bolts should be of sufficient length to permit loosening to allow removal/replacement of the spades without loss of structural integrity of the connection. Union-type connections with O-rings are permissible, but the securing nut must also have sufficient thread length to permit venting while maintaining the structural integrity of the connection. A single key for each service is considered to provide sufficient security.

13.72 In the event of leakage of the through or blanking spade, gas must be capable of venting to atmosphere and must not be able to enter either the valve port or the pipeline section blanked.

13.73 The appropriate NIST connector bodies with self-sealing check valves and lockable blanking nuts should be provided upstream and downstream of the flanges. Gas identity and flow direction arrows should be provided for each valve.

Note 37: A single NIST connector will suffice in ring-main branch connections between the three closely spaced valves.

13.74 LVAs should be provided as follows:

- at the connection of the pipeline to any source of supply;
- at the emergency inlet port (that is, it forms the emergency inlet point);
- at the pipeline entry to a building;
- at the pipeline exit from a building;
- at the connection of branches to the main pipeline run;
- at the connection to risers;
- at branches from risers to serve a number of similar departments;
- upstream, downstream and in the branch connection to a ring-main.

Note 38: a) Good practice with respect to patient safety should ensure that the oxidising medical gases, each capable of vigorously supporting combustion, in each department, ward area and floor can be speedily shutdown in an emergency fire situation.

b) Where departments on a floor are functionally very different, for example wards and diagnostic areas, each area when branching off the main floor pipeline should have a fire valve (AVSU) installed together with AVSUs within the area as detailed in Section 3.

c) Where a risk assessment has evaluated that the installation of an AVSU located at the riser would give cause for concern from tampering by unauthorised persons, an LVA can be installed in the riser at an accessible height.

d) Individual pipelines radiating from the riser to functionally different departments is not seen as a benefit towards higher fire safety practices.

e) Restrictions are placed on permitting mechanical connections for oxidising gases in ceiling spaces or voids, with or without elastomeric o-rings or materials, in the event of a leak resulting in an accumulation of gas. Where this possibility exists, mechanical ventilation would be required.

f) Installation of line valves, LVAs, pressure switches, etc. in risers can be considered if there is adequate movement of air within riser compartments.

AVSUs

13.75 AVSUs are provided for user access in an emergency (or for maintenance purposes). They should be in accordance with the requirements above for LVAs except that security is achieved by installing them in an enclosure with a lockable door designed such that it can be closed with the valve either in the “open” or “closed” position.

Note 39: The views of the building operator should be sought as to the level of security that will be required and hence the range of keys. The medical gas operator, e.g. Estates Department or Facilities Management provider’s views should be sought in determining the number of MGPS keys required per building:

a) One key and duplicate per service;

b) One key and duplicate per valve;

In either case, a key cabinet and valve schedule should be provided. The schedule should provide information of gas service, key and valve numbers and department and/or terminal units controlled by the valve.

Crossover pipelines above AVSUs should be avoided wherever possible.

13.76 In an emergency, the user must be able to gain access in order to operate the isolating valves quickly and simply without the need for a key. There are several

methods of providing such emergency access, for example break-glass panels and plastic push/pull-out inserts. Whichever method is used must be safe and secure and must clearly act as a deterrent to tampering without introducing undue risk of injury to the user. Float glass must not be used. The method of emergency access must be obvious and clearly labelled, and its use must be evident.

13.77 AVSUs may be designed for a single pipeline service for each gas type or combined within a multi-service module. Single AVSU covers should be gas specific, while multi-service AVSU module covers should only require a door for each valve, the covers need not be gas specific. However, access to each valve in a single AVSU or multi-service AVSU module should be by a unique lock and key. In the instance where a hose is to be connected to a NIST, for example to back feed a gas service during a system closure or for emergency supply to a department/room, the protocol for such a requirement would be for the connected cylinder to be permanently supervised by a suitably qualified person. In this case, the door would remain open during the temporary cylinder connection, thereby negating the need for hose access slots.

13.78 The enclosure should have adequate ventilation to prevent the accumulation of gas in the event of a leak. Pipe entries and other penetrations should be sealed to prevent gas escape by routes other than the vents or openings into the user space. The enclosure should be designed to facilitate sealing of these entries on site. Gas identity and flow direction arrows should be provided for each valve.

13.79 Provision and location of AVSUs is covered in Section 3.

Note 40: AVSUs should not be installed in positions where they can be obscured or damaged, for example within the “swing” of a department door or behind partitions.

Specific labelling requirements

13.80 All AVSUs should be labelled to identify the individual rooms, sets of terminal units etc controlled. The upstream and downstream NIST connectors should be clearly identified by a permanent label, securely fixed.

13.81 In critical care areas, where dual circuits and/or subdivisions of circuits occur, terminal units need to be correspondingly identified with the specific AVSUs (see Figures 4 and 5).

13.82 In the case of pneumatically-powered pendant fittings where, typically, medical air or preferably surgical air should be used for the power source that controls the pneumatically-powered devices, the appropriate controlling AVSU should be identified.

Pressure control equipment

13.83 Medical gases may be distributed at a higher pressure than the eventual nominal pipeline distribution pressure at terminal units. Where this is the case,

the maximum pressure should not exceed 980 kPa, and the local pressure "control" equipment should be installed in an area that has good ventilation and be housed in a clear-fronted lockable cabinet, fully identified for service and area served. It should be in a position where it is readily accessible for maintenance/service.

13.84 The pressure control equipment should include duplex pressure-regulating valves, each with upstream and downstream isolating valves, safety valves, up and downstream pressure gauges and NIST connectors. The safety valve discharges should be run to the exterior of the building; medical air and surgical air may be discharged within a plant space, for example a plantroom above an operating department, provided it is terminated in a safe position.

Pressure sensors

13.85 Pressure sensors to provide the alarm function will need to be fitted to pipeline distribution systems. In all cases they should be installed in a location which is adequately ventilated and having access for maintenance. They may be incorporated downstream of AVSUs. Where not incorporated into an AVSU, the pressure sensor should be close to the AVSU so that it is accessible for maintenance. Pressure sensors should be factory-set and be a replacement item. They should be connected to the pipeline by means of a minimum leak connector. Suppliers, contractors and training course providers must be fully aware of the difference in settings between HTM 02-01 and this Code of Practice.

Pressure switches can be installed within:

- AVSUs valve boxes;
- AVSU modular wall panels;
- individual wall box;
- pressure switches need not be installed close to an alarm panel, but appropriately located pressure switches can aid setting alarm conditions visually.

Pressure gauges

13.86 Pressure gauges are not usually required outside the MGPS source plantroom unless they form part of a remote regulating set. If provided, however, they should similarly be installed in an adequately ventilated location. They may be incorporated within AVSUs, operating room supply fittings etc. They should be installed with isolation cocks.

Test points

13.87 Each supply plant, that is, liquid facility, manifold (main and ERM), compressor plant, PSA and blending plant, should be provided with a test point comprising lockable valve and terminal unit. This should be within the plantroom or

enclosure, and be sited immediately upstream of the distribution pipeline isolating valve.

Emergency / maintenance inlet port

13.88 Medical oxygen and 400 kPa medical air systems should be provided with an emergency inlet port to the pipeline distribution system. This should be located downstream from the main source of supply line valve isolation point, in a remote location to permit connection of a temporary supply plant. The emergency inlet should comprise a 28mm dia. LVA, an additional non-return valve on the emergency inlet side and a connection that can be blanked, to which the emergency inlet can be made.

13.89 An emergency inlet port is not required for 700 kPa surgical air systems.

Line pressure alarms and safety valves

13.90 The purpose of the line pressure alarm is to warn users that the nominal line operating pressure is out of limits and that gas mixtures, whether supplied by a blender/mixer, an anaesthetic machine or patient ventilator, may deviate from the clinically desired proportion. Local action can then be taken to adjust the mixture, or when an anaesthetic machine is in use the reserve cylinders can be brought into use. The low-pressure alarm for nitrous oxide/oxygen mixture supply pipelines will warn of possible demand valve regulator failure so that a portable cylinder can be made available. The high/low pressure limits have been set to accommodate the design of most types of anaesthetic equipment where differential pressure or low pressure may affect performance.

13.91 The line pressure safety valve provides limited safety from differential pressure effects since the pressure at which maximum discharge occurs will result in a differential much greater than that for which the anaesthetic equipment has been designed. They are therefore strictly system protection devices. All safety valves should have a separate discharge pipe that is run to a safe position which – except for air – should be external.

13.92 The commissioning of medical gas pipeline line pressure regulators, warning and alarm systems, and pressure settings is crucial to the performance of anaesthetic equipment and patient safety; once commissioned, medical gas pipelines are subject to strict permit-to-work procedures. Decommissioning a complete system is highly disruptive to patient care and introduces considerable risk.

13.93 The Pressure Systems Safety Regulations 2000 require pressure safety devices to be tested periodically. It is not appropriate to test an MGPS by either raising the line pressure regulator setting or manually unseating the relief valve. Such action could result in failure of anaesthetic equipment and – if the safety valve fails to reseat – it could result in considerable gas loss and further hazard. Medical gas pipeline distribution systems should be provided with a pressure relief device downstream of the line pressure regulator connected by means of a three-way cock so that the safety device can be exchanged for a “certificated” replacement in accordance with the frequency required by the Regulations.

14. Design and construction of plant and manifold rooms

Location of manifold rooms

14.1 Cylinder gas/liquid supply systems should not be located in the same room as medical air compressors, PSA systems or vacuum plants.

14.2 Manifold rooms, emergency/reserve manifold rooms for PSA systems, VIE installations and medical compressed air systems should be located to take account of the risk assessment, but should also take account of the location of the medical gas cylinder storage area.

14.3 All manifolds, including the emergency reserve manifolds, may be located within the same room. Manifold rooms should be located on an external wall(s) to facilitate ventilation, which will be required at high and low level. Internally sited manifold rooms for gases other than medical air and cylinder stores may require mechanical ventilation.

14.4 The emergency/reserve manifold for liquid oxygen systems has traditionally been located within the VIE compound, but it is preferable to site the manifold separately. For new installations, these emergency/reserve manifolds should be located separately.

14.5 In the case of surgical air the volume of gas used is relatively small even though the instantaneous flow rates are high. Therefore, it may be more convenient to include the manifold within the operating department.

14.6 Where a surgical air 700 kPa manifold room is provided it may be used as the ready-use store for a small number of spare cylinders to be used on anaesthetic machines.

Note 41: It is permissible to accommodate medical compressed air plant, vacuum plant and AGS disposal system pumps within general plant areas accommodating such equipment as air handling units, water service systems etc. They should not, however, be located with heating or hot water service equipment or equipment likely to produce any fumes or odour.

Access

14.7 Access to manifold rooms should be from the open air, not from corridors or other rooms.

14.8 Normal commercial lorry access is suitable for gas cylinder delivery vehicles, but consideration should be given to the provision of a raised level loading bay to reduce cylinder handling hazards.

14.9 Two doors should preferably be provided in a manifold room. One should be large enough to facilitate cylinder handling and must be in an outside wall. Exits

must be free of all obstructions. Doors must open outwards. All doors must normally be locked to prevent unauthorised access, but should be provided with means of entry and exit in an emergency (for example by a push-bar arrangement on the inside).

14.10 Internal walls and ceilings, including any internal doors of the manifold room, should be of a suitable non-combustible two-hour fire-resistant material as defined in BS476-4:1970 and BS476 Parts 20–23 (1987). Internal doors should be avoided where practicable. Smoke detectors should be provided. The provision of automatic fire suppression / gas leak detection should be considered as part of a risk assessment which reflects local conditions.

Construction and layout of manifold rooms

14.11 The manifold room will contain the manifolds as well as cylinder racks holding sufficient spare cylinders to replace one bank of each manifold and the emergency/reserve manifold. (For nitrous oxide/oxygen manifolds, sufficient spare capacity for two banks of cylinders should be provided.) Further replacement cylinders should be supplied from the medical gas cylinder store. The size of the manifold room should therefore be determined by risk assessment. Adequate space should also be allowed for cylinder handling.

14.12 A typical automatic manifold with two duty and two stand-by cylinders is approx. 1,800mm long and 600mm deep. One extra cylinder on each bank adds approximately 500mm to the overall length, so that a 2 x 6 manifold is approximately 4,500mm long.

14.13 All medical gas manifolds may be installed in the same room. Additional floor area should be provided to accommodate separate storage racks for each gas. The racks should be designed along the lines of those on the manifolds, but the stored cylinders may be closer together. Racks should conform to ISO 32:1977. With the exception of small cylinders of N_2O/O_2 mixtures, under no circumstances should rooms contain gas cylinders other than those appropriate to their manifolds.

Heating and ventilation

14.14 Ventilation louvres should be provided at both high and low level for all manifold rooms, to allow circulation of air. A risk assessment should be carried out to assess the potential risk of staff being exposed to leaking gas within manifold rooms. BCGA Code of Practice 4 provides methods to calculate either oxygen depletion or enrichment and appropriate ventilation rates. Further consideration could require the inclusion of gas leak detection systems. However, these systems would only be required if the risk is high or the organisation responsible for accessing the manifold room deems it necessary.

14.15 Air intakes for compressor inlets should, if possible, be located externally. However, they should not be installed as an alternative to the provision of adequate ventilation for cooling purposes.

14.16 All ventilation louvres should be vermin/bird-proof.

14.17 PSA and medical air compressors liberate, under maximum flow conditions, considerable heat. Moreover, these plants aspirate air for breathing purposes. Generous natural ventilation should be provided, and where this is not possible if the plantroom is deep-plan, mechanical ventilation should be provided. The ambient temperature of manifold rooms and plantrooms should be maintained within the range of 10–40°C. The ventilation rates should ensure that the plantroom temperature does not exceed ambient temperature by more than 10°C.

14.18 Manifold rooms may be used to store small numbers of nitrous oxide/oxygen cylinders intended for portable use; these are taken from the main cylinder store for the purpose of temperature equilibration, before being delivered to wards etc.

14.19 To achieve temperature equilibration, additional heating may be required; the natural ventilation must not be reduced. Where such heating is provided, it should be by indirect means, for example steam, hot water or warm air. Naked flames and exposed electric elements should not be used, and excessive surface temperature should be avoided. If necessary, cylinders should be protected from excessive heat. Any primary heat source should be located in a safe position, preferably remote from the manifold room.

14.20 Cylinder recognition charts, supplied by the medical gas supplier, should be prominently displayed as appropriate.

Lighting

14.21 Manifold rooms and medical gas plantrooms should be provided with lighting to an illumination level of 200 lux by means of lighting fittings to BS EN 60529: 1992.

Noise control

14.22 Plantrooms should be designed and constructed to ensure the satisfactory control of noise emission. The effect of two vacuum pumps or compressors running together, in the case of duplex installations, and three or more in the case of multiplex installations, will be to increase the free-field noise level outside the plantroom by 5 dB(A) for each additional pump or compressor operation over and above the specified limits. Consideration should be given to providing acoustic enclosures to reduce the free-field noise levels in noise-sensitive areas adjacent to plantrooms.

14.23 Acoustic enclosure and/or plantroom design must not inhibit normal cooling functions or maintenance activities.

14.24 Free-field noise levels should be given to the architect to assist in acoustic design of the plantrooms.

14.25 The discharge from some vacuum pumps may require silencing.

14.26 Compressors and pumps should be mounted on properly-selected anti-vibration mounting, where necessary, to minimise transfer of noise and vibration to the structure of the building.

14.27 All pipework and electrical conduits connected to the plant should be fitted with flexible connectors where necessary to prevent the transmission of noise and vibration along the pipelines and conduits. Electrical bonding will be required.

Labelling/signage

14.28 Labelling for medical gas systems, equipment and accommodation should be in accordance with Appendix K.

15. Validation and verification

General

15.1 This chapter covers the validation and verification and filling for use of MGPS. Validation and Verification is required to determine that the designer and MGPS contractor have fulfilled all the necessary conditions by confirming and verifying the initial design data and substantiating that the contractor has installed the medical gas pipeline systems in accordance with the specification and to an acceptable standard. For this purpose the designer will supply the specification, drawings, isometrics and pipeline design calculations at an early stage of the contract. This ensures any design discrepancy can be rectified, preferably prior to installation work commencing.

15.2 This chapter describes the tests required and the test methods. The contractor should provide instrumentation for the engineering tests. The Quality Controller (MGPS) normally provides instrumentation for the gas quality and identity tests. Calibration certificates should be available for all instrumentation. Tests are listed in Appendix A with the associated forms.

15.3 The objective of testing and commissioning is to ensure that all the necessary safety and performance requirements of the MGPS will be met. Testing and commissioning procedures will be required for new installations, additions to existing installations and modifications to existing installations. The scope of work will dictate the specific test programme required. This is described in more detail in paragraphs 15.12 – 15.14.

15.4 For modifications and extensions (except for the final connection), all work should be performed with an inert gas shield; thus, it is essential that a physical break is employed between the pipeline being modified/extended and the system in use. This will usually be by deploying “spades” in AVSUs and LVAs, or by cutting and capping the pipe. Prohibition labels should be affixed to all terminal units of the system affected in occupied areas.

15.5 For small extensions comprising fewer than 20 brazed joints per gas service, all the tests may be performed with the working gas – the carcass pressure tests being replaced by a system leakage test of the complete extension. An extension comprising more connections would, however, be deemed to be a small installation, requiring all the appropriate tests to be carried out, up to the final connection; the final connection would be tested at pipeline distribution pressure. For the purpose of ascertaining the number of joints, a straight coupling comprises two joints and a “T” comprises three joints. On a minor modification, from which existing terminal units would not be removed, the carcass pressure test can also be omitted. All other tests would be required, including a working pressure test.

15.6 The programme of tests is divided into the following phases:

- validation of design

- tests and checks on the pipeline carcass;
- engineering testing, commissioning and purity of the medical and surgical air plant and the testing and commissioning of the vacuum plant;
- tests and commissioning of the complete pipeline system (with terminal units installed) for safety, performance and particulate contamination using test gas;
- filling of the systems with specific gases for the purposes of identity and quality tests of the specific gases prior to use for patient care;
- gas identity and quality tests.

Note 42: a) Systems that are not to be taken immediately into use should be filled with medical air and maintained at operating pressure. Systems other than medical, surgical or dental air supplied from compressors should be filled with medical air from cylinders.

b) Commissioning of liquid supply systems prior to handover should be avoided. (Under “no flow” conditions, liquid will evaporate and oxygen will blow off to atmosphere.)

15.7 The personnel and test equipment needed for these tests are listed together with the test requirements in Table 40. The particulate contamination test for all pipeline systems may be checked using medical air to establish that the pipeline has been constructed correctly and is not contaminated. Successful completion of the commissioning tests normally indicates the end of the installation contract. The systems may then be left under pressure, filled with medical air, for an indefinite period. Responsibility for the system during this period needs to be clearly defined in the contract; the Authorised Person (MGPS) under a conventional build hospital ultimately responsible for the day-to-day management of the MGPS after handover should be permitted access during contract work. This should be included in the contract agreement. For PFI/PPP projects, to ensure there cannot be a conflict of interest, the Contract Supervising Officer preferably from an independent organisation, can be appointed in accordance with Scottish Health Technical Memorandum 00, Scottish Health Technical Memorandum 02-01 Part B and be acceptable to all parties.

Note 43: In some circumstances an MGPS may not be taken into use immediately after construction and will be left filled with medical air. In these circumstances, the particulate contamination and odour/taste tests may be carried out before purging and filling with the working gas (see paragraphs 15.95 – 15.101).

Paragraph	Test	Personnel	Equipment
15.1	Validation of design prior to installation	CSO or AP	
15.11	Labelling and marking	CSO or AP and CR	Visual
	Sleeving and supports	CSO or AP and CR	Visual and tape
	Leakage	CSO or AP and CR	Pressure-measuring device
	Cross-connection	CSO or AP and CR	Pressure-measuring device
15.12	Functional tests of all supply systems	CSO or AP and CR	Flow meter / Dew-point meter/ electrical test equipment
	Leakage	CSO or AP and CR	Pressure-measuring device
	Closure of AVSUs and LVAs	CSO or AP and CR	Pressure-measuring device
	Zoning of AVSUs and terminal unit identification	CSO or AP and CR	Open probes or special test device
	Cross-connection	CSO or AP and CR	Open probes or special test device
	Flow and pressure drop at individual terminal units, mechanical function and correct installation	CSO or AP and CR	Special test device, certified probes
	NIST connectors	CSO or AP and CR	Full bore NIST probes and nut
	System performance	CSO or AP and CR	Metered leaks and special test device
	Supply systems	CSO or AP and CR	Visual
	Pressure safety valves	CSO or AP and CR	Visual
	Warning and alarm systems	CSO or AP and CR	Visual
	As-fitted drawings	CSO or AP	Visual
	Purging and filling	CSO or AP and CR	Gas source and delivery equipment
	a) Other supply system functional tests b) Particulate contamination (see note after paragraph 15.8)	CSO or AP and CR	Particulate matter test device (PMTD)
	AGS disposal systems	CSO or AP and CR	Metered leaks and AGS test device
15.13	Gas quality	CSO or AP, CR and QC (MGPS)	PMTD, oil, moisture, CO, CO_2, SO_2 and N_2 oxides measuring devices, O_2 and N_2O analysers
	Gas identification	CSO or AP, CR and QC (MGPS)	O_2 analyser and N_2O meter

Table 40: Personnel and test equipment requirements

Note 44: Refer to Scottish Health Technical Memorandum 02-01 Part B for description of the duties and responsibilities of the various parties included in Table 40.

15.8 All supply systems and their major components should have certificates (as specified in Model Engineering Specification C11 – 'Medical gases') which show that they meet the design requirements of the pipeline system.

15.9 Only contractors who are registered to BS EN ISO 9001: 2008/BS EN ISO 13485: 2003 with their scope of registration defined to include commissioning should undertake engineering validation and verification. Contractors who may not be registered as such, but who can actively demonstrate that they are working towards registration may also be considered for this work.

Note 45: BS EN ISO 9001: 2008 registration is also recommended for independent medical gas testing agencies but is not necessary for appropriately trained and appointed hospital-based QCs (MGPS).

15.10 All relevant tests should be carried out by the persons listed in Table 40 and witnessed by the appropriate persons, who must record the results of the tests in writing for the hospital authority.

Summary of tests

Tests and checks on the pipeline carcass

15.11 The following tests must be carried out after installation of the pipeline carcass but before concealment:

- visual check of pipeline labelling, marking, sleeving and supports;
- leakage test;
- tests for cross-connection;
- valve tests for closure, zoning and leakage. (These tests will be repeated as part of the pipeline system tests and the contractor may wish to defer closure and leakage, but may choose to carry out a zoning check.)

Tests on the pipeline system

15.12 The following tests and checks must be carried out after complete installation of the pipeline system:

- tests for leakage on each MGPS;
- tests of AVSUs for closure, correct service and control of the terminal units in the zone: checks for correct labelling of AVSUs for zone reference and identity of terminal units controlled and flow direction indication;
- tests of LVAs for closure and identification;
- tests for cross-connection, flow, pressure drop, mechanical function and correct identity of the terminal units: checks for correct labelling and

association with AVSUs (this is only required when, within a specific area, there are separate circuits for the same service, for example dual/ split circuits);

- tests for mechanical function and identity of NIST connectors;
- performance tests of the pipeline system;
- functional tests of all supply systems;
- checks of safety valve certification;
- tests of warning systems;
- tests for particulate contamination should be carried out by the contractor and the AP or CSO during the course of the engineering tests. Where it is shown that a high degree of oxide particles were present within the piped system (this would indicate a deficiency in the initial oxygen free nitrogen purging) the AP or CSO would decide whether to continue with the medical air purging or reject the system. At this stage the Quality Controller (MGPS) would not be required. If the AP or CSO is satisfied with the cleanliness and depending on the contract programme handover date, the QC (MGPS) could be invited to carry out particulate contamination, odour and taste tests using the working gases. An advantage in programming these tests at this stage is the use of the medical air which avoids the high usage of the working gases and risk factor to site staff. The CSO particulate test does not negate in any way the role and responsibility of the QC to repeat the test;
- tests for anaesthetic gas scavenging disposal systems.

Note 46: Nitrous oxide and nitrous oxide/oxygen mixture are not tested for odour.

Tests before use

15.13 The following tests must be carried out after purging and filling with the working gas:

- tests for particulate contamination (see para 15.94 and 15.131 to 15.137);
- tests for gas identity;
- tests for gas quality.

General requirements for testing

15.14 The tests described in this document are generally carried out, in the order given, for new installations. It may be necessary to amend the test programme for modifications or extensions to existing systems. Care must be taken, however, to ensure that the basic principles are followed. Para 15.33 to 15.46 give details of the tests required for modifications/extensions to existing systems.

15.15 In all cases involving plant, the medical air and vacuum plant should be tested during or immediately following carcass tests. This test will include the QC certification of the medical / surgical air plant.

15.16 On major projects the availability of the following plant is essential to progress the commissioning programme:

- vacuum plant to allow vacuum leakage and flow tests to be carried out on the completed system.
- medical air plant certificated by CSO or AP and QC to enable its use during the testing of all gas systems. Cylinder supply will not typically provide sufficient capacity when testing large MGPS installations.

Note 47: When tests and/or purging are/is carried out on systems fed by sources serving an operational hospital, it is essential to ensure that the flows generated during any tests do not result in interruption of continuity or impairment of adequacy of supply within the operational areas.

15.17 Testing for leakage is normally carried out in two stages: the first to the pipeline carcass, the second to the completed distribution system, which will include terminal units and medical supply units as appropriate.

15.18 Purging and testing must be carried out with clean, oil-free, dry air or nitrogen, except for those tests where medical air or the specific working gas is prescribed. All test gases must meet the particulate contamination requirements set out in paragraphs 15.131 – 15.137. The shield gas may be used for the tests on the pipeline carcass described in paragraphs 15.50 – 15.57. Cylinders of medical air will normally be used as the source of test gas for oxygen, nitrous oxide, nitrous oxide/oxygen mixture and helium/oxygen systems in order to prevent the possibility of contamination with oil.

15.19 However, in the case of a large oxygen system, for example a new-build, the use of cylinders will be impracticable for the total system performance test. As it may be undesirable to commission the liquid supply system, the total system performance test can be carried out by using the medical compressed air plant, provided that the quality tests have been satisfactorily carried out to demonstrate that the criteria set out in Table 43 have been met and that the air supply plant is continuously monitored for moisture during the test.

15.20 The medical compressed air plant can also be used for the single point performance tests etc and for initial purging and particulate testing of these systems. Once tests have been completed, the system should be maintained under pressure by means of air supplied from medical gas cylinders until filled with the working gas, when full QC checks will be carried out.

Note 48: The use of portable, non-medical air compressors is not appropriate. Not only should a Quality Controller (MGPS) check all compressors before use, but also QC checks during use are important. Preferably, an on-line dew-point meter should be fitted to the plant or pipeline system.

15.21 When employing medical compressed air plant for this type of test, it is important that the system demand should not exceed the maximum flow capacity of the dryers, otherwise wet air will result. It is suggested that the total flow required by the system under test should not be more than 75% of the flow capacity of the dryers.

15.22 It is also important not to introduce such a compressor after identity checks have taken place.

15.23 Special care will be required when carrying out QC checks, as some synthetic oils cannot be detected using portable equipment.

15.24 Special connectors will be needed to introduce test gas into different pipeline systems. These must be of distinctive construction and permanently labelled with their function and the contractor's name. The location of special connectors on the site must be recorded and should be subject to routine inspection under a planned preventive maintenance (PPM) system. They should be removed from site when work is complete and the contractor should record their removal.

15.25 New terminal units are supplied with "Do not use" labels. These labels should remain in place until the final identity and quality tests have been completed. They are then removed by the Authorised Person (MGPS).

15.26 In the case of existing systems, "Do not use" labels should be affixed to all terminal units within the section being modified.

15.27 The results of all tests must form part of the permanent records of the hospital and should show details of the services and areas tested. Examples of the appropriate forms are given in Appendix A. All signatories are entitled to copies of the test forms. The procedure for filing and retaining these forms should be included in the local MGPS operational policy.

15.28 For total system pressure tests on oxygen, nitrous oxide and nitrous oxide/oxygen mixture, the system under test must be physically isolated from the source of supply (for example by the use of spades). In the case of compressed air and vacuum systems, the pressure at the plant must be respectively below and above pipeline distribution pressure.

15.29 All errors found during testing must be rectified, and the relevant systems must be retested as appropriate before the records are signed.

15.30 The contractor (MGPS) must provide all engineering forms, labour, materials, instruments and equipment required to carry out the tests described in this chapter. In the case of engineering tests, this must include all cylinders of test gas together with "open" bore NIST connector probes, pressure-measuring equipment and gas specificity/ flow pressure testing device(s), metered leaks and AGS disposal system test equipment. The Quality Controller (MGPS) will be responsible for supplying all QC forms, unless otherwise requested by the Hospital Authority, calibrated test equipment, connections etc.

Note 49: If there is to be a delay between completion of the MGPS and when it is taken into use, it will be necessary to carry out the particulate and odour test prior to purging and filling with specific gases. In such cases the contractor must also provide labour, materials and equipment to carry out these tests.

15.31 The Quality Controller (MGPS) should provide the test equipment specified in Appendices D, E and F. The Quality Controller (MGPS) should provide all equipment for gas quality and identity testing. It should be regularly serviced and calibrated to an appropriate standard and the Quality Controller (MGPS) should maintain calibration records. On-site pre and post-testing calibration of equipment against an appropriate standard will be performed at the discretion of the Quality Controller (MGPS).

15.32 In a completely new installation, flow meters, anaesthetic trolleys etc should not be moved into rooms until validation and verification tests have been satisfactorily completed.

Note 50: In existing installations, particular care must be taken to ensure that medical gas equipment left in areas where work or testing is taking place is, and remains, disconnected from the system. Medical and nursing staff should be made aware of this situation by the posting of appropriate exclusion notices and terminal unit “Do not use” labels.

Modifications, extensions or repairs to existing systems

15.33 Where modifications, extensions or repairs to existing systems are carried out, the tests and the sequence of tests summarised in paragraphs 15.12 – 15.14 should be followed as far as possible.

15.34 The permit-to-work system should always be followed whenever any work is carried out on an existing system. The Authorised Person (MGPS) should act on behalf of the management and therefore would not normally be a member of the installation contractor’s staff.

15.35 Whenever modifications or extensions are carried out, it may be advisable but not always possible to test both the existing system and the new system separately before the break-in is made. Existing systems should, if possible, be tested to determine their performance and to identify any potential limitations that may arise as a result of modifications.

15.36 Where there is any doubt as to the cleanliness, it is in the interest of both the contractor and management for particulate tests to be carried out on the existing system prior to any break-in, and it is the responsibility of the hospital authority to ensure that these tests are carried out prior to the design phase of any modifications or extensions.

15.37 It is the responsibility of the hospital’s management to ensure that any required remedial work is carried out on an existing system before extensions are added.

15.38 No system should be modified during the process of testing. It is important that any modifications are documented and that any additional testing required, as a consequence of those modifications, is performed.

15.39 A permit-to-work (or another form of appropriate document) must be issued if additional works are to be carried out during the commissioning process, even though a permit will not have been issued for the original commissioning.

15.40 The tests for particulate contamination of any extension or modification may be carried out with medical air, prior to connection and handover to the Quality Controller (MGPS), although in extensions comprising fewer than 20 joints, the working gas will generally be used to perform all tests.

15.41 The Quality Controller (MGPS) will normally carry out all checks, including a repeat of the particulate matter test, using the working gas.

15.42 The exact tests to be carried out will depend on the nature of the modification/extension. A specification should be prepared for the performance of the completed system. This specification should be as close as possible to that given in Table 41.

15.43 Some older compressed air systems will have been designed to provide 250 litres/min at the terminal unit in accordance with Health Technical Memorandum 22 (1978). It may not be possible for such systems to provide 350 litres/min, as specified in Table 19, and there may be circumstances where this would be acceptable. This should be clearly stated in the specification for the performance of the completed system. However, every effort should be made to comply with the performance and quality specifications given here, although particular care must be taken to avoid degradation of air quality arising from dryer units working at flow rates above their design specification.

15.44 It may be necessary to repeat some of the system performance tests (such as flow and pressure drop) at selected terminal units on the completed system to demonstrate satisfactory performance (see paragraph 15.78). To ensure a valid result from such a test, it should be performed when flows in the system are representative of typical maximum demands.

15.45 The break-in to the existing system should be carried out with an inert gas shield where possible, for example where AVSUs have been installed, and a downstream blanking spade has been deployed. A leak test must be carried out using a suitable leak detection fluid on this final joint at working pressure, and the joint purged with the working gas.

15.46 Connection of the upstream side of the AVSU into the existing system will usually be made without use of the shield gas. This joint can be purged with the working gas (exiting via the AVSU upstream NIST).

Note 51: In some articulated pendant fittings, it is not always possible to achieve the specified pressure requirements for surgical air and vacuum. In the case of surgical air, it is most likely to be a potential problem in orthopaedic operating rooms. As these normally include an ultra-clean system into which can be incorporated surgical air (and other terminal units), supplied by rigid pipework, there may not be a problem in practice. If the static pressure exceeds the nominal pressure during flow by more than 25%, the possibility of installing hoses with a greater bore should be considered. In the case of vacuum, the flows required during surgery are less than those used during testing.

Medical gas	Plant Regulator Setting +/- 4% (kPa)	Distribution pressure (kPa)	Allowable pipeline losses to rear of terminal unit 5% (kPa)	Test flow (litres/min) (measured at terminal unit outlet)	Minimum pressure at design flow (kPa)
O_2	440	420	400	40*	380
N_2O	440	420	400	40*	380
O_2/N_2O mixtures	440	420	400	275 (LDRP) 40* (others)	310(2) 380
Medical air (400 kPa)	440	420	400	80 (critical care) 40* (others)	380
Surgical air (700 kPa) Wall outlet	860	825	784	350*	700
Surgical air (700 kPa) Pendant	940	900	854	350*	700
He/O_2	440	420	400	80 (critical care)	380
Vacuum	67 – 88 (500-660 mmHg)	60 kPa (450 mmHg)	55.3 kPa (400 mmHg)	40	40 kPa (300 mmHg)

Table 41: Validation and verification: pressure during pipeline system tests

Requirements for pipeline carcass tests

15.47 If sectional testing is performed, it is essential that as-fitted drawings are available so that the extent of the system(s) under test can be identified. For the purpose of the leakage test, all pressure gas systems may be interlinked, provided that the test can be performed at the highest pressure required. This also has the advantage that the pipeline carcass could be assigned to a different service.

Note 52: In the event of a leak, it will be necessary to test each system separately. It is advantageous to perform the tests with nitrogen, since – in the event of a leak or cross-connection – remedial action can be taken immediately. When connecting systems together, vacuum systems should not be included, as particulates from an un-purged vacuum system may be drawn into any part of any pressure gas system by venturi effects.

Labelling and marking

15.48 A visual check must be made on each pipeline system to ensure that the pipelines are labelled in accordance with the contract specification, and that the terminal unit base blocks are marked in accordance with. BS EN ISO 9170-1: 2008. The results of the checks are recorded on Form A2.

Sleeving and supports

15.49 A visual check must be made on each pipeline system to ensure that the pipelines are sleeved, where required, and supported in accordance with Table 39. The results of the checks are recorded on Form A2.

Leakage

15.50 The aim of the test is to establish that there is no leakage from the piped medical gas systems. This is demonstrated by the use of electronic pressure measuring equipment with a minimum resolution of 0.2 kPa in 1,000 kPa and 0.5 kPa in 2,000 kPa. If the performance of the measuring equipment is in doubt, recourse can be made to a test period extension of between 2 - 24 hours.

Note 53: With suitable equipment, it is possible to carry out this test during a relatively short period to minimise the effect of temperature change. To ensure fairness of the test, it is essential that temperature measurements are taken and recorded at the start and finish of the test irrespective of the period of the test. Over a one hour period with an allowance of 0.2 kPa, a small temperature change may be sufficient to fail the test. Appendix B provides information on the method of calculation. Temperature measurements should be taken throughout the area of test at the beginning of the test and the average temperature should be calculated. Temperature measurements should be taken at the end of the test at the same measurement points. The resulting temperature difference can be used to establish if a pressure loss/increase is acceptable.

15.51 During a test period of one hour, the maximum pressure loss should be ≤ 0.2 kPa for 400 kPa systems, plastic or copper vacuum and ≤0.5kPa for 700 kPa systems. Systems should be tested at a working pressure of

- For medical compressed air systems for surgical use - 18.0 bar (1,800 kPa);
- For all other compressed medical gas systems - 10.0 bar (1000 kPa);
- For vacuum systems constructed in copper 5.0 bar (500 kPa);
- For vacuum systems constructed in plastic 1.5 bar (150 kPa):
- Leakage tests for AGSS systems, the pressure should be set at 70 kPa (± 10%) with a pressure loss of no more than 10 kPa over a period of 15 minutes.

15.52 This test should be carried out with AVSUs, LVAs and other service valves open; any safety valves and pressure-sensing devices installed may be

removed and the connections blanked off. The results of the test may be recorded on Form A2.

Cross-connection

15.53 Before performing these tests, any links between systems should be removed and all pipelines should be at atmospheric pressure with all AVSUs etc open.

15.54 A single pressure source should be applied to the inlet of the system to be tested and at least one terminal unit base block on all other systems should be fully open.

15.55 Each terminal unit base block on the pipeline under test should be opened in turn, checked for flow and then re-blanked. (To permit refitting of blanking caps, it is necessary to partially open at least one base unit – but it is still necessary to achieve a detectable flow.) When the test on one pipeline has been completed, the pressure source should be removed and the pipeline should be left open to atmospheric pressure by removing at least one base block blanking plate.

15.56 The test is repeated for other systems, one at a time.

15.57 The results may be recorded on Form A2.

Requirements for pipeline system tests

15.58 There must be no links between the pipeline systems. Engineering (pressure) tests should be carried out with electronic pressure-measuring equipment with a minimum resolution of 0.2 kPa in 1,000 kPa, and 0.5 kPa in 2,000 kPa.

15.59 The scope of the system and scale of provision of terminal units, AVSUs, LVAs and warning and alarm system panel indicators should be checked for compliance with Table 11 and any deficiencies noted.

Leakage from total compressed medical gas systems

15.60 This test must be carried out on the completed system at working pressure with all terminal units, AVSUs, pressure safety valves and pressure transducers fitted. Once the test pressure has been applied, the system should be physically isolated from the plant. For the purpose of this test, the supply system extends from the last valve(s) nearest to the plant detailed on the appropriate schematic drawing. This point should be identified on the contract drawings. The test is performed at pipeline distribution pressure.

15.61 During a test period of one hour, the maximum pressure loss should be

- ≤ 0.2kPa for 400 kPa systems;
- ≤ 0.5kPa for 700/900 kPa systems.

The test results may be recorded on Form A3.

Leakage into total vacuum systems

15.62 Prior to testing, the vacuum plant should be operated to allow any moisture in the system to evaporate. With the system at pipeline distribution pressure and with the source isolated, the pressure increase in the pipeline must not exceed 1 kPa (7.5 mmHg) after one hour. There is no additional allowance for temperature correction in this test.

15.63 The test results may be recorded on Form A3.

Closure of area valve service units and line valve assemblies

15.64 For pressurised systems, the system upstream of the closed AVSU under test must be maintained at pipeline distribution pressure and the downstream line pressure should be reduced to about 100 kPa. The downstream pressure must be recorded, and there should be no change in pressure over a period of 15 minutes.

15.65 For vacuum systems, the systems on the supply plant side of the closed valve must be maintained at pipeline distribution pressure and the terminal unit side should be at about 15 kPa (115 mmHg). The upstream (terminal unit side) pressure must be recorded, and there should be no change in vacuum over a period of 15 minutes.

15.66 For LVAs, a similar test procedure is adopted. There is no change in the time for vacuum.

Note 54: The reduced residual pressure is intended to take into account any potential terminal unit leakage on the assumption that it is unlikely any such leakage would equate to that of the valve under test; there would be less certainty if the pressures were reduced to zero.

15.67 The test results may be recorded on Forms A4 and A5.

Zoning of AVSUs and terminal unit identification

15.68 This test is performed to ensure that each AVSU in the pipeline controls only those terminal units intended by the design. Each terminal unit must be checked to ensure that it is for the correct service and that it is in accordance with BS EN ISO 9170-1: 2008; unambiguous cross-referenced labelling of AVSUs and terminal units controlled by them, is essential. It is particularly important to establish correct identification where dual or separate circuits have been installed; often it is not obvious by the spatial relationship of AVSUs and terminal units which of the AVSUs controls which terminal unit arrays.

Note 55: a) The contractor may wish to carry out this test as part of the carcass tests before any section of the pipeline is "enclosed".

b) Terminal-unit first-fix back blocks inadvertently fitted upside-down will result in inverted second-fix components, unless gas-specific components are deliberately removed. Therefore, a selection of terminal unit second-fixes, for example one per ward area, should be removed and examined to ensure that no gas-specific components have been removed.

15.69 The test is performed by turning off an individual AVSU and venting the zone to atmospheric pressure. A check is then made to establish that only those terminal units controlled by the AVSU are at atmospheric pressure. All other terminal units, including those for other gas services, should be at the operating pressure. Once a zone has been vented, it is not necessary to re-pressurise. The other AVSUs are then tested successively.

Note 56: a) These tests can be performed at the same time as the cross-connection/terminal unit pressure drop tests.

b) Where pneumatically activated pendant fittings are installed, a check should be made to ensure that the source of air has been taken from the correct AVSU zone.

15.70 The test results may be recorded on Forms A4 and A5.

Cross-connection

15.71 All systems must be checked to ensure that there is no cross-connection between pipelines for different gases and vacuum. The tests should not commence until all installations are complete and plant operational. The tests can be performed using "test" gas or "working" gas.

Note 57: Oxygen and vacuum can be tested simultaneously, followed by medical air and surgical air simultaneously, followed by the other gases, that is, nitrous oxide and nitrous oxide/oxygen mixture. Helium/oxygen mixture usage is increasing, and pipeline systems may be encountered. Also, carbon dioxide pipelines are being installed.

15.72 The sequence of the test is, first, to open all valves on all systems (for example AVSUs, LVAs and any other valves). For oxygen and vacuum systems, the main plant isolation valves should be opened (the main plant isolation valves on other systems remain closed). A check must be made to ensure that there is a flow at every oxygen terminal unit and suction at every vacuum terminal unit, and that the systems are at the correct operating pressure; there must be no flow at any other terminal unit for the other gases.

15.73 For the next stage, the main isolation valves for medical air and surgical air, if present, are opened. (It is not necessary to return the oxygen and vacuum systems to atmospheric pressure.) A check is made to ensure that there is a flow at every medical air terminal unit and every surgical air terminal unit and

that the operating pressure is correct; there must be no flow from the nitrous oxide and/or nitrous oxide/oxygen mixture terminal units, if present, and helium/oxygen, if present.

15.74 The process is then repeated for nitrous oxide – again there is no necessity to return any of the previously tested systems to atmospheric pressure. A check is made to ensure that there is flow at every nitrous oxide terminal unit and that the operating pressure is correct; there must be no flow from the nitrous oxide/oxygen terminal units and helium/oxygen terminal units (if present).

15.75 The process is then repeated for nitrous oxide/oxygen mixture, and finally helium/oxygen mixture. If other medical gases are encountered, for example carbon dioxide, the sequential testing methodology will continue. As before, there is no necessity to return any of the previously tested systems to atmospheric pressure. Checks are made to ensure that there is no flow from any system that is still isolated at the plant.

Note 58: The tests can be carried out on a total system basis, departmental basis or sub-departmental basis, having previously checked for cross-connection up to the appropriate AVSUs. When carrying out the tests on a sectional basis, it is essential that as-fitted drawings are available such that the extent of the system(s) can be established.

15.76 This test must be repeated in full if any subsequent modifications are made to the pipeline system.

15.77 The test results may be recorded on Form A7/1.

Flow and pressure drop at individual terminal units, mechanical function and correct installation

15.78 These tests can be carried out as part of the cross-connection tests above using appropriate test devices as described in Appendix C with the correct probes inserted for the pipeline(s) under test. The pressure must achieve the values given in Table 41 at the specified flows.

Note 59: When performing these tests as part of the cross-connection tests, there is the possibility that the 400 kPa and vacuum test devices could be connected to the incorrect service, particularly a vacuum and oxygen reversal. The instruments used, therefore, should include appropriate directional check valves. (There is a possibility of damaging the gauges. Alternatively an open probe can be used to determine pressure or vacuum.)

15.79 It must be demonstrated for each terminal unit that the appropriate gas-specific probe can be inserted, captured and released, and it should be visually confirmed that an anti-swivel pin is present, or absent, in terminal units with a horizontal or vertical axis, respectively. Terminal units should be challenged by the test probes of all other gases within the department or ward to ensure non-interchangeability.

Note 60: a) Terminal units to BS EN ISO 9170-1: 2008 need not be challenged with the full complement of BS 5682:1998 test probes.

b) The terminal unit should be fitted complete with bezel plates etc. The clearance hole should be reasonably concentric with the terminal unit rim – it must not be in contact.

c) By connecting a flowmeter to the terminal unit, the terminal unit should be standard throughout by being proud of the wall, slightly greater than the movement necessary for the release action and sit parallel to the wall on a vertical axis.

15.80 The results of the tests may be recorded on Form A8.

15.81 All NIST connectors, including those provided on AVSUs, LVAs and pendants / flexible hoses, must be checked to ensure that gas flow is achieved when the correct NIST probe is inserted and mechanical connection made. The correct identification of gas flow direction should be confirmed for AVSUs (that is, which are the upstream and downstream NIST connectors). NIST connectors can be checked when performing other tests on AVSUs and LVAs.

Note 61: a) In certain circumstances factory-assembled units are dismantled for installation purposes and can be subsequently incorrectly re-assembled. In the case of LVAs (whether or not CE marked), disassembly and subsequent incorrect re-assembly or, indeed, insertion into an incorrect line, is also possible. The primary purpose of the test is to ensure that whenever it is necessary to make a connection, the appropriate connectors will be to hand; the test is a further safety aid, although it is assumed that personnel making connections to NIST fittings are appropriately qualified and authorised to do so.

b) All NIST connectors should have the manufacturer's certificate of test provided for fitted terminal units within pendants.

15.82 It must be demonstrated (except for vacuum) for each NIST connector that the self-sealing device substantially reduces the flow of gas when the connector is removed without hazard to personnel or reduction in pipeline pressure. This will not apply where the surgical air pendant hose self-sealing device of the NIST has been removed and replaced by an in-line valve.

Note 62: Personnel should take care not to stand in front of the NIST connector when performing this test.

15.83 The results may be recorded on Form A8.

Performance tests on the pipeline system

15.84 The performance of individual pipeline systems is measured by introducing a sufficient number of calibrated metered leaks (with orifice sizes providing different flows that replicate the range of medical devices for which the pipeline is designed; see Table 12) to represent the total "diversified" system design flow, less the flow generated by the test device. Thereafter, a representative

number of terminal units (see note below) are tested for pressure and flow: the diversified flows should be derived from the data in Tables 13, 15, 16, 18, 20 and 21.

Note 63: a) In a 28 bed ward module, metered leaks equal to the total design flow of the ward should be distributed through the ward. A pressure reading should be taken at the furthest located terminal unit and nearest to the entrance to give the pressure loss across the unit. No noticeable loss should occur with ward gases

b) This procedure is applied systematically for a total system design flow by applying metered leaks equal to the hospital diversified design flow. Pressure readings can be taken throughout the system from source to furthest terminal units from source. Normally an index run is selected based on the heaviest diversified flow demand concentration rather than distance from source.

c) In a ring main distribution system the total flow is designed by measurement in turn in each direction from the source. Requirement for sectional or phased testing to be included.

15.85 The metered leaks should be stamped or similarly be identified to show the flow (air equivalent) at, for example, 10, 20, 100, and 275 litres/min for 400 kPa systems, and 350 litres/min for 700 kPa systems.

Note 64: In principle it is permissible, although unlikely to be practicable for large installations, to test all systems simultaneously, particularly oxygen and vacuum, where terminal units are installed in pairs and where they require different metered leaks (this includes vacuum when testing oxygen will not significantly increase the time needed).

Functional tests of supply systems

15.86 All supply systems must be tested for normal and emergency operation, according to the manufacturers' manuals and contract specifications. For the purpose of the tests, the systems must be connected to both the normal and stand-by power supplies. The results of these tests should be recorded on Forms A9 - A13 and A17.

Pressure safety devices

15.87 Pressure safety valves are not tested. They should be examined to ensure that they are correctly rated for the pipeline system and are in accordance with the contract specification. Each should be provided with a test certificate confirming the certificated discharge pressure. Records of safety valve details should be noted on Forms A9 to A12 inclusive.

15.88 Check that the specified pressure safety valves have been fitted.

15.89 Verify that the pressure safety valves are certified to operate in accordance with the contract specification and conform to BS EN ISO 4126-1: 2004.

Warning and alarm systems

15.90 The operation of warning and alarm systems should be tested in all normal operating and emergency modes. Particular attention should be paid to the following:

- that all systems operate within the specified tolerance limits at all operating parameters and fault conditions, and can be seen and heard as specified in Tables 37 and 38;
- that systems react correctly following return to normal status;
- that all indicator panels and switches are correctly marked;
- that all functions on all indicator panels operate correctly;
- that the system will operate from the essential supply stand-by power source;
- that all indicator panels are labelled to show the areas they serve, or as detailed in the contract specifications.

15.91 The following tests should also be carried out:

- for central indicator panels, check that the operation of the mute switch cancels the audible alarm and converts the flashing signals to steady, for all systems and conditions;
- for repeater indicator panels, check that the mute switch cancels the audible alarm and that the flashing signals are converted to steady only on the central alarm panel, for all systems and conditions;
- for area alarm panels, check that the operation of the mute switch cancels the audible only, for all systems and conditions;
- check power failure operates red “system fault” indicator and the audible alarm;
- check that a contact line fault operates the “system fault” indicator, the main alarm displays and the audible alarm;
- check audible reinstatement for each alarm panel;
- check that the audible signal can be continuously muted via operation of the internal push-button for gas service alarm conditions only;
- check for correct identification of each gas service on alarm panels and “departmental” or plant specifying labels;
- check that each alarm panel emits the correct (two-tone) audible alarm. (Some manufacturers supply panels set for a single tone – in use, staff may confuse this sound with that emitted by some models of patient monitoring equipment.)

15.92 The results of the tests are recorded on Form A14.

Verification of as-fitted drawings

15.93 The as-fitted drawings should be checked to ensure that all variations from the contract drawings have been recorded and the results may be recorded on Form A18.

Filling with medical air

15.94 An indefinite time may elapse after completion of the MGPS before the system is taken into use. The installation contract may be written in the expectation that this will happen. In such circumstances the contract should require that the particulate contamination and odour tests, specified in para 15.131 to 15.137 are carried out as an interim measure, using medical air as the test gas. Satisfactory completion of these particulate contamination and odour tests may then signify the completion of the construction contract.

15.95 It is the responsibility of the contractor to ensure that proper provision is made in a specific contract for the maintenance of the systems, their integrity, and any special connectors that may be required during this interim period.

15.96 All MGPS should be left filled with medical air at pipeline distribution pressure until they are filled with the specific working gas shortly before use. The medical vacuum pipeline need not be maintained under vacuum.

15.97 Provision should be made for regular running and maintenance of all supply plant during such an interim period.

15.98 Details of the work carried out, as well as records of the system pressures, should be recorded. This information is required in order to demonstrate that the systems have been satisfactorily maintained under pressure during this interim period. Tests for particulate contamination should be carried out after the systems are filled with the specific gas. The extent of the tests is at the discretion of the Quality Controller (MGPS).

15.99 The “Danger – do not use” label should remain affixed to each terminal unit until all testing is completed.

15.100 When the construction contract has finished, the contractor should record the removal of all special connectors and cylinders from site.

Note 65: Special connectors and cylinders may be required to maintain the systems under pressure. This may be some time prior to the admission of patients. In such circumstances some contracts require systems to be completed and certificated for the purpose of practical completion and handover to the client.

Purging and filling with specific gases

15.101 Each pipeline system must be purged with the specific working gas shortly before use. The following conditions should apply:

- all sources of test gas must be disconnected;
- all special connectors must be removed from site;
- each pipeline system must be at atmospheric pressure with all AVSUs open;
- each system must be filled to pipeline distribution pressure with the specific gas from the supply system;
- with the supply system on, each terminal unit must be purged at a known flow with a volume of gas at least equal to the volume of the pipeline section being tested;
- all oxygen, nitrous oxide, nitrous oxide/ oxygen mixtures and helium/oxygen mixture discharged during the process must be released to a safe place.

15.102 The results of the purging process may be recorded on Form A19.

15.103 Purging is not necessary for vacuum systems.

Note 66: It may be possible to carry out the tests outlined in para 15.59 to 15.92 with the working gases, either sequentially or consecutively, followed by the appropriate pharmaceutical test. After the tests, “certification” arrangements should be put in place such that the client takes over responsibility for managing the system.

Pharmaceutical testing

15.104 When modifying existing systems, the test programme is agreed by the Quality Controller (MGPS) and Authorised Person (MGPS) and the system is taken back into use only after testing has been completed satisfactorily under a permit-to-work system.

15.105 Three types of work are identified:

- new;
- extension/upgrade; and
- repair.

For new installations, for example a new ward, a new department, or a complete hospital, the Quality Controller (MGPS) will prepare a report containing details of tests carried out and an inventory of outlets tested.

15.106 For extensions, upgrades and repairs, the permit will provide the minimum report, although a longer report may be provided at the discretion of the Quality Controller (MGPS).

15.107 Inclusion of details such as the mounting order of terminal units observed at the time of test should be confirmed by signature of the Authorised Person (MGPS) on the report.

15.108 This inventory should be checked by the Authorised Person (MGPS) to ensure that all terminal units have been identified and tested. NIST connectors will also need to be identified. The Authorised Person (MGPS) should then amend a copy of the Quality Controller (MGPS) report, confirming in writing that the system can be taken into use.

15.109 Although a structured approach to testing should be adopted, access and time limitations to parts of the MGPS may lead to some disruption of proposed test regimes.

Note 67: Important: These tests are described in the context of commissioning and repair/alteration to existing systems. However, it must be remembered that quarterly testing is also required by this Scottish Health Technical Memorandum and in accordance with Tables 41 and 42 for medical air generated by on-site air compressors, synthetic air from gas blending plant, and oxygen from oxygen concentrators using compressor plant. The Authorised Person (MGPS) should liaise with the Quality Controller (MGPS) to ensure that these tests are carried out and recorded.

Note 68: a)The role, responsibilities and relationships of Authorised Persons (MGPS) – in the context of both existing and new installations, where the Authorised Person (MGPS) may not have responsibility for the systems when in use – is covered in Part B.

b) Although precluded by adherence to the procedures recommended in this Scottish Health Technical Memorandum, there have been instances when a system undergoes further modifications after a Quality Controller (MGPS) has started testing. It is very important that any modifications are documented and that any additional testing required as a consequence of those modifications is performed. Use of the permit-to-work form should be considered in these cases.

c) If it is necessary to modify systems during or after completion of testing, the Authorised Person (MGPS) and Quality Controller (MGPS) will identify the extent of retesting that is required. If the system has been completed and all documentation handed over to the client or operator of the building, any further modification must be carried out strictly in accordance with the permit-to-work procedure.

d) The importance of NIST connectors in facilitating engineering and pharmaceutical testing and their value during shutdowns and emergency situations should not be underestimated. All LVAs are fitted with upstream and downstream NIST connectors.

Quality of medical gas systems

General

15.110 The objective of these tests is to establish whether the pipeline has been contaminated during construction or modification. The tests indicate whether

work has affected a gas, but they are not tests that indicate compliance with pharmaceutical specifications for licensed products.

15.111 Particulate contamination and odour tests may have been carried out prior to filling with the working gas, particularly if the system has been left for some time before use. However, the Quality Controller (MGPS) will define the extent of repetition of these tests, after the systems have been filled with the specific working gas.

15.112 The Quality Controller (MGPS) will also define the extent of all other pharmaceutical testing, depending on such factors as the extent and nature of the work and the age and condition of the existing systems.

15.113 The Ph. Eur. should be seen as a basic minimum standard when examining medical gas quality, as its principal application is to the manufacture and distribution of medicines according to well-established manufacturing processes. It is not intended to deal with the endless possibilities for contamination that are introduced by an MGPS, or the types of failure that might occur with on-site generation of gases.

15.114 Occasionally, the Quality Controller (MGPS) may need to resort to more sophisticated testing than is permitted by the use of portable equipment.

15.115 Oxygen, helium/oxygen mixture, nitrous oxide, and nitrous oxide/oxygen mixtures discharged during the process must be released to a safe place. These tests are not required on a vacuum system for any work including modifications or new works.

15.116 These test procedures are based on existing practice. The particulate contamination test is subjective in that it requires the QC to make a judgement on whether or not particles are visible on the filter.

15.117 The oil, water, carbon monoxide and carbon dioxide, sulphur dioxide and oxides of nitrogen tests can be carried out with detector tubes, but advances in detection technology have produced a range of suitable alternative instruments. The use of detector tubes giving a quantitative response is recommended but is not intended for re-use. If other equipment is used for validation purposes, it must provide a level of repeatability, resolution and accuracy at least equivalent to that of detector tubes and must be calibrated to appropriate Standards.

15.118 An electronic dew-point meter should be used in preference to water content measurements.

15.119 Detector tubes should be agent-specific. Non agent-specific (polytest) tubes can respond to various agents without identifying or quantifying the contaminants. Nevertheless without their use the degree of release of chemicals from hosing into the gas stream would never have been realised. Although BS5682 did not recommend tests on flexible plastic hosing, this related to theatre pendants where patients were subjected to the medical gases over a short period of time. The introduction of multi-movement pendants within the critical care departments requires research into the effects of prolonged exposure of the

patient to the leaching of contaminants from the flexible hosing into the gas stream.

15.120 However, it is recommended that the use of the polytest tube be considered as a general test for contamination of pipelines. It would be advantageous for the QC to record and transfer such readings to graphical form.

15.121 Users must be aware of the limitations of all types of detection equipment, including ambient operating conditions and cross-sensitivities specified for each type of detector tube.

15.122 These tests must be carried out on a representative sample of terminal units/NISTs in each system at the discretion of the Quality Controller (MGPS).

15.123 If terminal units are being tested, the sample must include, as a minimum, the most distant terminal unit on each branch. This may be the first terminal unit to be tested, but care must be taken to ensure, for example, that a new extension connected to old pipework is first well purged via a terminal unit/NIST connector as close as possible to the junction of the systems so as to avoid the spread of any contamination into the extension.

15.124 It will not normally be necessary to test the most distant terminal unit if distal NIST connectors are provided.

15.125 Depending on the results of this test, the Quality Controller (MGPS) should decide the number and location of additional terminal units/NISTs to be tested.

Note 69: Provision of NISTs throughout an MGPS is to be encouraged, as this will greatly facilitate testing, particularly QC testing.

15.126 These tests are summarised in Table 42.

15.127 All sources of supply should be tested for quality before the pipeline distribution system is filled with the working gas. This test is not intended as a test of certificated gases but is to ensure that supply source equipment (manifolds, compressors, VIEs etc) does not compromise the quality of such gases when delivering them to the pipeline systems.

15.128 When extending existing systems, supply sources will not normally be retested before being used to fill the extension with the working gases.

15.129 For new installations, quality tests should be carried out on the plant as well as on the pipeline distribution system.

15.130 The results of the test may be recorded on Form A21.

Particulate matter

15.131 MGPS should be free from particulate contamination, as they have been constructed using chemically cleaned, capped components and joined in a controlled process using a filtered shield gas.

15.132 However, on-site contamination can occur from ingress of building materials, dust etc. The presence of such particles can adversely affect the quality of the delivered gases. Therefore, tests to indicate their absence are important.

15.133 New systems should be purged until the particulate filter is completely clear of visible particles when viewed in a good light.

15.134 Older systems may exhibit particulates, even after considerable purging, as they can be released or carried along by the gas stream after disruption of the system, reverse gas flow, pressure waves down the pipe, or physical vibration.

Note 70: When connecting new pipework to an older (possibly contaminated) system it may be advisable to perform the first purge via the inlet NIST of the first AVSU, or the first terminal unit of the new system, in order to reduce the possible spread of contamination into the new system.

15.135 Where it is evident that extended purging may not completely clear the system of particulates, a decision to accept the level of contamination present, agree a cleansing procedure or, in very exceptional circumstances, condemn the system will be made.

15.136 The test for particulate matter should be carried out at every terminal unit on a new system. It can be carried out either after completion of the construction phase using medical air (see paragraph 15.94) or after the system has been filled with the specified gas. Once the system is filled with working gas, it would not normally be necessary to repeat the test at every terminal unit. The actual number of terminal units sampled is at the discretion of the Quality Controller (MGPS). It would, however, be necessary to repeat the test in full where there is insufficient evidence to show that the system has been satisfactorily maintained under operating pressure with medical air for the interim period.

15.137 When tested with a membrane filter at a flow not less than 150 litres/min for 30 seconds, the filter must be free from visible particles when viewed in good light. A suitable test device is described in Appendix D.

Note 71: a) When testing surgical air terminal units, a flow of 350 litres/min for 30 seconds should be used.

b) When testing nitrous oxide/oxygen mixture terminal units, a flow of 275 litres/min for 30 seconds should be used.

c) When testing helium/oxygen mixture systems, oxygen-free nitrogen is used at the manifold and this will require special connectors.

d) When tests and/or purging is carried out with the sources of supply serving an operational hospital, it is essential to ensure that the test flows used are not detrimental to the continuity or adequacy of supply in operational areas. When a flow rate of 150 litres/min or more may not be possible without compromising the hospital system, a lower flow rate should be used at the discretion of the Quality Controller (MGPS).

Oil

15.138 This test should be carried out at the plant test point of all newly installed medical/surgical compressed air plant and for all medical/surgical compressed air plant on a quarterly basis.

15.139 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test will not normally be required.

15.140 Work involving strip-down of compressor plant and subsequent replacement of oil-sealing components may require a follow-up oil test, at the discretion of the Quality Controller (MGPS).

15.141 Oil may be present as liquid, aerosol or vapour, and an appropriate test device is described in Appendix E.

15.142 The total oil content should be in accordance with Table 42.

15.143 It is desirable to carry out this test at a plant test point before any pipeline system is supplied by that plant so as to prevent inadvertent contamination of the distribution system.

15.144 A representative sample of terminal units on both new and modified medical compressed air and oxygen concentrator systems supplied by compressor plant may be checked at the discretion of the Quality Controller (MGPS).

15.145 Care should be taken in siting the test point to ensure a representative sample.

Water

15.146 This test is intended to identify contamination of the pipeline system by moisture. It should not be confused with the test for compressor plant dryer performance, although it may indicate a failure in the dryer system.

Note 72: a) When testing terminal units supplied via low pressure, flexible connecting assemblies, it is often found that – on initial testing – moisture levels exceed the 0.05 mg/litre limit; this is the result of desorption of minute quantities of moisture into the gas stream. This is particularly noticeable where the test flow is low, and should not cause undue concern. The Quality Controller (MGPS) should establish, however, that the elevated readings at such terminal units result from this effect and not water contamination of the pipeline. (For example, the results should be compared with the readings achieved at nearby terminal units supplied by copper pipework.) New developments in hose materials may lead to hoses with reduced water vapour permeability characteristics.

b) The effects of flow rate through dryer units and sampling times on detection equipment indications should also be taken into account when measuring water content.

15.147 The plant test point and a representative sample of terminal units distributed throughout the pipeline systems should be tested for total water content. The

water content must not exceed 67 vpm (equivalent to an atmospheric pressure dew-point of approximately –46°C). The typical water content of medical gas cylinders is normally below 5 vpm. Water vapour content may be measured using the appropriate test device described in Appendix E (see also paragraph 15.119).

Note 73: Older compressor/dryer combinations may fail to meet the Ph. Eur. requirement of 67 vpm. In these circumstances, the Quality Controller (MGPS) will decide whether application of the older atmospheric dew-point limit of –40°C (127 vpm) is acceptable (Scottish Health Technical Memorandum 2022: 2001).

Carbon monoxide

15.148 The most distant terminal units on each branch of a medical/surgical air pipeline system supplied from a compressor plant and PSA systems must be tested for carbon monoxide, although it would not normally be necessary to test more than five terminal units. The concentration of carbon monoxide should not exceed 5 ppm v/v. This may be measured at up to five terminal units in each system using the appropriate test devices described in Appendix E.

15.149 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test will not normally be required.

Carbon dioxide

15.150 The most distant terminal unit on each branch of a medical/surgical air pipeline system supplied from a compressor or an oxygen concentrator plant must be tested for carbon dioxide.

15.151 The concentration of carbon dioxide must not exceed 500 ppm v/v in medical air or 300 ppm v/v in oxygen from an oxygen concentrator plant.

15.152 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test will not normally be required.

Note 74: a) Increasing or fluctuating carbon dioxide readings in air or PSA-generated oxygen can be an early indication of dryer failure or poor compressor maintenance.

b) Carbon dioxide is no longer used as an inert shield gas during pipeline brazing.

c) If carbon dioxide has been installed (see Section11), the test methodology should be at the discretion of the Quality Controller (MGPS).

Sulphur dioxide

15.153 The most distant terminal units in medical/ surgical air pipeline systems supplied from a compressor plant, together with oxygen terminal units supplied from a PSA plant, must be tested for sulphur dioxide. It will not normally be

necessary to test more than five terminal units in a single system. The concentration should not exceed 1 ppm v/v.

15.154 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test (and those in para 15.112 to 15.115) will not normally be required.

Oxides of nitrogen (NO and NO_2)

15.155 The most distant terminal units in medical/ surgical air pipeline systems supplied from a compressor plant, and oxygen terminal units supplied from a PSA plant, must be tested for oxides of nitrogen. It will not normally be necessary to test more than five terminal units in a single system. The concentration should not exceed 2 ppm v/v.

15.156 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test (and those in para 15.112 to 15.115) will not normally be required.

Important: See Note (d) applicable to Table 42 on disparity between Ph. Eur. and EH40 with reference to acceptable levels of sulphur dioxide and oxides of nitrogen.

Nitrogen

15.157 Oxygen-free nitrogen is used as the inert gas shield, and all terminal units of all gas systems should be tested to ensure that the systems have been adequately purged.

15.158 For oxygen systems and nitrous oxide/oxygen, an oxygen analyser must be used to ensure that the oxygen concentration is not less than that given in Table 43.

15.159 For nitrous oxide systems, an instrument based on thermal conductivity, or an infrared meter, must be used to check that the system has been adequately purged at every terminal unit.

15.160 If a thermal conductivity meter is used, it will be necessary to prove absence of carbon dioxide (which could have been used inadvertently as a shield gas) by the use of a chemical reagent tube.

Pipeline odour/taste

15.161 An odour test is performed because it incorporates, qualitatively, many impurity checks, as several contaminants are detectable by odour. This test is normally carried out as the final test with the working gases, except for nitrous oxide, nitrous oxide/oxygen mixture and carbon dioxide, which should not be inhaled.

15.162 In certain circumstances (see paragraph 15.94), it may be carried out as the first test after completion of construction of the pipeline installation using

medical air as the test gas. In such circumstances, a pipeline odour/taste test can be carried out on nitrous oxide and nitrous oxide/oxygen systems.

15.163 In addition to all new terminal units, a representative sample of terminal units on existing parts of the systems must be checked.

Note 75: a) For some time it has been known that materials used in the construction of low-pressure connecting assemblies can present an odour. This was recognised in the 1984 version of BS5682:"Plastics materials currently in use will release small quantities of volatile organic matter into the gas stream throughout the life of the plastics components of the material. The quantities released appear to be below the levels normally considered toxic but, as yet, insufficient research has been carried out to be able to identify and quantify these components, therefore no tests are recommended."

b) More recent work has shown that the quantities of those agents that can be identified are significantly below levels considered to be toxic. It is possible that developments in hose material structure will result in the reduction of odour (and moisture retention).

c) The Quality Controller (MGPS) should perform additional oil and polytest analyses if indistinct odours are detected where flexible hoses are not involved.

d) New developments in hose materials may lead to hoses that are odour-free and do not leach chemicals into the gas stream. Until such hoses are available, present tests including moisture and polytest should continue on flexible hosing with findings recorded.

Gas and source	Particulates	Oil	Water	CO	CO_2	NO and NO_2	SO_2	Poly-test tube	Odour
Oxygen from PSA plant	Free from visible particles in a 75 litre sample	≤0.1 mg/m^3	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discoloration	None
Nitrous oxide	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	No discoloration	SAFETY Not performed
Nitrous oxide/oxygen mixture	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	No discoloration	SAFETY Not performed
Medical and surgical air	Free from visible particles in a 75 litre sample (for medical air) and 175 litre sample (for surgical air)	≤0.1 mg/m^3	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤900 mg/m^3; ≤500 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discoloration	None
Dental compressed air	Free from visible particles in a 75 litre sample	≤0.1 mg/m^3	≤1020 vpm (≤0.78 mg/ litre, atmospheric dew-point of - 20°C)	≤5 mg/m^3; ≤5 ppm v/v	≤900 mg/m^3; ≤500 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discoloration	None
Synthetic air	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	-	-	-	-	No discoloration	None
Oxygen from bulk liquid or cylinders	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/ litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	<300 ppm v/v	-	-	No discoloration	None
Helium/oxygen mixture O_2, < 30%			≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	<300 ppm v/v	≤2 ppm v/v	-	No discoloration	None

Table 42: Quality specification for medical gas pipeline tests (working gases)

Notes applicable to Table 42: a) The quality of the gases delivered at the terminal units should also comply with the specifications given in Table 42, above, which is inclusive of the current edition of the Ph. Eur. (see Table 43). Additionally, contamination introduced by the MGPS, and not limited by the Ph. Eur. specification, should not exceed levels that might pose a threat to patients. It should be borne in mind that the safe levels for medical gases delivered to patients are likely to be significantly lower than those permitted for healthy individuals. In addition to the monograph, the official standards section of the general notices should be read.

b) The tests for oil, carbon monoxide, carbon dioxide, sulphur dioxide and oxides of nitrogen are not normally carried out when the source of supply is from cylinders or cryogenic systems, although it should be noted that rare instances of oil contamination arising from the pipeline have occurred.

c) Synthetic air will be tested for identity as shown in Table 43. A GLC (gas-liquid chromatography) test for nitrogen is possible but not without practical difficulties. Nitrogen content will, therefore, usually be inferred from oxygen analyser test results.

d) The Health and Safety Executive has revised its guidance on exposure limits for sulphur dioxide, nitrogen monoxide and nitrogen dioxide. Occupational exposure standards (OESs) for nitric oxide, nitrogen dioxide and sulphur dioxide were removed from EH40 in the Amendment of April 2003.Time-weighted averages (TWAs) for nitrogen monoxide and nitrogen dioxide are now suggested as no greater than 1 ppm, and limits for sulphur dioxide exposure as less than 1 ppm for both 8-hour TWA OES and 15-minute STEL (short-term exposure limit).Some breathing air standards seek to limit the levels of such contaminants to 10% of the 8-hour TWA, as medical gases are intended for use by people who are not in the best of health. Therefore it is suggested, when testing for these specific compounds, or any contaminants not listed in the Ph. Eur., that a limit of 10% of the OES should be confirmed.

e) See Note following paragraph 15.147.

Gas and source	Oil	Water	CO	CO_2	NO and NO_2	SO_2	Odour/ Taste
Oxygen from bulk liquid or cylinders	-	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	-	-	None
Oxygen from PSA plant	0.1 mg/m^3	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	None
Nitrous oxide	-	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	N/A
Nitrous oxide/oxygen mixture	-	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	N/A
Medical and surgical air	0.1 mg/m^3	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤900 mg/m^3 ≤500 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	None
Synthetic air	-	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	-	-	-	-	None
Helium/oxygen mixture O_2, <30%	-	≤67 vpm (≤0.05 mg/litre, atmospheric dew-point of -46°C)	≤5 mg/m^3; ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	None

Table 43: Ph. Eur. Quality specifications for medical gases

Note 76: Particulate level tests and polytests are not included in the Ph. Eur.

Gas identification

15.164 The identity of the gas must be tested at terminal units on medical gas pipeline systems. This would include all new terminal units, whether on a new installation or a modification or extension, and a representative sample of terminal units on an existing system, which may have been affected by the work. All systems must have been filled with the specific gas according to paragraph 15.101.

15.165 The composition of all compressed gases must be positively identified. This can be accomplished using an oxygen analyser for oxygen, nitrous oxide/oxygen and air, and a thermal conductivity or infrared meter for nitrous oxide.

15.166 When checking the identity of nitrous oxide and nitrous oxide/oxygen mixture, the gas should be discharged in a manner that minimises pollution and personnel exposure.

15.167 When testing pipelines for helium/oxygen mixture, an initial test is carried out with nitrogen connected after completing the particulate test. An oxygen analyser is used and all terminal units are tested. After a zero reading is achieved, product cylinders are connected and the system is purged. A second test is performed with an oxygen analyser; the oxygen content should be as in Table 44.

15.168 The nominal gas concentration at specific terminal units is given in Table 44; vacuum must be identified by observation of suction at the terminal unit.

Gas and source	Paramagnetic oxygen analyser reading	Thermal conductivity (TC)/infrared (IR) instrument reading	Carbon dioxide detector tube indication if TC meter used	Vacuum probe
Oxygen from liquid or cylinders	Minimum 99.5%	-	-	-
Oxygen from concentrator	Minimum 94.0%	-	-	-
Nitrous oxide	-0.2%	Indicates “nitrous oxide” or gives a reading of 100% ± 2.0% (TC), ≥98% (IR)	≤300 ppm v/v	-
Nitrous oxide/oxygen mixture	50.0% ± 2.0%	50.0% ± 2.0%	-	-
Medical, surgical and dental air	20.9% ± 0.5%	-	-	-
Synthetic air	95-105% of nominal value of 21.0-22.5%	-	-	-
Vacuum	-	-	-	Suction present
Nitrogen shield gas	0%	0% (IR)	-	-
Helium/oxygen mixture: Test 1. Test 2.	 0% 20.9% ± 0.5%	 0% 20.9% ± 0.5%	-	-

Table 44: Gas concentrations for identification purposes

Note 77: The tolerance of the measuring instrument should be allowed in addition. For oxygen concentrator plant (PSA) supplied system, the minimum concentration must be 94% oxygen. A vacuum gauge may be used to obtain a quantitative reading of vacuum level and verify terminal unit performance.

Test results

15.169 The test results for gas identity may be recorded on Form A20.

AGS disposal systems

General

15.170 BS6834:1987 specifies the tests to be carried out on AGS disposal systems that comply with the British Standard. The tests specified are designed to ensure adequate performance and that the safety provisions of receiving systems will be met.

15.171 The responsibility for the tests should be clearly identified at the contract stage for new installations, in the same way as for the medical gas pipeline system. In general, the contractor should carry out the tests, which should be witnessed by the Authorised Person (MGPS).

Performance tests

15.172 All equipment should be tested to ensure that it performs satisfactorily during continuous operation under full load for one hour.

15.173 All electrically powered equipment should be tested as follows:

- check for correct rotation;
- check the current through the powered device at full load.

15.174 The disposal system should be tested to ensure that it meets the requirements set out in the table below, with the number of terminal units for which it has been designed in use.

	Disposal system standard			
	Pressure drop		Flow rate	
	BS6834: 1987	BS EN ISO 7396-2: 2007	BS6834: 1987	BS EN ISO 7396-2: 2007
Maximum	1 kPa	1 kPa	130 litres/min	80 litres/min
Minimum	4 kPa	2 kPa	80 litres/min	50 litres/min
Maximum static pressure	20 kPa (-ve)	15 kPa (-ve)	This check is made before performing the flow tests	

Table 45: AGS disposal system standards

Note 78: Since the preparation of BS6834: 1987, developments in anaesthesiology have resulted in reduced flows being used. Depending on local circumstances, it may be possible to commission systems for different flows in accordance with BS EN ISO 7396-2: 2007. Details of the test flows should be recorded in the commissioning documentation.

15.175 The test should be carried out as described in Appendix K of BS6834:1987. The test device is inserted into each terminal unit in turn and checked for pressure at flows of 80 litres/min and 130 litres/min for BS systems, and 50 litres/min and 80 litres/min for ISO systems. Adjustment is then made if necessary.

15.176 The test device and a number of metered leaks are then inserted into the system to replicate the design flow. The measurements above are repeated. If the test results are satisfactory, the test device is removed and substituted by a metered leak.

Note 79: The test device is designed to replicate either type of receiving system for which the disposal system has been designed.

15.177 The other terminal units are then tested in turn by substituting the test device for each metered leak including the test device.

Note 80: For the purposes of diversity, it may be assumed that in any operating department only one receiving system for each operating room is in use at any time. In a typical theatre suite with two terminal units in the operating room and one in the anaesthetic room, the total number of metered leaks used for testing is two; that is, one being placed in an operating room terminal unit and the other in the anaesthetic room terminal unit.

15.178 The operation of user-controlled switches, power-on indicators and alarm systems should also be checked.

15.179 AGSS terminal units should be checked for correct mechanical operation and that the check valve operates satisfactorily. All AGSS terminal units will incorporate an adjustable flow valve.

Requirements before a medical gas pipeline system is taken into use

General

15.180 Before a system is used, the appropriate persons must certify in writing that the tests and procedures required in para 15.48 to 15.100 and 15.109 to 15.179 have been completed, and that all systems comply with the requirements. This must include certification that all drawings and manuals required by the contract have been supplied and as-fitted drawings are correct (see Form A22).

15.181 All certificates must be dated and signed by the appropriate witnesses, by the CSO and by the representative of the contractor.

15.182 For modifications or extensions to existing systems, the performance tests for flow and pressure drop (as described in paragraphs 15.43 to 15.45) should be carried out on the completed system if practicable. If the performance is in accordance with the specification prepared (as described in paragraphs 15.34 to 15.46), the system may be taken into use, provided that all the other tests have been satisfactorily completed.

Note 81: In many cases, the extension/modification will be relatively small and unlikely to significantly affect the performance of the system.

Operational policy

15.183 A procedure must be available in accordance with Part B, and must ensure continuity of supply of cylinders and bulk liquid. This will incorporate a procedure for recording delivery, handling and storage of full and empty cylinders, with an indication of who is responsible for these activities. The supplier must certify the composition of the cylinder contents. All deliveries of bulk liquid oxygen should be tested for conformance to the product licence specification before dispatch by the supplier, and should be supplied with a certificate indicating compliance.

Cylinder storage and handling

15.184 There should be recorded visual checks for correct labelling, including batch numbers (see Part B).

Removal of construction labels

15.185 When all tests have been completed satisfactorily, the “Danger – do not use” labels affixed to terminal units should be removed on the authority of, or by, the Authorised Person (MGPS).

Appendix A: Testing, commissioning and filling for use: forms to be completed during testing and commissioning of piped medical gases systems

Contents:

Medical Gas Pipeline System Test Summary Sheet – A1

Hospital:	……	Date:	…….	Project No:	……

This is to certify that the following tests have been carried out:

System	Form	Tests Carried out Satisfactorily		
Carcass Tests		CSO	AP	
Labelling and Marking	A2			
Sleeving and Supports	A2			
Leakage Test	A2			
Cross-Connection Test	A2			
System Tests		CSO	AP	QC
Pipeline Pressure Test	A3			
Area Valve Service Unit – Zoning, Closure and NIST Tests	A4			
Line Valve Assembly and Line Valve – Zoning, Closure and NIST Tests	A5			
Pendant/Miscellaneous NIST Connectors - Specificity and Function Tests	A6			
Terminal Unit Schedule and Cross-Connection and Gas Specificity Tests	A7/1 & A7/2			
Terminal Unit Functional Tests	A8			
Plant Performance, Operation and Siting – Liquid Oxygen Systems	A9			
Plant Performance, Operation and Siting – Medical Gas Manifold Systems	A10			
Plant Performance, Operation and Siting – Medical Air / Surgical Air Plant	A11			
Plant Performance, Operation and Siting – Synthetic Air Systems	A12			
Plant Performance, Operation and Siting – Medical Vacuum Plant	A13			
Area Alarm Panel Test	A14			
Central Alarm Panel Test	A15			
Particulate Matter Tests	A16			
Anaesthetic Gas Scavenging System Tests	A17			
Design review and As Installed Drawings	A18			
Purging and Filling	A19			
Medical Gas Identification Tests	A20			
Medical Gas Quality Tests	A21			
Medical Gas Pipeline System – Completion Certificate	A22			
Medical gas permit-to-work form				
Construction labels removed				

Contract Supervising Officer (CSO) or Authorised Person (AP) and Quality Controller (QC MGPS)

Name:	Signed:.....
Status :	Date : .....
Name :	Signed:.....
Status :	Date : .....

Carcass Test Sheet –

1st Fix Pressure, Labelling/Marking, Sleeving/Supports and Cross-connection – A2

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Part 1 – Leakage, labelling and marking, sleeving, supports and cross-connections

Service	Gauge No.	Temp (ºC)	Test Pressure (kPa)	Test Start (Date/ Time)	Test Finish (Date/ Time)	ΔP (kPa)	Labelling & Markings	Sleeving & Supports	Cross-Connection Test	Pass/Fail Comments
Oxygen										
Nitrous Oxide										
Nitrous Oxide/ Oxygen (50/50)										
Medical Air 4 Bar										
Surgical Air 7 Bar										
Medical Vacuum*										
AGSS										

* - for plastic pipeline systems a pressure of 1.5bar/150kPa should be set.

Service	Test Pressure	Pressure Drop (max)	Timescale
Oxygen	10bar / 1,000 kPa	0.2 kPa	1 hour
Nitrous Oxide	10 bar / 1,000 kPa	0.2 kPa	1 hour
Nitrous Oxide/Oxygen (50/50)	10 bar / 1,000 kPa	0.2 kPa	1 hour
Medical Air 4 Bar	10 bar / 1,000 kPa	0.2 kPa	1 hour
Surgical Air 7 Bar	18bar / 1,800 kPa	0.5 kPa	1 hour
Surgical Air 9 Bar	18 bar / 1,800 kPa	0.5 kPa	1 hour
Medical Vacuum	5 bar / 500 kPa	0.2 kPa	1 hour
AGSS	70 kPa	10 kPa	15 mins

Part 2 – The following pipeline systems interconnections have been made to facilitate the pipeline tests indicated in Part 1.
Part 3 – The following pipeline systems interconnections have been removed as indicated in Part 2.

2nd Fix Pressure Test – A3

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Service	Gauge No.	Temp (ºC)	Test Pressure (kPa)	Test Start (Date/ Time)	Test Finish (Date/ Time)	ΔP (kPa)	Pass/Fail Comments
Pipeline pressure test							
Oxygen							
Nitrous Oxide							
Nitrous Oxide/ Oxygen (50/50)							
Medical Air 4 Bar							
Surgical Air 7 Bar							
Vacuum leakage test							
Medical Vacuum							

Service	Test Pressure	Pressure Drop (max)	Timescale
Oxygen	4 bar / 400 kPa	0.2 kPa	1 hour
Nitrous Oxide	4 bar / 400 kPa	0.2 kPa	1 hour
Nitrous Oxide/Oxygen (50/50)	4 bar / 400 kPa	0.2 kPa	1 hour
Medical Air 400 kPa	4 bar / 400 kPa	0.2 kPa	1 hour
Surgical Air 700 kPa	7 bar / 700 kPa	0.5 kPa	1 hour
Surgical Air 900 kPa	9 bar / 900 kPa	0.5 kPa	1 hour
Medical Vacuum	450 – 700 mmHg	1 kPa / 7.5 mm Hg	1 hour

Comments

Area Valve Service Unit – Zoning, Closure and NIST Tests – A4

Hospital:	……			Test by:	……..……
Project No:	……	Date:	……	Witnessed by:	……..

Area/Department/Room:……

Service	Gauge No.	Valve No.	No of TUs	Valve Zoning	NIST Specificity	NIST Function	Valve Tightness			
				Pass /Fail	Pass/Fail	Pass/Fail	Start Pressure/ Time	Finish Pressure /Time	Pass/ Fail	Comments
Oxygen										
Nitrous Oxide										
Entonox										
Medical Air 4 Bar										
Surgical Air 7 Bar										
Medical Vacuum						N/A				

Notes: 1. Pressure differential between upstream (working pressure) and downstream (approximately 300 kPa)

2. Vacuum systems to be; on vacuum system plant side at distribution pressure and on terminal unit side at approximately 15 kPa (112 mmHg)

3. Test should be conducted over a period of 15 minutes with no change in pressure.

Line Valve Assembly and Line Valve – Zoning, Closure and NIST Tests – A5

Hospital:	……	Date:	……	Test by:	……
Project No:	……			Witnessed by:	……

Area/Department/Room: ……..

Service	Gauge No.	Valve No.	No of TUs	Valve Zoning	NIST Specificity	NIST Function	Valve Tightness			
				Pass /Fail	Pass/Fail	Pass/Fail	Start Pressure /Time	Finish Pressure /Time	Pass/ Fail	Comments
Oxygen										
Nitrous Oxide										
Entonox										
Medical Air 4 Bar										
Surgical Air 7 Bar										
Medical Vacuum						N/A				

Notes:1. Pressure differential between upstream (working pressure) and downstream (approximately 300 kPa)

2. Vacuum systems to be; on vacuum system plant side at distribution pressure and on terminal unit side at approximately 15 kPa (112 mmHg)

3. Test should be conducted over a period of 15 minutes with no change in pressure

Pendant/Miscellaneous NIST Connectors - Specificity and Function Tests – A6

Hospital:	…………………………	Date:	………..	Test by:	………..………
Project No:	…………………………			Witnessed by:	………..………

Location: ……………………………………………..

Service	NIST Specificity	NIST Function	Comments
	Pass/Fail	Pass/Fail	
Oxygen			
Nitrous Oxide			
Entonox			
Medical Air 4 Bar			
Surgical Air 7 Bar			
Medical Vacuum		N/A	

Location: ……………………………………………..

Service	NIST Specificity	NIST Function	Comments
	Pass/Fail	Pass/Fail	
Oxygen			
Nitrous Oxide			
Entonox			
Medical Air 4 Bar			
Surgical Air 7 Bar			
Medical Vacuum		N/A	

Location: ……………………………………………..

Service	NIST Specificity	NIST Function	Comments
	Pass/Fail	Pass/Fail	
Oxygen			
Nitrous Oxide			
Entonox			
Medical Air 4 Bar			
Surgical Air 7 Bar			
Medical Vacuum		N/A	

Terminal Unit Schedule and Cross-Connection Tests – A7/1

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Area Department: ……

Room No./Name	Schedule of Terminal Units							Cross-connection						
	O2	N2O	N2O / O2	MA4	SA7	MV	AGS	O2	N2O	N2O / O2	MA4	SA7	MV	AGS

Comments

Terminal Unit Schedule and Gas Specificity Tests – A7/2

Hospital:	…….....…			Test by:	……..….
Project No:	……	Date:	……	Witnessed by:	……..….

Area Department: ……

Room No./Name	Schedule of Terminal Units							Gas Specificity						
	O_2	N_2O	N_2O / O_2	MA4	SA7	MV	AGS	O_2	N_2O	N_2O / O_2	MA4	SA7	MV	AGS

Comments

Terminal Unit Functional Tests exemplar – A8

Hospital:	……			Test by:	……..……
Project No:	……	Date:	……	Witnessed by:	……

Room / Department	Service	Terminal Unit Number	Specified Flow (litres/min)	Specified Flow Achieved	Specified Terminal Unit Pressure Drop	Specified Terminal Unit Pressure Drop Achieved	Mechanical Function (Pass / Fail)	Comments
	O_2				15 kPa			
	N_2O				15 kPa			
	N_2O/O_2				15 kPa			
	MA4				15 kPa			
	SA7				70 kPa			
	MV				15 kPa			
	O_2				15 kPa			
	N_2O				15 kPa			
	N_2O/O_2				15 kPa			
	MA4				15 kPa			
	SA7				70 kPa			
	MV				15 kPa			

Note: 1. Mechanical function test to include, probe insertion, capture and release. The anti-swivel pin is present or absent dependent of orientation.

Plant Performance, Operation and Siting – Liquid Oxygen Systems – A9

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Location:	……	Manufacturer /Model:	……
Type:	Bulk Liquid Supply – Liquid cylinder supply	Function:	Primary / Secondary / Emergency Reserve (delete as appropriate)

Item	Function / Operation	Pass / Fail	Comments
1	Power supplies provided		
2	General operation		
3	Leakage on joints		
4	Indication – System condition panel		
5	Central Alarm Panel		
6	Safety valve exhaust pipes discharge to a safe location		
7	Separation distances in compliance with Table 23 and BCGA CP19		
8	Compound / room provided with hazard / warning signs in accordance with Appendix K		
9	Access to and within compound acceptable		
10	Lighting provided		
11	Plant provided with all necessary valves and ancillaries.		
12	Plant schematic provided		

Plant Performance, Operation and Siting – Medical Gas Manifold Systems – A10

Hospital:	……			Test by:	……..
Project No:	……	Date:	……	Witnessed by:	……..

Location:	……	Manufacturer /Model:	……
Type:	Oxygen - Nitrous Oxide - Nitrous Oxide/Oxygen Mixture - Medical Air 4 Bar - Surgical Air 7 Bar / Other	Function:	Primary / Secondary / Emergency Reserve (delete as appropriate)

Item	Function / Operation	Pass / Fail	Comments
1	Power supplies provided		
2	General operation		
3	Leakage on joints		
4	Heater operation		
5	Operation of Emergency Manifold		
6	Correct Sequence on start-up / power failure		
7	Indication – System condition panel		
8	Central Alarm Panel		
9	Safety valve exhaust pipes discharge to a safe location		
10	Spare cylinder racks provided in accordance with the specification		
11	Manifold room ventilation adequate		
12	Manifold room provided with hazard / warning signs in accordance with Appendix K		
13	Access to and within manifold room acceptable		
14	Manifold room heating provided, type and method of control acceptable		
15	Lighting provided external / internal		
16	Plant schematic provided		

Plant Performance, Operation and Siting – Medical Air / Surgical Air Plant – A11

Hospital:	……			Test by:	……..….
Project No:	……	Date:	……	Witnessed by:	……..….

Location:	……	Manufacturer /Model:	……..….
Type:	Medical Air 4 Bar - Surgical Air 7 Bar	Function:	Primary / Secondary / Emergency Reserve (delete as appropriate)

Item	Function / Operation	Pass / Fail	Comments
1	Power supplies provided		
2	General operation		
3	Leakage on joints		
4	Excessive vibration and noise		
5	Oil leakage		
6	Earthing / bonding		
7	Correct sequence on start up / power failure		
8	Indication – System condition panel		
9	Central Alarm Panel		
10	Safety valve exhaust pipes discharge to a safe location		
11	Plantroom ventilation adequate		
12	Plantroom provided with hazard / warning signs in accordance with Appendix K		
13	Access to and within plantroom acceptable		
14	Plantroom heating provided if specified, type and method of control acceptable		
15	Lighting provided external / internal		
16	Condensate drain system provided, and drained via oil/water separator to drain point		
17	Plant schematic provided		

Plant Performance, Operation and Siting – Synthetic Air Systems – A12

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Location:	……	Manufacturer /Model:	……
Type:	Bulk Liquid Oxygen and Nitrogen Supply	Function:	Primary / Secondary / Emergency Reserve (delete as appropriate)

Item	Function / Operation	Pass / Fail	Comments
1	Power supplies provided		
2	General operation		
3	Leakage on joints		
4	Indication – System condition panel		
5	Central Alarm Panel		
6	Safety valve exhaust pipes discharge to a safe location		
7	Separation distances in compliance with Table 23 and BCGA CP19 and BCGA 21		
8	Compound and blending station room provided with hazard / warning signs in accordance with Appendix K		
9	Access to and within compound and blending station room acceptable		
10	Lighting provided		
11	Plant schematic provided		

Plant Performance, Operation and Siting – Medical Vacuum Plant – A13

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Location:	……	Manufacturer /Model:	……
Type:	Medical Air 4 Bar - Surgical Air 7 Bar	Function:	Primary / Secondary / Emergency Reserve (delete as appropriate)

Item	Function / Operation	Pass / Fail	Comments
1	Power supplies provided		
2	General operation		
3	Leakage on joints		
4	Excessive vibration and noise		
5	Oil leakage		
6	Earthing / bonding		
7	Correct sequence on start up / power failure		
8	Indication – System condition panel		
9	Central Alarm Panel		
10	Vacuum pump exhaust pipes discharge to a safe location		
11	Plantroom ventilation adequate		
12	Plantroom provided with hazard / warning signs in accordance with Appendix K		
13	Access to and within plantroom acceptable		
14	Plantroom heating provided if specified, type and method of control acceptable		
15	Lighting provided external / internal		
16	Condensate drain system provided, and drained via oil/water separator to drain point		
17	Plant schematic provided		

Area Alarm Panel Test – A14

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Location:……

Make / Model	Service	High Pressure Alarm	Low Pressure Alarm	Pass/ Fail	Function / Operation (Pass / Fail)		Comments
					Sequence / Identification		
					Anti-confusion		
					Mute Function (15 mins.)		
					System Fault / Power Failure		
					System Fault / Open Circuit		
					System Fault / Short Circuit		
					Audible Reinstatement		
					Test Function		

Location:……

Make / Model	Service	High Pressure Alarm	Low Pressure Alarm	Pass/ Fail	Function / Operation (Pass / Fail)		Comments
					Sequence / Identification		
					Anti-confusion		
					Mute Function (15 mins.)		
					System Fault / Power Failure		
					System Fault / Open Circuit		
					System Fault / Short Circuit		
					Audible Reinstatement		
					Test Function		

Location:……

Make / Model	Service	High Pressure Alarm	Low Pressure Alarm	Pass/ Fail	Function / Operation (Pass / Fail)		Comments
					Sequence / Identification		
					Anti-confusion		
					Mute Function (15 mins.)		
					System Fault / Power Failure		
					System Fault / Open Circuit		
					System Fault / Short Circuit		
					Audible Reinstatement		
					Test Function		

Central Alarm Panel Test – A15

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

Alarm Panel Location: ……

Service	1	2	3	4	5	6	7	8	9
Oxygen									
Nitrous Oxide									
Nitrous Oxide/Oxygen (50/50)									
Medical Air 4 Bar									
Surgical Air 7 Bar									
Medical Vacuum									

List of tests:

1. for central alarm panels, check that the operation of the mute switch cancels the audible alarm and converts the flashing signals to steady;
2. for repeater alarm panels, check that the mute switch cancels the audible only, and that the flashing signals are converted to steady via the central alarm panel;
3. for area alarm panels, check that the operation of the mute switch cancels the audible only;
4. check power failure operates red system fault indicator and audible;
5. check that a contact line fault operates the system fault indicator, the alarm indicator and the audible;
6. check communication/wiring faults between central and repeater alarms operate the system fault indicator and audible;
7. check audible reinstatement for each alarm panel;
8. check that the audible can be continuously muted via operation of the internal push-button for gas service alarm condition only;
9. check for correct identification of each gas service on alarm panels.

Particulate Matter Tests – A16

Hospital:	……			Test by:	……
Project No:	……	Date:	……	Witnessed by:	……

The following services where tested for particulate matter:-

Location: ……

Service	Pass/Fail	Observations
Oxygen		
Nitrous Oxide		
Entonox		
Medical Air 4 Bar		
Surgical Air 7 Bar		

Location: ……

Service	Pass/Fail	Observations
Oxygen		
Nitrous Oxide		
Entonox		
Medical Air 4 Bar		
Surgical Air 7 Bar		

Location: ……

Service	Pass/Fail	Observations
Oxygen		
Nitrous Oxide		
Entonox		
Medical Air 4 Bar		
Surgical Air 7 Bar		

Anaesthetic Gas Scavenging System Tests – A17

Hospital:	……			Test by:	……
Project No:	……	Date:	……..	Witnessed by:	……

Location: …… Department Served: ……

Manufacturer:		**Model reference:**	
Pump Duty (litres/min):		Duplex/Simplex:	
Number of Remote Switches		Remote Switch Voltage (V)	

Test	1	2	3	4	5	6	7	8
BS 6834;1987								
Single Flow Rates								
AGSS Outlet point@ 1 kPa (130 litres/min maximum)								
AGSS Outlet Point@ 4 kPa (80 litres/min minimum)								
BS EN ISO 7396-2: 2008								
Single Flow Rates								
AGSS Outlet point@ 1 kPa (80 litres/min maximum)								
AGSS Outlet Point@ 2 kPa (50 litres/min minimum)								

Pump Pressure Setting : …… mBar

Pump Total Flowrate: …… litres/min

Pump Design Flowrate: …….. litres/min

Design Review and As Installed Drawings – A18

Hospital:	……			Test by:	……
Project No:	……	Date:	……..	Witnessed by:	……

This is to certify that the design has been reviewed and verified as compliant with the contract documents and SHTM 02-01, Part A

Comments

The following 'As Installed' drawings schedule records all variations from the contract drawings:-

Drawing Number	Revision	Description	CSO/AP	Date

Purging and Filling – A19

Hospital:	……			Test by:	……
Project No:	……	Date:	…….…	Witnessed by:	……

This is to certify that the medical gas systems have been purged and filled with medical air/Oxygen Free Nitrogen/working gas (delete as appropriate) in accordance with paragraphs 15.95 – 15.101 and/or 15.102 – 15.103 as follows:-

Action	O_2	N_2O	N_2O/O_2	MA4	SA	MV	H_2/O_2	CO_2
Special connectors/cylinders removed from site						N/A		
Filling with working gas								
Purge pipeline via terminal units, gases to be vented to a safe place						N/A		
Particulate tests performed and meet specification						N/A		
Odour tests performed and specification met.						N/A		
All terminal unit Danger stickers applied/removed								

Medical Gas Identification Tests – A20

Hospital:	……	Date :	……..	Project No:	……

This is to certify that medical gas systems have been tested in accordance with paragraphs 15.165 – 15.169 as follows (insert values for gases and tick for vacuum):-

Gas and Source	Paramagnetic oxygen analyser reading	Thermal conductivity/infra-red instrument reading	Carbon dioxide detector tube indication if TC meter used	Vacuum probe
Oxygen from liquid or cylinders		-	-	-
Oxygen from concentrator		-	-	-
Nitrous oxide				-
Nitrous oxide / oxygen mixture			-	-
Medical, surgical and dental air		-	-	-
Synthetic air		-	-	-
Vacuum	-	-	-	
Nitrogen shield gas			-	-
Helium / oxygen mixture Test 1 Test 2			-	-

Contract Supervising Officer (CSO) / Authorised Person (AP)

Name:	Signed:.....
Status:	Date: .....

Quality Controller (QC)

Name:	Signed:.....
Status:	Date: .....

Medical Gas Quality Tests– A21

Hospital:	……...	Date:	……..	Project No:	……...

Quality specifications for medical gas pipeline tests (working gases). This is to certify that medical gas systems have been tested in accordance with paragraphs 15.111 – 15.164as follows:-

Gas and Source	Particulate	Oil	Water	CO	CO_2	NO & NO_2	SO_2	Poly-test tube (optional)	Odour	Pass / Fail
Oxygen from bulk liquid or cylinders	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	-	-	No discolouration	None	
Nitrous Oxide	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C)	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	No discolouration	SAFETY Not performed	
Nitrous oxide / oxygen mixture	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	No discolouration	SAFETY Not performed	
Medical and surgical air	Free from visible particles in a 75 litre sample	≤0.1 mg/ m^3	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤900 mg/m^3 ≤500 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discolouration	None	
Dental compressed air	Free from visible particles in a 75 litre sample	≤0.1 mg/ m^3	≤1,020 vpm (≤0.05 mg/l, atmospheric dew point -20^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤900 mg/m^3 ≤500 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discolouration	None	

Gas and Source	Particulate	Oil	Water	CO	CO_2	NO & NO_2	SO_2	Poly-test tube (optional)	Odour	Pass / Fail
Synthetic air	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C	-	-	-	-	No discolouration	None	
Oxygen from PSA plant	Free from visible particles in a 75 litre sample	≤0.1 mg/m^3	≤67 vpm (≤0.05 mg/l, atmospheric dew point-46^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	≤1 ppm v/v	No discolouration	None	
Helium / oxygen mixture O_2< 30%	Free from visible particles in a 75 litre sample	-	≤67 vpm (≤0.05 mg/l, atmospheric dew point -46^{0}C	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	-	No discolouration	None	

Contract Supervising Officer (CSO) / Authorised Person (AP)

Name:	Signed: .....
Status:	Date: .....
Quality Controller (QC) Name:	Signed: .....
Status:	Date: .....

Medical Gas Pipeline System – Completion Certificate – A22

Hospital:	……	Client:	……
This is to certify that the following tests have been performed.			
Mechanical Carcass and Functional tests:		Forms A2 to A19 inclusive	
Quality and gas identity tests:		Forms A20 to A21 inclusive	
Validation of MGPS Design: The tests have been performed in accordance with Scottish Health Technical Memorandum 02-01 Part A Section 15, and that the test results are satisfactory.			

Contract Supervising Officer (MGPS) / Authorised Person (MGPS)

Name:	Signed: ……
Status:	Date: .....

Contractor's Representative (MGPS)

Name:	Signed: ……
Status:	Date: .....

Quality Controller (MGPS)

Name:	Signed: ……
Status:	Date: .....

We, the Healthcare Organisation/FM provider/Owner

Accept responsibility for the systems above and undertake to carry out any future work and maintenance in accordance with the recommendations of Scottish Health Technical Memorandum 02-01 and the permit-to-work procedures.

Name:	Signed: ……
Status:	Date: .....

Appendix B: Gas pressure variation with temperature

General

1 Tests are specified for leakage of the pipeline carcass and the pipeline systems. During these tests, pressure changes may occur that are caused by temperature changes rather than leakage.

2 Pressure changes due to temperature difference may be calculated according to the Gas Laws (see the 'Glossary' in Part B).

3 It is assumed that the temperature in the pipeline is uniform in all branches. If substantial runs are external, an average temperature should be chosen.

Calculation

4 The change in gas pressure with temperature is as follows:

$P_1/T_1 = P_2/T_2$

where:

P_1 = the initial absolute pressure of a fixed volume of gas;

P_2 = the final absolute pressure of a fixed volume of gas;

T_1 = the initial absolute temperature;

T_2 = the final absolute temperature.

Therefore:

$P_2 = (P_1 \times T_2)/T_1$. (1)

5 Care must be taken to express pressure and temperature in absolute values.

6 Pressure is normally expressed in "gauge" pressure: Absolute pressure = gauge pressure + atmospheric pressure.

7 Temperature is normally expressed in K.

Examples

8 The carcass of a surgical air pipeline is tested for leakage at a working pressure of 13.5 bar. The temperature is 13°C at the beginning of the test and 17°C at the end of the test:

P1 = 13.5 + 1.0 = 14.5 bar

T1 = 273 + 13 = 286 K

T2 = 273 + 17 = 290 K.

9 Therefore, using Equation (1):

P2 = (14.5 x 290)/286

= 14.7 bar (absolute pressure)

= 13.7 bar (gauge pressure).

10 That is, gauge pressure should read 13.7 bar at the end of the test, assuming that no leakage has occurred.

Appendix C: Pressure-drop test device

General

1 Special test devices are required to measure the pressure at specified flows at each terminal unit.

2 Suitable test devices are commercially available or may be constructed in accordance with the outline specification given below.

Measurement principle

3 Flow at a specified pressure may be measured either with a calibrated orifice or with a flowmeter.

4 Pressure may be measured with a bourdon gauge.

5 A gas-specific probe conforming to BS5682:1998 should be used to connect the device to the terminal unit.

6 The test device is connected to the terminal unit by the gas-specific probe and the pressure at the specified flow is read on the gauge.

Functional requirements

7 The test device should consist of the following components:

- gas-specific probe to BS5682:1998;
- body on/off valve pressure gauge;
- orifice or flowmeter.

8 The body may be of a design that allows exchange of the following components:

- gas-specific probes;
- calibrated orifices;
- pressure gauges.

9 An on/off valve may be incorporated into the body.

10 The complete assembly should be tested for leaks.

Orifices

11 The orifices should be selected from the information on the manufacturer's data sheets or from practical testing.

12 These devices should be checked against a flowmeter before use.

Flowmeter

13 A bobbin flowmeter calibrated to a flow of 40 litres/min may be used to measure flow under vacuum.

Pressure gauge

14 A 50mm bourdon gauge with an appropriate full scale reading and interval should be used as follows:

Test pressure kPa	Scale	Scale interval
400	0-7 bar	0.1 bar
700	0-11 bar	0.5 bar
Vacuum	0-100 kPa(0-760 mmHg)	5 kPa /50 mmHg
1 bar = 100 kPa approximately		

Table C1: Test pressure gauge scales

Note 82: Generally it is found that three separate test devices for 400 kPa, 700 kPa and vacuum provide greater convenience. Because the test methodology in Section 15 has the potential for exposing the 400 kPa and vacuum devices to pressure or vacuum, it is desirable that they include an appropriate directional check valve.

Appendix D: Membrane filter test device

General

1 The function of this test device is to collect particulate material which may be present in the pipeline.

2 Filter holders appropriate to the pressure encountered are commercially available.

3 The filter holder should be specified for use at pipeline-distribution pressure and be oxygen-compatible.

Measurement principle

4 A known volume of gas is passed through a membrane filter that will collect all visible particles.

5 Hydrophobic membrane filters of pore size 0.45µm should be used.

Test equipment

6 The following equipment is required:

- a membrane filter holder;
- a supply of white hydrophobic membrane filters of not more than 0.45µm pore size and with high mechanical strength;
- a means of connecting the filter to the pipeline;
- a means of controlling the flow through the filter, which is connected downstream of the filter. One method of achieving this is to use the appropriate Amal jets to achieve a minimum flow of 150 litres/min at 400 kPa and 350 litres/min at 700 kPa;
- all equipment must be oxygen-compatible and hoses should be antistatic.

Appendix E: Equipment for contaminant testing

General

1 The function of these tests is to establish whether the pipeline has been contaminated during construction or modification. The specifications for the permissible concentrations of each component are summarised in Table 29.

2 Simple equipment that is of the required sensitivity and is suitable for use on site is commercially available.

Measurement principle

3 A known volume of gas is passed through a tube packed with an absorbent, which is coated with specific colorimetric reagents. The reagents react quantitatively with the compound to be measured and produce a colour change along the length of the tube, which is proportional to the concentration of the compound being measured.

4 Tubes are available with appropriate sensitivities for the measurement of oil, water, carbon monoxide and carbon dioxide, sulphur dioxide, and higher oxides of nitrogen.

Note 83: Non-agent-specific detector tubes are difficult to interpret and are not recommended because of their qualitative and non-quantitative response.

Appendix F: Equipment for gas identification

General

1 The function of these tests is positively to identify medical gases by measuring their oxygen, nitrous oxide and nitric oxide content.

2 Portable equipment of the required specificity and sensitivity is commercially available.

3 Thermal conductivity meters do not give a positive identification of nitrous oxide in the presence of carbon dioxide, and should not be used as a sole means of identification of nitrous oxide. A specific nitrous oxide meter should be used. If carbon dioxide pipelines are present, for example in IVF (in vitro fertilisation) clinics, a carbon dioxide detector tube should be used.

Specificity

Oxygen

4 Oxygen-specific sensors using different measurement principles are currently in manufacture. The oxygen sensor should not give greater than ±1% response in the presence of 100% nitrous oxide or 100% nitrogen.

Note 84: A paramagnetic meter is the specified instrument for identity of oxygen.

Nitrous oxide

5 The nitrous oxide sensor should not give greater than ±1% response in the presence of 100% oxygen, 100% nitrogen or 100% carbon dioxide. An infrared/fuel cell meter is now commercially available.

Specification

6 The equipment should be portable, preferably battery-powered, with digital or analogue indication of 0–100% to one decimal place. The battery should give at least eight hours' continuous running between recharging or replacement.

7 Accuracy better than ±1% is required, with a zero stability of 2.5% per day.

8 The response time must be not more than 15 seconds to 90% of the final reading.

Appendix G: Pressure loss data

Pipeline pressure-drop calculations

1 Example: Calculate the pressure drop in a 15mm diameter pipe, 11m in length, with two 90o elbows, carrying medical air at a design flow rate of 800 litres/min.

Solution

2 The pressure drop Δp across the pipe can be calculated from the formula:

$$\Delta p = \frac{TL_{ACTUAL}}{L_{TABLEG1}} \times \left[\frac{Q_{ACTUAL}}{Q_{TABLEG1}}\right]^2 \times \Delta p_{TABLEG1} \qquad (2)$$

where:

Δp = Pressure drop across pipe section (kPa)

$\Delta p_{TABLE\ G1}$ = Pressure drop from Table G1 (kPa)

TL_{ACTUAL} = Measured length of pipe, plus total equivalent length for fittings, valve, etc. (m)

$L_{TABLE\ G1}$ = Nearest length of pipe from Table G1 (m)

Q_{ACTUAL} = Design flow (litres/min)

$Q_{TABLE\ G1}$ = Nearest flow from Table G1 (litres/min)

3 Total length of pipe including fittings.

TL = L + EL

Where:

L = Measured length of pipe (m)

EL = Sum off all fitting equivalent lengths from Table G6

TL = Total length

Therefore;

TL = 11 + (0.47 x 2)

TL = 11 + 0.94 = 11.94m

4 From Table G1, the nearest length to 11.94m is 15m and the nearest flow rate to the design flow of 800 litres/min is 711 litres/min in the 15m column, at which there is a pressure drop of 21 kPa across a 15mm diameter, 15m length of pipe.

5 Using these values, Equation (2) gives a pressure drop across the pipe of:

$$\Delta p = \frac{11.94}{15} \times \left[\frac{800}{711}\right]^2 \times 21$$

Δp= 21.16 kPa

6 If this loss is unacceptable, use the next (higher) pipe size, that is 22mm. The nearest flow rate to 800 litres/min is now 1135 litres/min, representing a pressure loss of 7 kPa over 15m.

7 In this instance:

Note that due to the increase in pipe diameter the fitting equivalent lengths will change thus;

TL = 11 + (0.63 x 2)

TL = 11 + 1.26 = 12.26m

$$\Delta p = \frac{12.26}{15} \times \left[\frac{800}{1135}\right]^2 \times 7$$

Δp = 2.84 kPa

Old BS 659 size	New British Standard size (BS EN 1057: R250, Table X)				Distance from source at 400 kPa for 7, 14 and 21 kPa (0.07, 0.14 and 0.21 bar) pressure loss					
Nominal bore (inches)	Outside diameter (mm)	Wall thickness (mm)	Mean internal diameter (mm) (inches)		8 m (25 ft)			15 m (50 ft)		
⅜	12	0.6	10.8	0.4252	311	455	564	209	307	382
½	15	0.7	13.6	0.5354	579	845	1038	391	572	711
¾	22	0.9	20.2	0.7953	1677	2441	3023	1135	1656	2053
1	28	1.2	26.2	10.315	3363	4881	6034	2283	3320	4109
1¼	35	1.2	32.6	1.2835	6023	8720	10758	4096	5943	7344
1½	42	1.2	39.6	1.5591	10103	14587	17963	6883	9963	12290

Table G1: Section of pressure drop table for medical air

	6 mm	8 mm	10 mm	12 mm	15 mm	22 mm	28 mm	35 mm	42 mm	54 mm	76 mm	108 mm
Ball valve	0.10	0.10	0.20	0.30	0.30	0.60	0.90	0.90	1.10	1.20	1.40	2.0
Tee (Thru')	0.12	0.15	0.18	0.21	0.32	0.42	0.54	0.70	0.82	1.05	1.56	2.0
Tee (Branch)	0.46	0.52	0.70	0.80	0.95	1.26	1.60	2.10	2.45	3.14	4.67	6.0
90° Elbow	0.17	0.20	0.25	0.33	0.47	0.63	0.80	1.05	1.23	1.58	2.36	3.0

Table G6: Equivalent lengths (in metres) for copper fittings

8 It is possible to insert the above formula into a spreadsheet and use mathematical functions to calculate required pressure drops (see Tables G2-G5).

9 Another alternative is to derive graphs from the tables, although it may be necessary to draw several graphs, at different scales, to obtain accurate results.

10 The graphs of flow versus pressure drop provide a pressure loss per metre of pipe, not a total pressure loss. This figure must be multiplied by the length of the pipe in order to find the actual total pressure drop.

11 Because a pipe and the fittings in the system cause frictional resistance to the gas flow, a pressure loss occurs that is greater than that which would occur if the gas were flowing through the same distance of straight pipe.

12 Each valve, fitting etc is allocated a “length” equivalent in frictional resistance to a straight piece of pipe of the same diameter. This length is hence known as the equivalent length of the fitting.

13 To calculate design pressure drops, the sum of the lengths of the straight runs of pipe plus the sums of the equivalent lengths of all of the fittings etc. in that run are added.

14 In practice many designers simply add 25–30% to the total measured length or use only 60–75% of the allocated pressure drop when sizing.

15 Equivalent lengths of some fittings are given in Tables G6 and G7.

British Standard Size Tube BS EN 1057: R250, Table X		Distance from source (m) at 400 kPa for 7,14 ,21 kPa (1, 2, 3 psi) pressure loss																
Outside Diameter (mm)	Pressure loss (kPa)	8	15	30	61	91	122	152	183	213	244	274	305	335	366	396	427	457
		Free air flow rate (litres/min)																
12	7	311	209	141	95	75	64	56	50	46	43	40	37	35	34	32	31	30
	14	455	307	207	139	110	94	82	74	68	63	59	55	52	50	47	45	40
	21	564	382	258	174	138	117	103	93	85	78	73	69	65	62	59	57	55
15	7	579	391	263	177	140	119	105	94	86	80	75	70	66	63	60	58	56
	14	845	572	386	260	207	175	154	139	127	118	110	104	98	93	89	85	82
	21	1038	711	481	325	258	219	192	173	159	147	137	129	122	117	111	107	102
22	7	1677	1135	768	518	411	349	307	277	254	235	220	207	196	186	178	170	164
	14	2441	1656	1123	759	604	513	451	407	373	345	323	304	288	274	262	251	241
	21	3023	2053	1395	945	751	638	562	507	465	431	403	379	359	342	326	313	301
28	7	3363	2283	1547	1047	832	706	622	560	514	476	445	419	397	378	361	346	332
	14	4881	3320	2257	1530	1218	1035	912	823	754	699	653	615	583	555	530	508	488
	21	6034	4109	2800	1901	1514	1287	1135	1024	938	870	814	767	726	691	660	633	609
35	7	6023	4096	2783	1886	1500	1275	1124	1013	928	861	805	758	718	683	653	626	602
	14	8720	5943	4051	2752	2192	1865	1644	1483	1360	1261	1180	1111	1053	1002	957	918	883
	21	10758	7344	5018	3415	2723	2317	2044	1845	1692	1569	1468	1383	1310	1248	1192	1143	1099
42	7	10103	6883	4685	3180	2533	2154	1899	1713	1570	1456	1362	1283	1215	1157	1105	1060	1019
	14	14587	9963	6806	4633	3694	3145	2775	2504	2296	2130	1993	1878	1780	1694	1619	1553	1493
	21	17963	12290	8421	5743	4584	3904	3446	3112	2855	2648	2478	2335	2213	2107	2014	1932	1858
54	7	14974	10588	7487	5294	4323	3743	3348	3056	2830	2647	2496	2368	2257	2161	2076	2001	1933
	14	21176	14974	10588	7487	6113	5294	4735	4323	4002	3743	3529	3348	3192	3056	2937	2830	2734
	21	25935	18339	12968	9169	7487	6484	5799	5294	4901	4585	4323	4101	3910	3743	3597	3466	3348
76	7	37754	26696	18877	13348	10899	9438	8442	7706	7135	6674	6292	5969	5692	5449	5236	5045	4874
	14	53392	37754	26696	18877	15413	13348	11939	10899	10090	9438	8899	8442	8049	7706	7404	7135	6893
	21	65392	46239	32696	23119	18877	16348	14622	13348	12358	11560	10899	10339	9858	9438	9068	8738	8442

Table G2: Pipeline pressure loss: 400 kPa (4 bar) pipelines

Examples:

1. 122m of 28mm pipe would carry 706 litres/min of free air per minute with a pressure loss of 0.07 bar (7 kPa), or 1287 litres/min with a loss of 0.21 bar (21 kPa). ie: $122/122 \times (706/706)^2 \times 7$
2. A flow of 1,200 litres/min in 122m of 28mm pipe would result in a pressure loss of 18.26 kPa. ie: $122/122 \times (1200/1287)^2 \times 21$
3. 140m of 28mm pipe would carry 800 litres/min with a pressure loss of 9.92 kPa. Ie: $140/152 \times (800/912)^2 \times 14$

British Standard Size Tube BS EN 1057: R250, Table X		Distance from source (m) at 700 kPa for 7, 14, 34 kPa (1, 2, 5 psi) pressure loss																
Outside Diameter (mm)	Pressure loss (kPa)	8	15	30	61	91	122	152	183	213	244	274	305	335	366	396	427	457
		Free air flow rate (litres/min)																
12	7	408	276	186	125	99	84	74	67	61	56	53	50	47	45	43	41	39
	14	599	405	274	185	147	124	109	99	90	84	78	74	70	66	63	61	58
	34	979	664	450	304	242	205	181	163	149	138	129	122	115	110	105	100	96
15	7	759	514	347	234	186	158	139	125	114	106	99	93	88	84	80	77	74
	14	1112	754	510	345	274	232	205	184	169	156	146	138	130	124	118	114	109
	34	1811	1231	836	566	450	383	337	304	279	258	242	227	215	205	196	188	180
22	7	2192	1488	1009	682	542	460	406	366	335	310	290	273	259	246	235	225	217
	14	3198	2175	1478	1001	797	677	597	538	493	457	482	403	381	363	347	332	320
	34	5180	3533	2410	1638	1306	1111	980	884	811	752	704	663	628	598	571	548	527
28	7	4387	2984	2027	1374	1093	929	819	739	677	628	587	553	524	498	476	456	439
	14	6382	4351	2963	2013	1604	1364	1203	1086	995	923	863	813	771	734	701	672	646
	34	10290	7038	4816	3283	2620	2232	1970	1779	1632	1514	1417	1335	1266	1205	1152	1105	1063
35	7	7841	5345	3638	2470	1968	1674	1476	1332	1221	1132	1059	998	945	900	860	825	793
	14	11380	7775	5307	3612	2881	2453	2165	1954	1792	1662	1556	1466	1389	1323	1264	1212	1166
	34	18271	12528	8599	5876	4696	4003	3536	3194	2931	2720	2547	2401	2276	2168	2073	1988	1912
42	7	13128	8964	6113	4159	3316	2823	2490	2248	2061	1912	1789	1686	1598	1521	1454	1394	1341
	14	19010	13012	8901	6070	4847	4129	3646	3293	3021	2803	2624	2473	2344	2232	2134	2047	1969
	34	30392	20892	14381	9849	7881	6723	5942	5371	4930	4577	4286	4042	3833	3651	3491	3349	3223

Table G3: Pipeline pressure loss: 700 kPa (7 bar) pipelines

Examples:

1. 122m of 28mm pipe would carry 929 litres/min of free air per minute with a pressure loss of 0.07 bar (7 kPa), or 2232 litres/min with a loss of 0.34 bar (34 kPa).
2. A flow of 1,800 litres/min in 122m of 28mm pipe would result in a pressure loss of 22.11 kPa. i.e: $122/122 \times (1800/2232)^2 \times 34$
3. 140m of 28mm pipe would carry 1,100 litres/min with a pressure loss of 10.78 kPa. i.e: $140/152 \times (1100/1203)^2 \times 14$

British Standard Size Tube BS EN 1057: R250, Table X		Distance from source (m) at 1100 kPa for 7, 14, 34 kPa (1, 2, 5 psi) pressure loss																
Outside Diameter (mm)	Pressure loss (kPa)	8	15	30	61	91	122	152	183	213	244	274	305	335	366	396	427	457
		Free air flow rate (litres/min)																
12	7	487	356	252	177	144	124	112	102	94	88	84	79	75	72	69	67	65
	14	689	503	355	249	204	177	158	144	133	124	118	111	106	102	98	94	91
	34	1084	791	560	392	321	277	249	227	210	197	185	176	167	161	154	148	143
15	7	867	634	448	314	257	222	199	181	168	157	148	141	134	128	124	119	115
	14	1226	895	633	444	363	314	281	257	238	222	209	199	189	181	174	168	162
	34	1929	1409	996	698	572	494	443	403	373	350	330	313	298	285	275	264	256
22	7	2332	1703	1205	845	692	598	535	487	452	423	399	378	360	345	332	319	309
	14	3294	2405	1701	1193	977	844	755	689	638	597	562	534	509	487	468	451	436
28	7	4469	3263	2308	1618	1325	1145	1025	935	866	809	764	724	691	660	636	612	591
	14	6311	4608	3259	2286	1872	1616	1448	1320	1223	1143	1078	1022	976	933	897	864	835
	34	9935	7255	5130	3598	2946	2544	2279	2077	1926	1799	1698	1609	1535	1469	1412	1359	1315
35	7	7718	5636	3985	2795	2289	1976	1771	1614	1495	1397	1319	1250	1192	1141	1097	1056	1021
	14	10898	7959	5628	3947	3231	2791	2500	2279	2112	1973	1862	1765	1684	1611	1549	1492	1442
	34	17157	12530	8860	6213	5087	4394	3936	3587	3325	3107	2932	2779	2651	2537	2439	2348	2271
42	7	12550	9166	6481	4545	3721	3214	2879	2624	2432	2272	2144	2033	1940	1855	1784	1718	1661
	14	17724	12944	9152	6418	5255	4538	4066	3706	3435	3209	3029	2871	2739	2620	2519	2426	2345
	34	27902	20377	14409	10104	8273	7145	6401	5834	5407	5052	4768	4519	4312	4125	3966	3819	3692

Table G4: Pipeline pressure loss: 1,100 kPa (11 bar) pipelines

Examples:

1. 122m of 28mm pipe would carry 1145 litres/min of free air per minute with a pressure loss of 0.07 bar (7 kPa), of 2544 litres/min with a loss of 0.34 bar (34 kPa). ie $122/122 \times (1145/1145)^2 \times 7$
2. A flow of 2,200 litres/min in 122m of 28mm pipe would result in a pressure loss of 25.43 kPa. i.e: $122/122 \times (2200/2544)^2 \times 34$
3. 140m of 28mm pipe would carry 1,300 litres/min with a pressure loss of 10.39 kPa. i.e: $140/152 \times (1300/1448)^2 \times 14$

British Standard Size BS EN 1057, R250, Table X		Distance from source (m) at 59 kPa (450 mmHg) for 1.3, 2.6, 3.9, 6.5 kPa (10, 20, 30, 50 mmHg) pressure loss																
Outside Diameter (mm)	Pressure loss (kPa)	8	15	30	61	91	122	152	183	213	244	274	305	335	366	396	427	457
		Free air flow rate (litres/min)																
15	1.3	59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2.6	89	59	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3.9	113	76	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6.5	153	103	69	46	-	-	-	-	-	-	-	-	-	-	-	-	-
22	1.3	173	116	78	52	41	-	-	-	-	-	-	-	-	-	-	-	-
	2.6	260	174	117	79	62	53	46	42	-	-	-	-	-	-	-	-	-
	3.9	330	222	149	100	79	67	59	53	49	45	42	40	-	-	-	-	-
	6.5	445	301	203	137	108	92	81	73	67	62	57	54	51	49	46	45	43
28	1.3	350	236	159	106	84	71	63	56	51	48	44	42	40	-	-	-	-
	2.6	525	353	238	160	127	107	94	85	78	72	67	63	60	57	54	52	50
	3.9	666	448	303	204	161	137	120	108	99	92	86	81	76	73	69	66	64
	6.5	900	607	412	278	220	187	164	148	135	125	117	110	104	99	95	91	87
35	1.3	637	427	288	193	153	130	114	102	94	87	81	76	72	69	65	63	60
	2.6	947	638	431	290	230	195	171	154	141	131	122	115	109	103	99	95	91
	3.9	1198	808	548	369	293	248	218	197	180	167	156	147	139	132	126	121	116
	6.5	1614	1091	743	503	399	339	298	269	246	228	213	200	190	180	172	165	158
42	1.3	1074	724	488	328	260	220	194	174	160	148	138	130	123	117	111	107	103
	2.6	1598	1079	731	493	391	331	291	262	240	222	208	196	185	176	168	161	155
	3.9	2016	1363	926	626	497	422	371	334	306	283	265	249	236	224	214	205	197
	6.5	2706	1833	1254	851	677	574	506	456	417	387	361	340	322	306	293	280	270
54	1.3	2191	1480	1001	674	535	453	399	359	329	304	284	268	253	241	230	220	212
	2.6	3246	2196	1493	1010	802	681	599	540	494	458	428	403	381	363	346	332	319
	3.9	4083	2766	1889	1281	1019	865	762	687	629	582	545	513	485	462	441	423	406
	6.5	5448	3699	2549	1737	1384	1176	1037	935	856	794	742	699	662	630	601	576	554
76	1.3	5521	3773	2563	1733	1377	1169	1029	927	849	786	735	692	655	623	595	570	548
	2.6	8070	5563	3807	2586	2058	1749	1541	1389	1273	1179	1103	1038	983	396	894	857	823
	3.9	10041	6968	4801	3274	2609	2219	1957	1765	1617	1499	1402	1320	1250	1190	1137	1090	1048
	6.5	13166	9233	6439	4421	3533	3009	2655	2396	2197	2037	1906	1796	1701	1619	1547	1483	1426
108	1.3	12874	9140	6543	4552	3732	3280	2879	2628	2433	2276	2036	1941	1919	1858	1785	1712	1641
	2.6	18207	12874	9235	6578	5274	4552	4071	3716	3441	3219	3035	2879	2745	2628	2525	2422	2325
	3.9	22494	15905	11374	8114	6509	5657	5030	4592	4251	3976	3750	3557	3391	3247	3119	2992	2870
	6.5	29238	20675	14708	10520	8445	7343	6538	5968	5526	5169	4873	4623	4408	4220	4055	3889	3730

Table G5: Pipeline pressure loss (vacuum)

Examples:

1. 122m of 28mm pipe would carry 71 litres/min of free air per minute with a pressure loss of 10 mmHg (1.3 kPa), or 187 litres/min with a loss of 50 mmHg (6.5 kPa). ie 122/122 x $(71/71)^2$ x 1.3
2. A flow of120 litres/min in 122m of 28mm pipe would result in pressure loss of 2.99 kPa. ie: 122/122 x $(120/137)^2$ x 3.
3. 140m of 28mm pipe would carry 90 litres/min with a pressure loss of 2.20 kPa. ie: 140/152 x $(90/94)^2$ x 2.6

Fitting Type	6 mm	8 mm	10 mm	12 mm	15 mm	22 mm	28 mm	35 mm	42 mm	54 mm	76 mm	108 mm
Ball valve	0.10	0.10	0.20	0.30	0.30	0.60	0.90	0.90	1.10	1.20	1.40	2.0
Tee (Thru')	0.12	0.15	0.18	0.21	0.32	0.42	0.54	0.70	0.82	1.05	1.56	2.0
Tee (Branch)	0.46	0.52	0.70	0.80	0.95	1.26	1.60	2.10	2.45	3.14	4.67	6.0
90° Elbow	0.17	0.20	0.25	0.33	0.47	0.63	0.80	1.05	1.23	1.58	2.36	3.0

Table G6: Equivalent lengths (in metres) for copper fittings

Fitting Type	40mm	50mm	70mm	100mm	125mm
Tee (Thru')	0.95	1.23	1.65	2.20	2.56
Tee (Branch)	2.76	3.38	4.57	6.12	7.68
90° elbow	1.25	1.71	2.44	3.08	3.84

Table G7: Equivalent lengths (in metres) for ABS (acrylonitrile butadiene styrene) vacuum fittings

Appendix H: Checklist for planning/installing/upgrading a cryogenic liquid supply system

1 Information given in this Appendix can be used to determine the need for a particular capacity or type of supply system. Many of the factors described will also apply to planning an upgrade to an installation by way of increase in system size or a change of system type.

2 Some factors that should be considered are outlined below.

Delivery frequency

- Does current frequency cause logistical problems for the supplier/your site?

Calculating consumption

- Consumption is rising at approximately 10% per annum. It doubles in seven years.
- Use pharmacy records for cylinder/liquid consumption. Look for peaks in demand, for example winter influenza epidemics.
- When average and peak flow rates are known, calculate the required size of the emergency supply.

Age of current system

- The secondary supply of older VIE systems will be a compressed gas cylinder manifold, which may have very limited capacity. Consideration should be given to either a single VIE plus fully automatic manifold or, preferably, a dual VIE system.

Siting of system and the site survey

- what planning restrictions apply (vessel size, noise etc)?
- what are convenient locations for cylinder/ liquid delivery?
- advantages of separating primary and secondary supplies, if space is available;
- will other facilities be lost/reduced, for example car-parking space?
- it will be less economical in terms of delivery charges and unit gas costs to deliver large loads (for example 20 tons) using rigid vehicles (maximum 12 tons). Articulated vehicles will deliver the largest loads but may require roadway/access modifications;
- cranage access for vessels;
- when choosing liquid cylinder systems, will adequate ventilation be available?

- emergency supply location;
- pipeline protection and possible need for dual feeds;
- pipeline extension into other sites if applicable, for example two hospitals supplied from the same VIE system. There are possible insurance issues with this arrangement;
- modifications to the alarm system may have to be made;
- alarm panel + telemetry in waterproof enclosures;
- are alarms compatible with the existing system?
- alarm arrangement for dual (but separate) tank installations;
- cable ducts and trays: examine possible routes;
- possible need to move gates/fences to install new pipework;
- clearance of trees/building;
- sealing windows of adjacent buildings;
- position of frame for valve tree (fix to fence for rigidity?);
- position of emergency gate;
- position of fill couplings must allow driver to see tank gauges;
- cabling and alarm runs for the emergency supply manifold (ERM);
- availability and presentation of alarms for ERM;
- power and lighting during work;
- drainage – catch pits, diversions, pad resizing;

Costs

- Make sure a**ll** costs are allowed for, for example:
  - site inspection;
  - cost of continuing delivery using rigid and non-articulated vehicles;
  - gas charge/HCM (hundred cubic metres) and any inflation likely;
  - facility charges (rental);
  - delivery charge for equipment;
  - loan charges and changes in interest rate on any loan if the installer funds any part of the installation;
  - road/compound loans will be seen as £x added to gas price over y years;
  - climate change levy;
  - professional fees (consultancy);
  - planning permission;
  - building Regulations clearance;

  - all civil engineering work;
  - quoted price for gas/facilities/delivery charges may be dependent on payment by direct debit;
  - introduction/modification and maintenance of services, for example lighting, power supplies, drainage;
  - engineering and pharmaceutical testing;
  - additional emergency provision and any associated cylinder charges;
  - modifications to alarm and telephone systems;
  - security;
  - charges for ERM cylinders during installation (may have to be charged and then recovered);
  - cranage charges;
  - contingency 10%
  - what, if any, commitment is required by the gas company?
- how will gas prices vary during this period?
- is there any agreement to provide, for example, modified roadway facilities if rigid vehicular deliveries are too frequent to be convenient to supplier? Or if such roadway modifications take place within a defined timescale, new rates etc may need to be negotiated;
- check defects liability (usually 12 months).

Emergency provision

- examine the vulnerability of current system and main feeds to hospital;
- consider minimum size of manifold plus cylinder storage to meet four-hour supply requirement. Is a second VIE a better option?
- operational requirements of ERM;
- protection/housing/security of ERM;
- alarm/monitoring systems and power supplies for ERM and its accommodation.

System shutdown during installation

- often it will be necessary to interrupt site supplies during connection of new plant. How will this be managed?
- disruption of two hospitals simultaneously if plant to be upgraded is supplying both sites;
- examine planned plant and pipework systems carefully to ascertain the best way of minimising downtime and facilitating engineering and pharmaceutical testing;

- while installing, fit extra valves to allow for future expansion and emergency supply manifolds to protect vulnerable parts of the system;
- fit NIST fittings wherever this will facilitate system purging;
- fit test points/emergency inlet ports as recommended in this guidance or investigate any likely requirement for additional (local) manifolds to support high-dependency areas.

Paperwork

- site survey details;
- register of contractors with contact names/ telephone numbers;
- keep a record of all dates, for example:
  - tender invitation;
  - tender open;
  - tender close;
  - award and regret letters to tenderers;
- copies of all letters to/from contractors;
- NICEIC (National Inspection Council for Electrical Installation Contracting) test certificate for electrics;
- validation and verification results (engineering and pharmaceutical);
- Health and Safety policies of contractors;
- method statements from contractors;
- insurance agreement with gas supplier for VIE system(s);
- MGPS operational policy protocols.

Health and safety

- Health and Safety policy (contractors and their employees, and subcontractors and their employees, must comply when employed by the trust and working on trust properties);
- inform contractors of specific site hazards;
- Hazard notices on site and on final installation;
- lighting during installation and for completed compound;
- road markings and signage.

Preparation

- carefully plan phasing of building work to maximise efficiency of installation programme. (Remember concrete plinths will take three days to harden before vessels can be sited.);

- plan phasing of engineering and QC testing to avoid wasting APs'/QCs' time;
- consider methods of maintaining supplies during essential shutdowns. Cylinder supplies may be needed during commissioning. Gas supplier may be able to arrange multi-cylinder pallets;
- road base preparation, if required, must be completed in an early phase of the work to allow necessary access for cranes and, eventually, delivery vehicles;
- road surfacing/kerbing/drainage/lighting;
- retaining walls around compound if required, for example on sloping sites;
- maintaining rights of way;
- oxygen compound civil engineering work;
- if you are changing supplier, your original supplier will need to remove old equipment before plinth can be extended to fit new vessels;
- electrics for alarms, tank, lighting and, possibly, vehicle pump;
- floodlighting and telephone line;
- plan vehicular parking during (and after) work;
- the old plinth may require skimming to provide a reasonable surface.

Installation

- if an ERM (as a third means of supply) is installed first, this can be used to supply the hospital system during vessel replacement;
- decide who arranges emergency cylinder supplies for ERM. When plinth extensions are required, specify oxygen-compatible sealant for gaps between old and new plinth sections;
- remember to post health and safety notices during the work;
- alarm systems will not be fully functional until system is fully commissioned. Therefore, all staff must be kept aware of the different alarm situation;
- concrete will need two to three days to harden on any pad extension;
- the first vessel filling is a very noisy procedure with much vapour and can take several hours (consider restrictions);
- concrete sample testing will be required during new plinth construction;
- use temporary steel sheeting to support a new vessel on tarmac alongside the plinth;
- access for cranage must be kept open (car parking control);
- drainage (may have to move existing drains/ soakaways and create new pipe runs; remember oxygen separation distances);
- road markings and signage;
- possible new kerbs/footpaths;

- electrical supplies: single phase can be used for lighting, alarms etc but a three-phase 60 A supply will be needed for delivery vehicle pump if appropriate;
- earth bonding/lightning protection for fences;
- alarm interface/telemetry boxes at a sensible height for viewing;
- lagging of liquid lines;
- if using 200 bar unregulated cylinders for supply during installation or on ERM, take care that they are not mixed up with 137 bar cylinders;
- proximity of flammables and vital services during installation – vulnerability to mechanical damage (cutting discs, etc.), welding and cutting flames/sparks;
- power and lighting supplies during work;
- water supply (washing and concrete) during work.

Follow-up

- routine maintenance and monitoring of complete installation;
- cylinder changes and stock management for ERM;
- establish system management arrangements for vessels supplying more than one site (see Part B, Appendix G);
- update MGPS operational policy and any relevant insurance policies.

Appendix J: Upgrading surgical air systems

Background

1. An increasing number of surgical air pipeline systems are designed to operate at a line pressure above the nominal 700 kPa, for example 1,000 – 1,100 kPa. This enables the system to deliver 350 litres/min (at 700 kPa) at the front of the surgical air terminal unit.

2. Such a system will comprise a high-pressure supply pipeline installation, in the order of 1,000–1,100 kPa and local pressure regulation (for example adjacent to the operating suite) such that the maximum static pressure does not exceed 900 kPa.

3. Existing Health Technical Memorandum 22 systems run at a line pressure of 700 kPa and will provide a flow of 250 litres/min at the front of the terminal unit.

4. Users must be made aware (preferably by written report) that such systems will not meet the demands of some modern air tools and that use of such tools may result in both a lack of tool performance and frequent low-pressure alarms on the surgical air system.

5. Tools are available that require a flow up to 500 litres/min at an operating pressure of 1,400 kPa. Such tools will require discrete cylinder supplies.

Modifying “old” systems

6 Increasing line pressure to meet the latest recommended flow rates is often proposed, but needs to take account of the following:

- **is the compressor receiver suitable for use at the proposed pressures?** A typical “old” 700 kPa system will employ a receiver operating at typically 10 bar pressure. A “new” system, with a typical line pressure of 10.5 bar, requires a receiver operating at a typical pressure of 13 bar. Ensure that the test, design and working pressures of the current receiver are acceptable, and that the capacity of the receiver is appropriate to the new demand;
- **is the compressor plant capable of meeting the increased duty cycle?** Overheating and premature plant failure may result if this is not the case. The system may be supplying both surgical and medical air. Plant failure/flow reduction resulting from an overburdened surgical air system may have serious consequences in terms of medical air provision, particularly as this is the recommended driving gas for patients’ ventilators;
- **are the pressure safety valves (PSVs) suitably rated?** PSVs on pipelines and the receiver will need to be changed to meet the new operating conditions. Certificated replacement PSVs should be used;
- **Are pressure switches suitably rated and adjusted?** Pressure switches on plant and pipelines will need to be changed or adjusted accordingly;

- **has the pipeline been suitably pressure-tested?** There may be occasions when existing 4 bar systems (or parts thereof) are proposed for use at 7 bar or higher. 4 bar systems are only tested to 10 bar; they will need to be retested at 18 bar to ensure a leak-free high-pressure system;
- **will you still be insured?** If the pipeline system contains large diameter pipe (120mm or above), the insurance company should be consulted to ascertain whether the system would be capable of withstanding not only the pipeline operating pressure but also any test pressure that may be applied during system refurbishment or extension. A new Written Scheme of Examination will have to be prepared for the new system;
- **labelling.** Ensure that all relevant labels are in place before the system is accepted;
- **other issues.** There may be other system defects discovered during the upgrading process, for example lack of pipeline support/protection. There may also be a potential contamination issue resulting from the transfer of particulate matter from older, silver-soldered systems into new inert gas shield brazed pipework, although it should be noted that this is not an issue limited to air systems. These issues will need to be addressed before the system is accepted for use. Ensure that any system amendments and changes in working practices are documented in the MGPS operational policy.

Appendix K: Signage requirements

Location	Wording	Notes
Plantroom	Medical Gas Plant Room – No unauthorized Entry	Adjacent to or on external door
	Fire action	On door/wall External or internal
	Keep locked	On door(s)
	Noise Hazard (+ ear defender symbol) Electric shock hazard Permit-to-work must be used	Adjacent to, or on, external door
	Plant is connected to essential electricity supply	"E" symbols can be used on switches etc
	Danger 400 Volts	On plant/switchgear
	Danger 240 Volts	On plant/switchgear
	Danger rotating machines Warning: These machines stop and start automatically without warning Guards must be in position Do not isolate without a Permit	Posted adjacent to plant
	Biological symbol	Vac filters and exhausts Also for AGSS units/exhausts/drain Flasks
	Medical air intake Do not obstruct	On external intakes only
	Emergency Tel No Gas Supplier Estates Pharmacy Porters	External wall
	Health and Safety Law	Internal wall
	First aid	Internal wall

Table K1: General Plantroom Signage

Notes applicable to Table K1: "Bacteria filter change procedure" sign is not available commercially and will have to be made locally.

No "Danger medical gas/vac/AGSS exhaust" sign is commercially available but "Danger explosive gases, no smoking, no naked lights" is available and would suffice.

"Danger 400/240 Volts", "Warning: These machines stop and start automatically/without warning" and "Biohazard" labels would need to be added to AGSS plant remote from main plantroom, plus any relevant plantroom notices.

Location	Wording	Notes
Manifold room	Medical gases manifold room – No unauthorised entry	Adjacent to or on external door
	No parking	Adjacent to or on external door
	Approved personal protective equipment must be worn	Adjacent to or on external door
	Fire action	Internal/external wall
	Cylinder status tag	On manifold cylinders
	Valve open	On line valves/ERM cylinders
	Valve closed	On line valves/ERM cylinders
	Make sure cylinders are secure at all times	Internal, near cylinders
	Danger No smoking	External (on door or wall)
	Danger compressed gas	External (on door or wall)
	Warning oxidizing agent	External (on door or wall)
	Danger oxygen	External (on door or wall)
	Emergency Tel No Gas suppliers Estates Pharmacy Porters	External (on door or wall)
	Keep locked	On door

Table K2: Manifold Room Signage

Notes applicable to Table K2: Also required:

Cylinder ID charts, manifold cylinder change procedure, emergency manifold operating procedure.

Check with fire officer for any local fire brigade requirements for fitting "HAZCHEM" signs e.g. "HAZCHEM 2SE Cylinders"

Location	Wording	Notes
Main cylinder store	Medical gases cylinder store – No unauthorised entry	Adjacent to or on external door
	No parking	Adjacent to or on external door
	Keep loading bay/doors clear	Adjacent to or on external door
	Approved personal protective equipment must be worn	Adjacent to or on external door
	Make sure cylinders are secure at all times	Adjacent to cylinders
	Fire action	Internal/external wall
	Full cylinders	On bays
	Empty cylinders	On bays
	Emergency exit keep clear	May be already fitted
	Danger No smoking	On door
	Danger compressed gas	On door
	Warning oxidizing agent	External (on door or wall)
	Danger oxygen	External (on door or wall)
	Emergency Tel No Gas suppliers Estates Pharmacy Porters	External wall
	Keep locked	On door
	Push bar to open	Emergency exit and main door(s)

Table K3: Main Cylinder Stores

Notes applicable to Table K3: “Danger liquid nitrogen” sign is available for a separate liquid nitrogen store (see BCGA CP30).

Cylinder ID chart(s) to be posted

Check with fire officer for any local fire brigade requirements for fitting “HAZCHEM” signs e.g.

“HAZCHEM 2SE Cylinders”.

Location	Wording	Note
Ready to use cylinder store	Medical gases cylinder store – No unauthorized entry	Adjacent to or on external door
	Make sure cylinders are secure at all times	Adjacent to cylinders
	Emergency Tel No Gas suppliers Estates Pharmacy Porters	External wall
	Danger No smoking	On door
	Danger compressed gas	On door
	Fire action	Internal/external wall

Table K4: Ready to Use Cylinder Stores

Notes applicable to Table K4: Post cylinder ID chart(s) and cylinder change procedure.

Check with fire officer for any local fire brigade requirements for fitting "HAZCHEM" signs, eg "HAZCHEM 2SE Cylinders"

Location	Wording	Notes
Ward (Cylinder parking bay)	Medical gas cylinder parking area	Defines cylinder parking as per new Scottish Health Technical Memorandum
	Emergency Tel No Gas suppliers Estates Pharmacy Porters	External wall
	Gas leak action	On nurses' station

Table K5: Ward cylinder parking bay

Notes applicable to Table K5: Post cylinder chart(s) and cylinder change procedure.

Operational policy may dictate posting of AVSU emergency operation and MGPS alarm responses.

Location	Wording	Notes
Work area	Maintenance in progress	There may be other site safety notice requirements to fulfil
	Medical gas test area	
	Confined space	
	Hot work in progress	
	Danger pressure test in progress	
	Danger nitrogen purging in progress	

Table K6: Medical equipment workshop (EBME)

Notes applicable to Table K6: These signs should be posted during installation/modification/maintenance of an MGPS. Multiple signs may be required.

Location	Wording	Notes
Pipework	Gas identity	
	Flow direction	

Table K7: Pipeline identification

Location	Wording	Note
Line Valves& Lockable Valve Assembly	Gas identity	On pipeline label
	Flow direction	
	Valve No	Sequential number system
	Key No	

Table K8: Line Valve & Line Valve Assembly identification

Location	Wording	Notes
AVSUs	In emergency break glass and shut off valve	On/off positions to be shown on AVSU body
	Gas identity	
	Flow direction	
	Area controlled	
	Key No	
	Valve No	Sequential number system

Table K9: AVSU identification

Location	Wording	Notes
Alarm displays	Area monitored	Responses may be posted nearby, in accordance with MGPS operational policy
	Gas names	
	Fault/normal/condition indicators	

Table K10: Alarm system identification

Location	
VIE/Liquid cylinders/PSA/synthetic air	Signage will be determined by the equipment supplier but will usually include plant schematic, safety warnings and emergency actions

Table K11: Bulk liquid oxygen/Liquid oxygen cylinder/PSA/Synthetic Air plant

Appendix L: Important notes for use of medical vacuum and anaesthetic gas scavenging

Infectious disease units

1 Medical vacuum should neither be extended to an Infectious Diseases Unit (IDU) nor provided to such a unit from a central vacuum system.

2 Portable suction units will be required. Decontamination will require specialised protocols and the advice of the infection control officer should be sought.

Note 84: Systems already exist whereby an IDU is, by local agreement, serviced via a central vacuum system. If such agreements exist, or are to be accepted, great care must be taken to ensure that the exhausts of such a plant are kept well away from all air intakes and the plant is labelled to indicate its function. Ideally, the plant should be housed in separate accommodation but, where this is not possible, safety signage and strict operational protocols are extremely important. Personnel changing filters, or carrying out work on such a system, should wear personal protective equipment and follow protocols that have been devised in liaison with the infection control officer.

Laser/surgical diathermy smoke extraction

3 An additional contamination hazard can arise if smoke from procedures employing laser or surgical diathermy equipment is exhausted using a cannula attached to the vacuum system.

4 Clinical staff should be advised against this practice and either instructed to use dedicated laser smoke removal units (incorporating dedicated, filtered, portable vacuum pumps) or a specially designed laser smoke filter fitted to a medical vacuum system terminal unit.

Dental vacuum systems

5 Medical vacuum systems operate at relatively low flow rates at the terminal units (~40 litres/min). Such flows are unsuitable for use as dental vacuum, which operates at much higher flow rates (typically 300 litres/min). Medical vacuum systems should not be used to provide dental vacuum.

Anaesthetic gas scavenging (AGS)

Active AGS systems (medical)

6 Active anaesthetic gas scavenging systems operate at relatively high flow rates (80–130 litres/min in a BS6834:1987 system; and 50–80 litres/min in a BS EN ISO 7396-2: 2007 system).

7 It is unlikely that receiving systems designed for use with these scavenging systems will operate correctly with a medical vacuum system. Severe spillage of

waste gases into the operating area may occur. Therefore, medical vacuum systems should not be used as waste anaesthetic gas disposal systems.

Active AGS (dental)

8 Active AGS systems for use with dental nasal scavenging masks operate by maintaining a flow of air through the outer layer of a specially designed concentric nose mask. Waste gases from the patient pass from inner to outer layers of the mask and are carried away to the exhaust termination by this air stream.

9 The flow rate necessary to achieve effective removal of waste gases by such a method is in the order of 45 litres/min, which is less than the flow rate achieved at a dental vacuum system terminal.

10 Active dental scavenging systems using this type of mask must therefore be driven (via a special flow adjuster) from the dental vacuum system, a dedicated separate high-flow vacuum system, or an active medical AGS system. In the case of a medical AGS system, the special flow adjuster would be plugged directly into an AGS system wall terminal. A receiver (air break) system would not be used between the wall terminal and the special flow adjuster.

Appendix M: Oxygen usage data

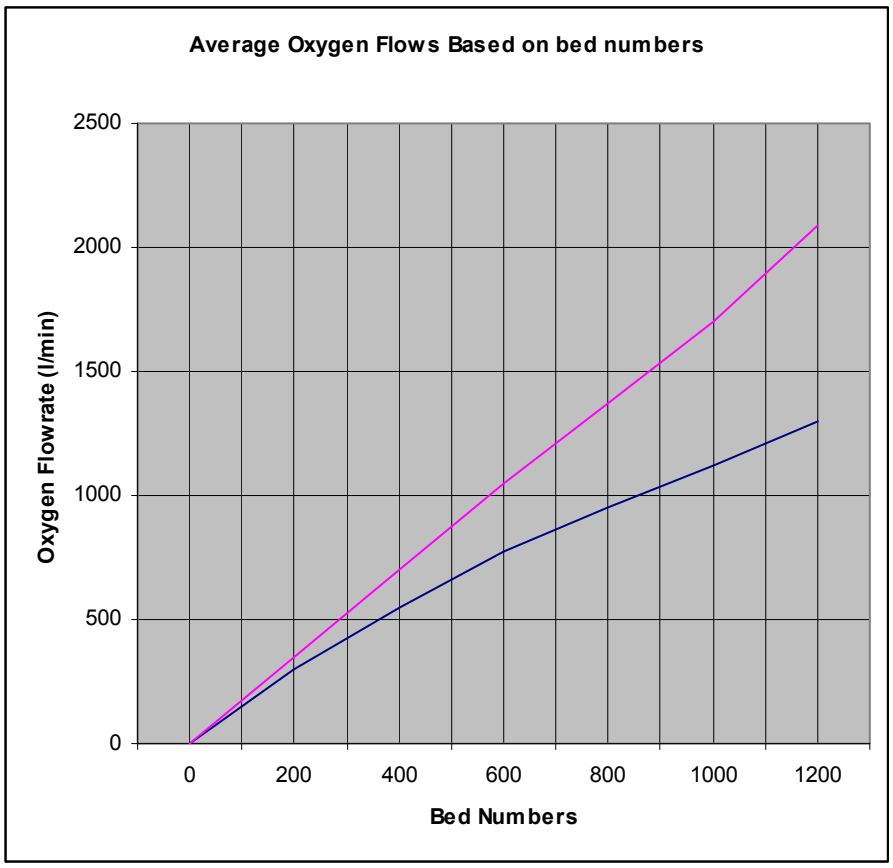


Figure M1: Oxygen usage nomogram

Lower graph shows average flows to be expected in a typical acute hospital.

Upper graph shows flows to be expected when the hospital has specialties using larger amounts of oxygen, e.g. those with multiple large critical care areas (>20 beds) and an increased use of CPAP (>5 machines).

NB. These graphs are issued for guidance only. There will be hospitals for which average flows will, for a given number of beds, be higher or lower than the maxima and minima shown here.

NB. The flows are representative of oxygen provided from a VIE plant and do NOT take into account additional consumption from compressed gas cylinders.

Appendix N: Pressure conversion table

Pressure	Multiply units in left column by factor below							
	kPa	lb/in^2	lb/ft^2	Int atm	kg/cm^2	mmHg @ 0°C	In Hg @ 0°C	ft water @ 4°C
1 pound/in^2	6.895	1	144	0.0682	0.0703	51.713	2.0359	2.307
1 pound/ft^2	0.048	0.00694	1	0.0005	0.00052	0.3591	0.01414	0.01602
1 int atmosphere	101.3	14.696	2116.2	1	1.0333	760	29.92	33.9
1 kilogram/cm^2	98.07	14.223	2048.1	0.9678	1	735.56	28.958	32.81
1 mmHg (1 torr)	0.133	0.0193	2.785	0.0013	0.00136	1	0.0394	0.0446
1 in Hg	3.387	0.4912	70.73	0.0334	0.0345	25.400	1	1.133
1 ft water	2.984	0.4335	62.42	0.0295	0.0305	22.418	0.8826	1
1 kilopascal (kPa)	1	0.145	20.92	0.0099	0.0102	7.519	0.295	0.3346

Table N1: Pressure conversion table

Appendix O: Pressure testing procedure

The following provides guidance in relation to the safe procedures related to pneumatic pressure testing of medical gas pipelines. The guidelines are based upon the Health and Safety Executive guidance note GS4; 1998. Note that the appropriate method statements and risk assessments should always be prepared for all pressure testing. All necessary safety warning signs should be posted throughout the test area. All unauthorised personnel should vacate all areas under test.

First Fix Pressure Test

Prior to First Fix test being carried out a leak test should be performed; all pipeline ancillaries which can be affected by the higher pressures should be removed or blanked, e.g. safety valves, pressure switches.

First fix pressure tests should be carried out in the following manner:

1. An initial leak test pressure should be set at no more than 100 kPa. This test should allow significant leaks to be detected and rectified prior to the main pressure test.

2. The pressure should be increased gradually over a period of time, e.g. 200 kPa increments and leave for 10 minutes, while monitoring the pressure reading. If the pressure drops during this period, retest for leaks.

3. If the pressure is stable, continue to increase to the agreed test pressure, leave for 1 hour as indicated in 15.51 and 15.52.

4. The test pressure(s) and temperature(s) should be witnessed by the Authorised Person (MGPS) or CSO at the start and at the end of the test period with all necessary test sheets completed and signed.

5. The pressure should be reduced in a safe manner to a maximum pressure of 100 kPa, or to the pressure agreed on the particular site.

Service	Test Pressure	Pressure Drop (max)	Timescale
Oxygen	10 bar / 1,000 kPa	0.2 kPa	1 hour
Nitrous Oxide	10 bar / 1,000 kPa	0.2 kPa	1 hour
Nitrous Oxide/Oxygen (50/50)	10 bar / 1,000 kPa	0.2 kPa	1 hour
Medical Air 4 Bar	10 bar / 1,000 kPa	0.2 kPa	1 hour
Surgical Air 7 Bar	18 bar / 1,800 kPa	0.5 kPa	1 hour
Surgical Air 9 Bar	18 bar / 1,800 kPa	0.5 kPa	1 hour
Medical Vacuum	5 bar / 500 kPa	0.2 kPa	1 hour
AGSS	70 kPa	10 kPa	15 mins

Second Fix Pressure Test

Second fix pressure tests should be carried out in the following manner:

1. All pipeline ancillaries such as; terminal units, pendant hoses, pressure switches, etc. should be connected and tested for leakage in the same manner as indicated in 1st fix Pressure Test procedure item 1.

2. The pressure should be increased gradually over a period of time, e.g. 200 kPa increments and leave for 10 minutes, while monitoring the pressure reading.

3. If the pressure drops during this process, retest for leaks.

4. If the pressure is stable, continue to increase to the agreed test pressure, leave for 1 hour as indicated in 15.62 and 15.63.

5. The test pressure(s) and temperature(s) should be witnessed by the Authorised Person (MGPS) or CSO at the start and at the end of the test period with all necessary test sheets completed and signed.

6. If the remaining functional tests are not to be performed immediately after the 2nd fix pressure test, the pressure should be reduced in a safe manner to a maximum pressure of 100 kPa or to the pressure agreed on the particular site.

7. The pressure for each service should be monitored over the period until the pipelines are to be set to working pressures for functional tests.

Service	Test Pressure	Pressure Drop (max)	Timescale
Oxygen	4 bar / 400 kPa	0.1 kPa	1 hour
Nitrous Oxide	4 bar / 400 kPa	0.1 kPa	1 hour
Nitrous Oxide/Oxygen (50/50)	4 bar / 400 kPa	0.1 kPa	1 hour
Medical Air 400 kPa	4 bar / 400 kPa	0.1 kPa	1 hour
Surgical Air 700 kPa	7 bar / 700 kPa	0.5 kPa	1 hour
Surgical Air 900 kPa	9 bar / 900 kPa	0.5 kPa	1 hour
Medical Vacuum	450 – 700 mmHg	1 kPa / 7.5 mm Hg	1 hour

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