NHS National Services Scotland

Medical Gas Pipeline Systems

Scottish Health Technical Memorandum

Part A - Design, installation, validation and verification

SHTM 02-01 Part A

Draft 1.02 - November 2025.

Contents

Preface

About Scottish Health Technical Memorandum

Scottish Health Technical Memorandums (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 good practice. They are applicable to new and existing sites and are for use at various stages during the whole building lifecycle.

Language usage in technical guidance

In SHTMs verbs such as “must”, “should” and “may” are used to convey notions of obligation, recommendation or permission. The choice of modal verb will reflect the level of obligation needed to be compliant.

The following describes the implications and use of these modal verbs in SHTMs (readers should note that these meanings may differ from those of industry standards and legal documents):

A. “Must” is used when indicating compliance with the law
B. “Should” is used to indicate a recommendation (not mandatory/ obligatory), for example among several possibilities or methods, one is recommended as being particularly suitable - without excluding other possibilities or methods
C. “May” is used for permission, for example to indicate a course of action permissible within the limits of the SHTM
D. “Shall”, in the obligatory sense of the word, is never used in current SHTMs.

Typical usage examples

A. “All pipeline components must be clean for oxygen service.” [obligation]
B. “This document makes recommendations for the allocation of duties to personnel and the manner in which these duties should be performed.” [recommendation]
C. “Further advice on the application of this guidance may be obtained from the Authorising Engineer (Medical gas pipeline systems (MGPS))” [permission]

Project derogations from the Technical Guidance

Healthcare facilities built for the NHS are expected to support the provision of high-quality healthcare and ensure the NHS Constitution right to a clean, safe and secure environment. It is therefore critical that they are designed and constructed in accordance with appropriate technical standards and guidance. This applies to all new and refurbishment projects, regardless of procurement model.

Note 1: The healthcare organisation, and their project teams, should ensure that they have a fully documented list of technical standards and guidance that are applicable to the specific project.

The starting point for all NHS healthcare projects at Project Initiation Document (PID) and/ or Strategic Business Case (SBC) stage is one of full compliance.

It is recommended that the starting point for all projects should be one of full adherence to the SHTM guidance. While it is recognised that derogations may be required in some cases, these must all be risk-assessed and documented in order that they may be considered within a structured derogation review and approval process. In all instances derogations must not compromise the health and safety or operational resilience of the healthcare facility. Healthcare organisations should ensure that any derogations do not impact on their legal or statutory obligations.

Derogations must be properly authorised by the project's Senior Responsible Officer (SRO) and informed and supported by appropriate technical advice including that of the Medical Gas Safety Group (MGSG), irrespective of a project's internal or external approval processes.

A schedule of derogations should be created for any project, including details of approvals, risk assessment and identified mitigations.

Note 2: This guidance does not alter the healthcare organisations legal or statutory obligations.

NHS Scotland Sustainable Development Policy Drivers

Responding to the global climate emergency is one of the Scottish Government's highest priorities. Sustainable development, the concept that the needs of the present must be met "without compromising the ability of future generations to meet their own needs" is integral to the Scottish Government's overall purpose. The Scottish Government's National Performance Framework (NPF) shares the same aims as the United Nations' Sustainable Development Goals. It highlights the need for a 'whole system approach' to

successfully deliver the NPF's national outcomes for Health and recognises the important role that NHS Scotland has in helping to achieve this.

Over recent years the current and future impact of climate change has been well documented, with risks to human health and to health and social care delivery highlighted within Scotland's summary report of the UK Climate Risk Independent Assessment. For more information, visit the UK Climate Risk website for the CCRA Evidence Report Scotland Summary. NHS Scotland is committed to the delivery of a high quality, environmentally and socially sustainable health service that is resilient to the locked-in impacts of climate change. Director Letter (DL) (2021) 38 'A Policy for NHS Scotland on the Climate Emergency and Sustainable Development' provides the framework for this aim to become a reality, and to maximise NHS Scotland's contribution to mitigating and limiting the effect of the global climate emergency.

Executive Summary

Introduction

Since the last revision of Scottish Health Technical Memorandum (SHTM) 02-01 Part A there have been considerable changes and advances in the way in which medical gases are supplied and distributed clinically, environmentally and technically. The key drivers for this are:

- global warming - a reduction in use of nitrous oxide and other anaesthetic agents due to their environmental impact. General anaesthetic practice is now based largely around low-flow inhalation techniques and greater use of total intravenous anaesthesia (TIVA), the utilisation of anaesthetic agent harvesting systems and other capture technology means, the local exhaust ventilation (LEV) control measures for this anaesthetic gas scavenging system (AGSS) should be assessed as to their continuing functionality/ suitability
- net-zero requirements and embodied carbon - resulting in some services now not requiring to be provided as a central plant or piped installation and the most appropriate supply source being identified by an informed design process (IDP) for their specific application, medical vacuum (MV) being an example of this
- similarly changes in technology rendering surgical air not being required as a centrally piped system
- 'never-event' investigations and subsequent research by the National Patient Safety Agency has determined that medical air has limited clinical applications and is now not a preferred installation requirement due to numerous sub-optimal outcomes and fatalities from rebound hypoxia when it has been administered instead of oxygen
- the continued use from a non-anaesthetic perspective of piped nitrous oxide and oxygen for dental sedation and pain management. This will include pre-mixed 50%/ 50% (oxygen/ nitrous oxide) gas mixtures such as, Entonox or Equanox
- The lessons learned from the COVID-19 pandemic in respect of acute respiratory care, respiratory medicine and practices for oxygen supply sources and distribution systems

"Primo Nil Nocere"- First do no harm

"First do no harm" is part of the Hippocratic Oath and it is globally accepted for healthcare professionals as part of the creed for caring and nurturing human beings.

In the wider context of healthcare, the actions and services we use to treat patients should not damage the environment which we inhabit, otherwise we are breaching that first tenet of the Hippocratic Oath.

There is a global climate crisis, and society is awakening to the need for net-zero carbon and zero E. Healthcare is very energy and carbon intensive in its construction, operation and treatment therefore the basic principles of net-zero in our design construction and operation must be embraced to limit this and do no harm to the planet on which humanity depends upon.

Patient safety and resilience is key to the provision of health care buildings, facilities and the environments in which care is given. This has been paramount in design guidelines from the pre global crisis era.

Current guidance has tended to oversize and oversupply services and provision of utilities, medical gas supply systems being a key example of this. Guidance tables and algorithms provided within previous revisions of SHTM 02-01 Part A included large margins of supply source capability and over provision of terminal units and gas flowrates due to historic design criteria that did not match modern clinical application. This results in high capital expenditure, high operational costs of maintenance, electrical energy to drive the devices, and the embodied carbon in the construction materials, fittings and equipment that are not necessarily required.

The pitfalls of overdesign and oversupply of medical gas systems were realised during the COVID-19 pandemic when the poor understanding of supply systems and associated equipment led to difficulties with the supply of oxygen for acute respiratory care. Whilst there was sufficient oxygen available at healthcare facilities, the distribution and application/ administration for treatment was far from straightforward or understood and this raised questions of competences and communication within specialities/ disciplines and organisations as a whole.

A key requirement throughout this document suite is that of competency and the ability to be able to demonstrate the Knowledge, Skills and Behaviours (KSBs) required to perform the relevant functions within the overall design and management of medical gas pipeline systems (MGPS) and supply sources in a suitable and sufficient manner. Crucial to this has been the development of a National NHS Education for Scotland (NES) supported educational training framework in Scotland based on specific National Occupational Standards (NOS) (created from the recommendations of the Healthcare Safety Investigations Branch (HSIB) report into oxygen use during the pandemic) for all the designate person disciplines identified within the MGPS speciality area.

Competency at all levels has been the cornerstone of many recent public inquiry outcomes and this area is soundly addressed within the new suite of guidance from the conceptualisation stage as an IDP, to the competent person installing, maintaining and testing these systems for safe, efficient use for patient therapy.

Status

This 2025 version of SHTM 02-01 Part A supersedes all previous versions of SHTM 02-01 Part A 'Medical gas pipeline systems - Design, installation, validation and verification'.

General

This SHTM is divided into two parts. Guidance in this part (Part A) covers piped medical gases and MV installations. It applies to all MGPS installed in healthcare premises. Anaesthetic gas scavenging disposal systems are also included. Specifically, it covers the design, installation, and validation and verification (testing and commissioning) of a MGPS. Part B covers operational management.

Aim of this guidance

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 an IDP prior to installation. The IDP should be undertaken as described in Section 1 of this document. This process is risk-assessment based in accordance with British Standards (BS) EN International Standard (ISO) 7396-1 and BS EN ISO 14971.

Existing installations should be assessed for compliance with this guidance document based on risk in accordance with BS EN ISO 14971 and the IDP risk assessment. The standard of safety should be to the same level that is given in this document. A plan for upgrading the existing system should be prepared if required, taking account of the priority for patient safety.

Throughout this document, ‘medical gas pipeline system(s)’ will be described by the term MGPS.

Other guidance

Guidance on the provision of MGPS is given in the Scottish Health Planning Notes (SHPNs), Health Building Notes (HBNs) that are applicable in Scotland and other relevant British, European, and international standards. Other guidance should be referred to as appropriate including British/ European/ International standards as well as guidance produced by such bodies as the British Compressed Gases Association (BCGA) and the European Industrial Gases Association (EIGA).

Who should read this guidance?

This document will be of interest and practical help to those involved in the design, installation, validation and verification of MGPS and equipment.

Main changes since the 2012 edition

The 2025 edition is an update to the previous version of SHTM 02-01 Part A as published by NHS Scotland. Key changes in this SHTM include:

A. this guidance is now a comprehensive design document for an informed design. It is no longer based on ready reckoners and algorithms from outdated clinical practice and technical standards
B. it now aligns with all relevant national and international standards
C. It embraces national guidance and statutory requirements for net-zero carbon targets, reduction of embodied carbon, and reduction of global warming potential (GWP) emissions
D. it incorporates the outcome requirements from the HSIB investigation and International Standard (ISO) Thermal Conductivity (TC) 121 into oxygen use during the Covid-19 pandemic
E. Section 7 of SHTM 02-01 Part B utilises the new NOS for the designated roles within the MGPS management structure that are incorporated with NES
F. there is a comprehensive guided risk assessment process based on the ‘well-reasoned argument’ (WRA) approach
G. inhalation sedation (IS) for dental procedures and pain management guidance has been included

The four tenets of gas safety

Patient safety is paramount in the design, installation, commissioning and operation of MGPS. 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 source is sufficient to provide the required flows of gases and vacuum for the intended number of patients to be treated at any one time. The adequacy of supply is established during the IDP and validated during the 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 the application of a safe system of work 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 source supply system. Systems are also connected to the safety power 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.

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. The Responsible Pharmacist has overall responsibility for ensuring the quality of the supply gas to ensure patient safety is not compromised.

General uses of gas and pipeline installations

The general uses of medical gases and pipeline installations are described as:

- 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. Changes in clinical practice due to the occurrence of ‘Never-Events’ has

resulted in revised methods of administration for nebulised and inhaled medication. This has much reduced use of medical air from flowmeters

- piped and cylinder nitrous oxide is used for sedation and analgesic purposes, being mixed with oxygen in a localised blender for dental sedation and pain management applications. Pipeline systems for a 50% mixture of oxygen and nitrous oxide are installed for analgesic purposes, particularly in maternity departments
- vacuum is provided in clinical areas where oesophageal aspiration is an identified risk. The IDP will determine the most effective supply source for the vacuum by risk assessment
- the control of occupational exposure to waste anaesthetic gas (nitrous oxide) and inhalational agents is a legal requirement under the Control of Substances Hazardous to Health (COSHH) Regulations 2002. Where nitrous oxide is provided for anaesthetic or sedation purposes, scavenging systems must be considered as part of the control hierarchy

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Key NHS Scotland Assure personnel involved in the production of this updated document:

Lead Authors

Mike Ralph, Interim Head of Energy, NHS Scotland Assure

Colin McKie, Senior Engineer, NHS Scotland Assure

Editorial Team

Graham Carracher, Authorising Engineer (Medical gas pipeline systems (MGPS)), Hulley & Kirkwood Ltd

Graeme Dunn, Authorising Engineer (MGPS), Merkland Design & Engineering Consultancy Ltd

Peter Henrys, QRA Technical Manager UK, Ireland and Africa, BOC Healthcare

John Roach, Independent Cryogenic Design Engineer

Ian Sandford, Authorising Engineer (MGPS), Ian Sandford Associates Ltd

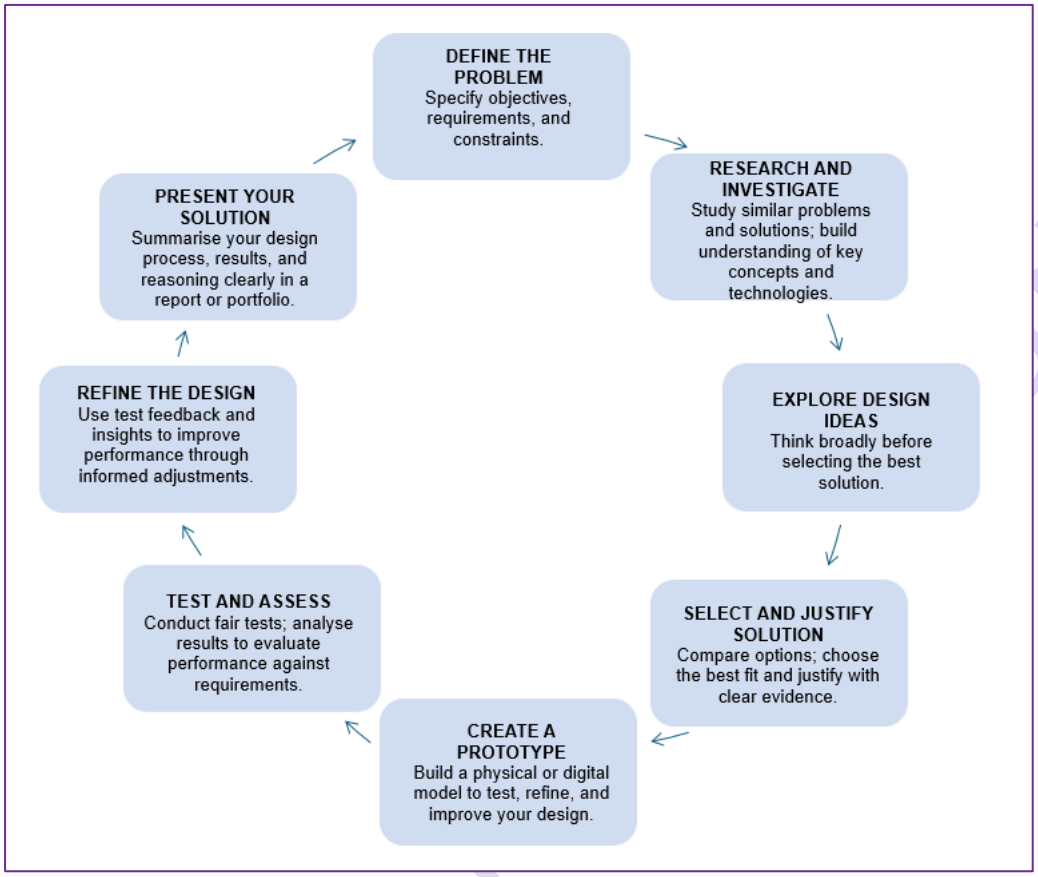
Malcolm Thompson, Authorising Engineer (MGPS), Healthcare Engineering Services Ltd

Steve Wallace, Project Manager, NHS Scotland Assure

1. Medical gas pipeline system design

The informed design process

Figure 1.1 - Informed design process



1.1. Figure 1.1 above depicts the overall informed design process (IDP) cycle. The cycle uses familiar design stage terminology. The phases are described as follows:

- clarify design specifications and constraints. Describe the problem clearly and fully, noting constraints and specifications
- research and investigate the problem. Search for and discuss solutions to solve this or similar problems. Identify related problems, issues, and questions. Complete a series of guided knowledge and skill builder activities (such as prepared templates) that will help identify the variables that affect the performance of the design and inform the teams knowledge and skill base
- generate alternative designs. Don't stop at one solution. Approach the challenge in new ways and describe alternatives
- choose and justify optimal design. Rate and rank the alternatives against the design specifications and constraints. Reflect on what is the best design; justify based upon ratings, and new learning acquired from knowledge and skill builders. The chosen alternative will guide the preliminary design

- develop a prototype. Make a model of the solution. Identify modifications to refine the design and make these modifications
- test and evaluate the design solution. Develop and carry out a test to assess the performance of the design solution. Complete or review Knowledge, Skills and Behaviours (KSBs) focused on developing a fair test. Collect and analyse performance data to show how well the design satisfies the problem specifications and constraints
- redesign the solution with modifications. Examine the design and assess other designs to see where improvements can be made. Identify the variables that affect performance and determine which clinical and engineering concepts underlie these variables. Indicate how to use engineering concepts and system modelling to enhance performance
- complete a design portfolio or design report that documents the previously mentioned steps. Justify the design solution and review against relevant risk assessment model

1.2. This is the common method for an IDP. These steps can be taken and overlaid onto the Royal Institute of British Architects (RIBA) stages template, to produce a framework which enables the identification of the relevant stakeholders and interactions. This can then be used to inform a Responsible, Accountable, Consulted, and Informed (RACI) matrix for each of the groups and put in a system of control and governance for the design and record the decisions and assumptions for the progression to completion of the project.

1.3. Whether it is an additional terminal unit, a ward upgrade or an entire new healthcare facility the principles are the same and should be followed.

1.4. The scope for the design needs to be around a common naming protocol and with the increasing use of modular design and modern methods of construction (MMC), these designs would be broken down into delivery units (DU). For a small upgrade this may only be the one or possibly two DUs. For a larger project such as a new healthcare facility project or major refurbishment this may be multiple DUs that are linked by a supply system.

Delivery Unit

1.5. The DU is a notional quantity used to describe the extents of a particular area within a project. A DU may range from an extension of a few terminal units to a ward refurbishment or new build clinical area. The scope will be defined by a particular clinical speciality group who are able to provide in depth information to the design of the medical gas needs to meet specific clinical requirements. With the drive for MMC/ standardised units and modular construction, the DU concept lends itself to strategic modelling and adjacencies for new-build hospital complexes and the ability to incorporate modern technology to aid control and delivery. The DU will connect into the medical gas supply system for the facility and at that point would be designed to have a zero pressure drop for the system at the design flow rate (if a new build) or as minimal resistance as would be obtained if an existing system/ part of infrastructure).

Supply systems

1.6. A supply system is a specific type of DU that links the delivery units together. They should follow the same protocols, principles and engineering standard to British Standard (BS) EN International Standard (ISO) 7396-1-2 and the like. ‘Business as usual’ and escalation capabilities should be risk assessed and evidenced in accordance with Annex H of BS EN ISO 7396-1 to confirm the assumptions of the IDP.

Figure 1.2 - Medical gas pipeline systems (MGPS) informed design process

RIBA Stages	Medical Gas Pipeline Systems (MGPS) Design Process			Stakeholders
1. Preparation and Brief	**Healthcare facility design development**			
	1. Determine facility function i) Confirm facility type ii) Determine clinical service delivery	**2. Facility Specifics** i) Will the facility require any specific medical gas equipment ii) Will the clinical services delivered from the facility require medical gases	**3. Medical Gas Feasibility** i) Undertake options appraisal for medical gases provision ii) If medical gases are deemed to be required, proceed to Stage 2	**Design development group 'C'**
2. Concept Design	**Delivery unit concept design**			
	1. Determine Delivery Unit requirements i) Patient cohort ii) Clinical need iii) Categorisation of delivery unit types (high, medium and low) iv) Quantity of delivery units	**2. Determine Delivery Unit Medical Gases requirement** i) The medical gas provision design process should be undertaken by a multi-disciplinary team ii) The design process should be informed based on an assessment of the clinical requirement	**3. Risk Assessment** i) A risk assessment for the provision or exclusion of each gas type should be completed ii) The risk assessment should identify if an MGPS is required ensuring the three sources of supply requirement is met iii) The risk assessment should identify the alternative medical gas provision if MGPS is not required (refer to Section 8 Part B cylinder management and configuration section) iv) If an MGPS is deemed to be required, proceed to Stage 3	**Design development group 'A'**
3. Spatial Coordination	**Delivery unit spatial co-ordination**			
	1. Determine MGPS requirements i) Quantity of bed spaces ii) Flow rates iii) Quantity of terminal units	**2. MGPS Plant and Storage requirements** i) Allowances for pipe-routes ii) Allocation for plant space iii) Additional capacity connection point locations iv) Identification of appropriate storage locations	**3. Spatial coordination** i) Equipment locations ii) Area valve service unit (AVSU) locations iii) Room layouts iv) Proceed to Stage 4	**Design development group 'A' and 'C'**
4. Technical Design	**MGPS Technical Design**			
	1. Delivery unit requirements i) Confirm function ii) Confirm and record clinical requirements and any specific therapies or activity	**2. Technical Design Development** i) Confirm medical supply unit requirements ii) Confirm locations of terminal units iii) Confirm valving arrangement iv) Confirm AVSU provision v) Confirm alarm provision and location	**3. Technical Design** i) Confirm flow rates ii) Undertake plant configuration and sizing iii) Complete pipeline design sizing iv) Undertake risk assessment of MGPS in accordance with Annex H of ISO 7396-1 iv) Issue construction information v) Proceed to Stage 5	**Design development group 'B' and 'D'**
5. Construction and Manufacture	**MGPS Installation and Equipment Manufacture**			
	i) Equipment manufactured ii) Plant and equipment acceptance tests	i) Pipeline system installation	i) Installation quality control checks	**Delivery group 'A'**
6. Handover	**MGPS Commissioning, Operation and Maintenance**			
	i) Engineering commissioning	i) QC Commissioning Testing	i) MGPS Taken into use ii) Ongoing operation and maintenance	**Delivery group 'B'**

1.7. MGPS should be designed based on an informed process. The IDP set out in Figure 1.2 follows the industry-recognised RIBA stages of design:

1. preparation and brief
2. concept design
3. spatial coordination
4. technical design
5. construction and manufacture
6. handover

The stages above align with the NHS Scotland Assure Key Stage Assurance Review (KSAR) process that is applicable to larger projects.

Note 3: The KSAR process examines projects at key points in their lifecycle. It does not remove any legal or contractual obligations from the NHS board, their designers or contractors. It provides assurance to progress successfully to the next review point, and the process will be mandated for projects requiring Capital Investment Group (CIG) approval.

KSARs focus on the assessment of the delivery approach and will work with the NHS board's project team to ensure there is comprehensive understanding of the patient cohorts utilising the facility. KSARs also ensure relevant guidance is fully implemented and any technical derogations have been fully reasoned, transparently discussed, the implications understood, recorded and signed off by the NHS board and their advisors.

With a focus on construction elements where previous reviews have demonstrated potential patient safety concerns, KSARs concentrate on water, ventilation, electrical, plumbing, medical gas installations, fire, and associated Infection Prevention and Control (IPC) guidance. If further issues are raised with the review team, they will fully incorporate those issues into the reporting process.

Further information on KSAR and the workbooks are available on the National Services Scotland (NSS) website.

Healthcare facility design development

1.8. Stage 1 of the process is where the brief of the MGPS design is prepared. This is the stage where the high-level requirements of the healthcare facility are determined. The function and specifics of the facility are confirmed, and the completion of this stage will provide an indication as to whether an MGPS will be required.

Delivery unit concept design

1.9. The concept design and the MGPS requirements for the delivery units are determined at Stage 2 of the process. It is at this stage where the first design risk assessment should be completed for the provision or exclusion of each gas type, the individual gas question sets can be used to assist (see Appendix I).

Delivery unit spatial co-ordination

1.10. At Stage 3 the spatial co-ordination of the delivery units are assessed. It is at this stage where flow rates are first established, pipe routes are considered, space for plant is allocated, room layouts are developed, and equipment provision and location(s) are coordinated.

MGPS technical design

1.11. Stage 4 is where the technical design of the MGPS is undertaken. It is at this stage where the delivery unit function, clinical requirements and flow rates are fully confirmed, equipment and pipe sizes are determined, and construction information is generated. A risk assessment for the final technical design is completed in accordance with the IDP risk assessment (refer to paragraphs 1.24 - 1.31 and Figure 1.5).

MGPS equipment manufacture and installation

1.12. It is at this stage where the physical installation works are undertaken, and the equipment specified at Stage 4 is manufactured. During Stage 5 the quality control checks (see Section 11) are undertaken during manufacture and installation. The risk assessment completed during Stage 4 should be reviewed and updated during Stage 5.

Commissioning and handover

1.13. Stage 6 is the final stage of the cycle where engineering and quality control commissioning checks are completed (see Section 13). It is at this stage where the installation contractor or project team handover the MGPS for operational use to the healthcare facility.

Stakeholders

1.14. The stakeholders who are involved in the IDP differ at each stage. The stakeholders are divided into design and delivery groups. The table below shows which stakeholders are required to be involved at each stage.

1.15. Design development group 'A' is typically made up of:

- Users (clinical staff)
- Authorising Engineer (MGPS)
- Lead Designated Clinical Officer (DCO)
- Anaesthetist
- Intensivist/ Respiratory therapy lead
- Nursing (Specialism)
- Estates and Facilities
- Pharmacy
- Biomedical/ Clinical Engineering

1.16. Design development group 'B' is typically made up of:

- Medical Gas Safety Group members

1.17. Design development group 'C' is typically made up of:

- Client Project Team
    - Clinical Lead (Nursing)
    - Clinical Lead (Medicine)
    - Project Manager
    - Director Of Estates and Facilities
    - Healthcare Planners
    - Architect
    - Finance Representative
- Project Design Team
    - Architect
    - Mechanical and Electrical Consultants
    - Project Manager

1.18. Design development group C should liaise and coordinate with other stakeholder groups as defined in the project RACI matrix which will vary with project scale and complexity.

1.19. Design development group 'D' is typically made up of:

- Mechanical and Electrical Consultants

- MGPS Designers
- Medical Gas Suppliers
- MGPS Equipment Manufacturers

1.20. Delivery group ‘A’ is typically made up of:

- Contract Supervising Officer (CSO)
- MGPS Installation Contractors
- MGPS Equipment Manufacturers
- Authorising Engineer (MGPS)

1.21. Delivery group ‘B’ is typically made up of:

- MGPS Installation Contractors
- MGPS Equipment Manufacturers
- Authorising Engineer (MGPS)
- Authorised Person (MGPS)
- Quality Controller (MGPS)
- Lead DCO

1.22. Table 1.1 details the recommended stages where the appropriate design development and delivery groups should be involved in the IDP.

Table 1.1 - IDP Stakeholder involvement

Stakeholders	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Design development group ‘A’		✓	✓			
Design development group ‘B’				✓		
Design development group ‘C’	✓		✓			
Design development group ‘D’				✓		
Delivery group ‘A’					✓	
Delivery group ‘B’						✓

Design overview

1.23. Once an initial brief is received for a delivery unit configuration, the requirement for MGPS can be assessed using the relevant question set templates. The process of the informed

design can be followed with the aid of the master control sheet (MCS). This enables the basic flowrate information to be assessed, any supply source requirements interrogated, and the peak and average continuous demand established. This leads on to Stage 3 where the spatial arrangement information and any additional major incident escalation requirements or major incident immediate action's give layout information and pipe length estimations for sizing and pressure drop. This and the final clinical briefing leads to the Stage 4 final technical design and then the IDP risk assessment.

Master control sheet

1.24. The MCS is the primary control document for the IDP before the final risk assessment is completed. It is an aide memoire for the process and a signpost to the additional design resource such as the individual gas question prompt sheets, it's use for all projects, no matter how large or small will give a clear trail for the key lines of enquiry providing a 'Claims, Argument, Evidence' basis for the design proposition. For some minor designs, with limited design stakeholder groups it may, in proportion, be enough to satisfy the safety risk and reliability requirements for the Medical Gas Safety Group. An example of the MCS is provided in Figure 1.3 and Appendix J .

Figure 1.3 - Master control sheet

Objective	Category	Design Requirements	Design Criteria	IDP Stage Checked					
				Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Quantity	Pipeline system	Determine use in each Delivery Unit	Complete gas design question-set (O2, N2O, O2/N2O, MA4, SA7, Vac)	Yes	Yes	Yes	Yes	Yes	Yes
			Area/ Department type (Theatre/ ITU/ Respiratory)						
			Number of beds/ theatres/ cots						
			Clinical/ Treatment Procedures						
			Point of use flow and pressure requirements						
			Equipment and equipment flows: Ventilators/ CPAP/ oxygen high-flow therapies						
			Does flow rate require MGPS						
			Changes in use to area – decant and the like						
			Patient cohort type						
			Pendants/ Bedhead Units						
	Sources of supply	Size and capacity of supply source	Supply system flow capacity to be established						
			Confirm expected design flow – Average continuous demand and peak demand flow rates						
			Determine type of supply system to meet the peak demand flow (ACD??)						
			Does flow rate require MGPS						
			Are there any extensions/ expansions planned						
		Supply system types	To meet the total system peak flow design capacity						
		Additional supply – examples include pandemic preparedness, major incident	Strategically located Inlet ports						
Continuity and Identity	Sources of supply	Configuration	Three sources of supply						
			Primary and secondary supply located separately (VIE)						
		Location	To prevent mechanical damage to the installation						
			Appropriate vehicle delivery access						
			Meet the required safety distances						
			Meet ventilation requirements						
			Allow safe unhindered access						
			Safe storage						
		Additional emergency supply provisions – tertiary manifolds (ERM's)	Continuous supply to critical care areas in the event of a supply or pipeline failure						
	Pipeline system	Emergency inlet ports	Strategically located Inlet ports						
			Ring main system						
			Future extensions/ expansions						
			Impact on existing services						
Quality	Sources of supply and pipeline system	Engineering commissioning and testing and Pharmaceutical QC checks	Refer to Section 14 and Appendix						

Signature _____ Date _____

IDP Risk assessment

1.25. The IDP risk assessment process follows the requirements for safety, reliability and risk (SRR). The process mirrors the system outlined in BS EN ISO 7396-1 annexe H which is based upon the risk management in accordance with ISO 14971 (both of which may also be considered in the assessment). The assessment process outlined here, is based around that of foreseeability and proportionality rather than consequence and probability matrices and will give a well-reasoned argument (WRA) as its form of summation.

1.26. Potential hazards need to be evaluated at all stages of the IDP, from design, installation and commissioning through to operational management, maintenance and disposal.

1.27. The foreseeable hazards that would need to be considered should include as a minimum but not be limited to:

- patient safety hazards including:
  - discontinuity of supply
  - incorrect pressure and/ or flow
  - wrong gas supply
  - gas composition out of specification
  - contamination
  - leakage
  - fire
- electromagnetic energy
- hydraulic/ pneumatic energy
- chemical/ physical energy
- acoustic energy
- mechanical energy (potential energy, moving parts)
- chemical compatibility
- biocompatibility
- interface with users
- software
- loss of utilities (for example electricity, water, coolant)

1.28. These hazards would require to be evaluated against their potential impact on all relevant persons involved in the process including but not limited to, clinical or medical users, patients and visitors and other technical staff who are working with medical devices that utilise these gases or services.

1.29. The WRA has been developed as a means of demonstrating that risks have been reduced to as low as reasonably practicable (ALARP). It is structured on the principle of 'Claims, Argument, Evidence' and should be as objective as practicable, describing the incident scenarios, the possible risk reduction measures (RRM) which have been employed or rejected and why. The arguments should be logical and scientific together with any relevant data on the system or its components. It should show that the duty holder has done all that is reasonably practicable to understand the complexities and sociotechnical nature of the hazardous system. It should minimise and justify any assumptions or omissions.

1.30. This does not mean that all WRAs are comprehensive reports, or that they will even be necessary. If all the hazards are generic and all possible RRMs have been adopted, there may be no need for a WRA.

1.31. It is not possible to state precisely the level of detail required in a WRA, but the Proportionality Matrix assists in providing broad guidance, including what level of studies may be necessary, as shown in Figure 1.4 below.

Figure 1.4 - The proportionality matrix

		Typical Requirements for a Proportionate Risk Analysis			
		No assessment	Identify Hazards, Apply Good Practice, Guidance, Standards, & Hierarchy of Controls (Note 1)		
				Identify Initiating Mechanisms/ Failure Modes & Barrier Flaws (Note 2)	
					Identify Causes & Performance Influencing Factors (Note 3)
Worst Reasonably Foreseeable Consequences		A	B	C	D
Single injury or health effects	1				
Single fatality or chronic health effect, or multiple injuries	2				
Multiple fatalities or chronic health effects	3				

Key:

- Not acceptable
- May be proportionate if the system has:
  - no foreseeable potential for further risk reduction or it would be grossly disproportionate, and/ or
  - low complexity (all variables and their effects are apparent).
- Proportionate

Note 4: Hazard: Any reasonably foreseeable object, material, energy, situation, action, reaction, or behaviour that has the potential to cause harm, for the purpose of preventing it, or mitigating the risk, for example, overload, aircraft stalls while turning onto final approach, collision, radiation, flammable material, sharp edge on chef's knife, poisoning, explosion.

Note 5: Initiating Mechanisms/ Failure Modes provide more detail to a hazard source, such as intergranular corrosion, flying too slowly, failed seat belt, no electrical isolation, exceeding design limits. Depending on the nature and complexity of the system, this could justify some specialist study work.

Note 6: Causes and Performance Influencing Factors (PIF), such as incorrect valve position, human factors/ error, procedures, training, communications, software error, design error. Studies, such as Systems Theoretic Process Analysis (STPA), Hazard and Operability (analysis) (HAZOP), bow ties, Task Risk Analysis (TRA), Safety Critical Task Analysis (SCTA), and ergonomics may need to be considered and justified if not undertaken.

1.32. Importantly, if correctly applied the Proportionality Matrix is legally defensible, whereas risk matrices are not. When applied to the IDP it should endeavour to mitigate in the control hierarchy of inherently safe design, protective measures in applications and devices or by sociotechnical modelling and safety information. Figure 1.6 identifies key lines of enquiry but is not an exhaustive list. Other references and ISO 14971 may also be consulted as per individual IDP requirements.

Figure 1.5 - MGPS key lines of enquiry for a well reasoned argument

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Blockage/ partial blockage of the pipeline	Loss or reduction of supply to patient	• Flow and pressure drop tests at every terminal unit before use	Delivery Group B
Continuity of supply	Loss of supply from the supply source in operation	• System supplied from the reserve/ emergency source if primary source fails • Loss of supply to patient if all systems fail	• Ensure reserve and emergency supply sources are included in the layout design of the supply source • Ensure reserve and emergency supply sources are included in the capacity and location of the supply sources	Design Development Group A
			• Stock Management system established • Preventative maintenance system set up for each source of supply • Operational procedures established to handle cylinders for emergency situations to ensure supply continuity • Procedures established to minimise use in emergency situations • Operational Management Document to address failure of supply	Design Development Group B
			• Routine testing of the reserve and emergency sources of supply to ensure they will function when primary source fails • Routine testing of the alarm system	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Catastrophic failure of the pipeline	Total loss of supply to the patient	• Design of pipework route to limit areas of high risk to the pipeline • Identify location of pipeline routes. Use suitable markers to indicate presence • Location of the sources of supply relative to the usage areas • Back-feed protection for ring main designs	Design Development Group A and C
			• Design of pipework routing to limit pipework corrosion • Design of supply source installation to prevent mechanical damage to the installation • Support pipework to provide adequate support/ protection and to limit corrosion • Component design with direct contact with the pipeline to be compatible to minimise electrolytic corrosion • Earthing of pipeline system to limit electrolytic corrosion • Check installation for pipework protection in high-risk areas	Design Development Group B and D
			• Permit to Work system • Use of emergency manifold systems local to the usage points • Use of emergency inlet points at Area Shut Off Valves • Routine testing of the alarm system	Delivery Group B
			• Emergency plans for areas with high dependency patients • Operational Management Document addresses issues of pipeline supply failure	Design Development Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Inadequate/ poor capability of the gas supplier	• Late delivery of liquid or cylinder gases • Supplier not capable to deliver product in an emergency • Supplier insufficient stocks of cylinders or tanker too small	• Location of cylinder storage areas	Design Development Group A and C
			• Selection of gas supplier using risk management principles • Adequate stock management and reordering systems established • Number of cylinders held on site • Emergency plan • Routine review of delivery planning requirements • Operational Management Document addresses issues of supply failure	Design Development Group B
			• Appropriate sizing of the storage tank • Use of Telemetry on storage tanks	Design Development Group D
			• Capability to change cylinders on manifold with trained personnel	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Poor supply source location/ housing	• Mechanical damage to the supply source leading to loss of supply • Supply source affected by incident involving an adjacent facility • Potential damage to other sources of supply • Eventual failure of the supply source • Access blocked to all sources of supply leading to loss of supply	• Review risks associated with two sources being located adjacent to each other	Design Development Group A and C
			• Ensure separation distances follow national regulations/ guidelines • Site procedures to maintain access to supply sources • Routine review of supply source design of location to ensure system remains safe.	Design Development Group B
			• Ensure that plant rooms and manifold rooms have adequate temperature control and ventilation. • Adequate physical protection from mechanical damage • Clear signage to • maintain delivery areas kept clear	Design Development Group D

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Failure of Alarms	Alarm condition not detected	• Operational Management Document addresses issues of alarm failure	Design Development Group B
			• UPS electrical supply to ensure continuity of electrical supply to alarms	Design Development Group D
			• Connect alarms to the emergency electrical supply to ensure continuity of electrical system	Delivery Group A
			• Visual mechanical display of the critical parameters • Routine testing of the alarm system • Routine review of the alarm system	Delivery Group B
Continuity of supply	Electricity supply failure	Failure of operation of electrical components potentially leading to loss of supply	• Operational Management Document addresses issues of electrical supply failure	Design Development Group B
			• UPS or emergency electrical supply to ensure continuity of electrical system • Check capacity of the emergency electrical supply	Design Development Group D
			• Routine testing of the emergency electrical supply • Procedure to ensure that all components are restored to an operational condition following reinstatement of the power supply	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Continuity of supply	Component failure	Potential for the loss of supply with failure of critical components	• Operational Management Document addresses issues of critical component failure	Design Development Group B
			• Review and identification of critical components • Specific preventative maintenance for critical components • Specification for the critical components from approved suppliers • Alarm systems checked to ensure that failure of critical components detected • Adequate spares/ redundancy for critical components	Delivery Group B
Continuity of supply	Failure of the maintenance system	Potential failure of components and subsequent failure of supply system	• Operational Management Document addresses issues of critical component failure	Design Development Group B
Continuity of supply	Supply failure to areas of high dependency patients	High risk to patient with failure of supply	• Identification of areas of high risk • Review of emergency supply systems to high-risk areas • Operational Management Document addresses issues of critical component failure	Design Development Group B
			• Design of system to provide higher levels of redundancy of critical components	Design Development Group D
			• Alarm systems checked to ensure that failure of critical components detected	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
System Performance	Incorrect design/ specification of components and pipeline systems	Inadequate supply to the patient	• Provide usage information • Operational Management Document addresses periodic checks of usage	Design Development Group B
			• Correct design of components/ pipework based on usage information • Design validation in accordance with Section 13	Design Development Group D
			• Commissioning checks following installation	Delivery Group B
System Performance	Inadequate corrosion protection of pipework/ components	Failure of pipework/ components. Leakages. Collapse of supports	• Operational Management Document addresses periodic inspection and maintenance of MGPS	Design Development Group B
			• Correct design/ protection of pipework/ components	Design Development Group D

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
System Performance	Failure of pressure control – high pressure	High pressure at the terminal unit.	• Operational Management Document addresses periodic testing and maintenance of relief valves • Operational Management Document addresses periodic checks of high-pressure alarm systems • Operational Management Document addresses periodic inspection and maintenance of pressure regulators • Operational Management Document addresses checks of equipment used on MGPS rated to a suitable pressure to cope with failure of pressure control system	Design Development Group B
			• Correct design of pressure relief valves to protect against component failure • Correct design of high-pressure alarm system to indicate high pressure condition	Design Development Group D
System Performance	Failure of pressure control - low pressure	Low pressure at terminal unit leading to low flow conditions	• Operational Management Document addresses periodic checks of low-pressure alarm systems • Operational Management Document addresses periodic inspection and maintenance of pressure regulators	Design Development Group B
			• Correct design of low-pressure alarm system to indicate low pressure condition	Design Development Group D

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
System Performance	Incorrect design / specification of sources of supply	Failure of supply. Inadequate supply to pipeline.	• Provide usage information • Operational Management Document addresses periodic checks of supply source installation, layout and access. • Operational Management Document addresses periodic checks of usage to review the supply source capability	Design Development Group B
			• Correct design/ size of supply source based on usage information and supplier's capabilities/ contractual arrangements • Design validation in accordance with Section 13	Design Development Group D
			• Commissioning checks following installation	Delivery Group B
System Performance	Leakage from pipework	• Potential fire risk. • Potential risk of asphyxiation • Potential risk of high concentrations of gases. • Potential inadequate/ reduced supply to terminal unit.	• Operational Management Document addresses periodic checks for leakage from pipeline • Operational Management Document addresses periodic maintenance of pipeline	Design Development Group B
			• Commissioning of the system	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Quality of Gas supplied to patient	Wrong specification supplied to the supply source	• Gas delivered or manufactured on site not to the specification. • Gas supplied to the patient not to the correct specification. • Wrong cylinders / mobile cryogenic tanks supplied / connected to the manifold	• Certified product supplied by gas supplier • Correct contractual arrangements with the gas supplier • Operational Management Document to identify the Pharmacist/ QC responsibilities. • Correct design of gas mixing/ manufacturing processes run on site • Commissioning of gas mixing/ manufacturing processes run on site • Operational Management Document to identify correct maintenance of gas mixing/ manufacturing processes run on site • Operational Management Document to identify correct testing of gas mixed/ manufactured on site • Operational Management Document to specify the correct procedures for connecting supply source to manifold • Operational Management Document to review quality requirements for gases supplied on site	Design Development Group B
			• Check the correct connections on the manifold tailpipes (gas specific where possible) • Check that the correct labels are fitted to terminal outlets and Area Shut Off Valves • Check that the correct signs are fitted to manifold rooms, cryogenic tanks and medical gas cylinder stores • Check pipelines are marked for the correct gas	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Quality of Gas supplied to patient	Contamination of gases	• Gases contaminated by components not cleaned to an appropriate standard • Cleaning material left in component and pipework • Post construction purging not completed • Contamination from compressors/ vacuum pumps/ oxygen concentrators	• Operational Management Document to identify correct cleaning procedures and testing requirements • Operational Management Document to identify correct maintenance of gas compressors/ vacuum pumps • Operational Management Document to identify correct testing procedures medical air supplies for all potential contaminants	Design Development Group B
			• Correct procedure and specification of the cleaning pipework and components • Correct procedure for validating cleanliness of components used within the MGPS	Delivery Group A
			• Correct testing procedures identified to demonstrate that conditioning systems are operating correctly • Commissioning of the MGPS to ensure the correct cleaning/ purging standard	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Quality of Gas supplied to patient	Excessive particulate in MGPS	• Blockage of filters used on delivery equipment leading to reduced flow. • Failure of components (regulators and the like). • Leakage of components	• Operational Management Document to identify correct filter cleaning/ replacement procedures and testing requirements for MGPS filters • Operational Management Document to identify correct filter cleaning/ replacement procedures and testing requirements for medical device filters connected to the MGPS • Operational Management Document to identify correct maintenance of filters	Design Development Group B
			• Correct procedure and specification of the cleaning pipework and components and for checking filters after commissioning • Correct testing procedures identified to demonstrate that filters are not blocked (and that there is not excessive particulate in system)	Delivery Group B
Quality of Gas supplied to patient	Ignition/ decomposition of components used in the MGPS	• Toxicity gases released in the gas stream	• Operational Management Document to ensure that all replacement parts used on the MGPS are in compliance with ISO 15001	Design Development Group B
			• Check that all components used are in compliance with ISO 15001	Delivery Group A

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
Quality of Gas supplied to patient	Back-feeding of gases within an MGPS	• Potential loss of supply to the patient. • Potential contamination of the supply source or the gas supplied to the patient	• Operational Management Document to identify correct testing and maintenance of backflow protection devices and differential pressure settings	Design Development Group B
			• Correct design of the MGPS to prevent back-feeding of product	Design Development Group D
			• Commissioning checks to demonstrate performance of any backflow protection devices or differential pressure settings	Delivery Group B
Quality of Gas supplied to patient	Cross connections between MGPS	• Contamination of the supply source or the gas supplied to the patient	• Operational Management Document addresses control of cross contamination when system is modified/ extended	Design Development Group B
			• Correct design of MGPS to prevent cross connections	Design Development Group D
			• Commissioning of MGPS to demonstrate no cross connections	Delivery Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
System Operation	Incorrect operation or maintenance of the MGPS	• Wrong quality of gas/ vacuum supplied to the patient. • Failure of supply to the patient	• Define the correct operational procedures for each section/ component of the MGPS • Define responsibilities for all associated staff/ users of the MGPS • Define training requirements for all associated staff/ users of the MGPS • Operational Management Document to specify the need to assess competency of all associated staff/ users of the MGPS and specify the retraining requirements. Recording of training	Design Development Group B
			• Ensure all Area Shut Off Valves, control panels, alarm panels are located in an appropriate location and correctly labelled	Delivery Group A
			• Train all associated staff/ users of the MGPS	Delivery Group B
System Operation	Insufficient resources to operate and manage the MGPS	• Wrong quality of gas/ vacuum supplied to the patient. • Failure of supply to the patient	• Review the manning requirements for safely operating the MGPS (in and out of normal working hours) • Operational Management Document to specify the need to review manning requirements on a regular basis	Design Development Group B

Risk Category	Foreseeable Hazards	Performance influencing Factors	Risk Reduction Measure (RRM)	Responsibility and review by
System Operation	Inappropriate action taken in the event of an emergency condition with the MGPS	• Wrong quality of gas/ vacuum supplied to the patient. • Failure of supply to the patient	• Define the correct procedures for the operation of MGPS in an emergency condition • Define emergency training requirements for all associated staff/ users of the MGPS • Operational Management Document to specify the need to assess competency of all associated staff/ users for emergency operation of the MGPS and specify the retraining requirements. Recording of training	Design Development Group B
			• Provide emergency training for all associated staff/ users of the MGPS	Delivery Group B

2. General requirements

Introduction

2.1. A Medical gas pipeline system (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 (MV) can be provided by means of a pipeline system if it is the most appropriate solution identified during the informed design process (IDP) (see Section 1). Anaesthetic gas scavenging disposal systems are provided to control occupational exposure to waste anaesthetic gases and agents.

2.2. Dental compressed air and vacuum systems have differing requirements and are not specifically covered in this guidance. However, the IDP can be applied with relevant question sets that are determined from specific dental application guidance such as British Dental Association (BDA), The Society for the Advancement of Anaesthesia in Dentistry (SAAD) and the Scottish Dental Clinical Effectiveness Programme (SDCEP). Further advice is contained in SHTM 02-01 Supplement 1: 'Dental compressed air and vacuum systems'.

2.3. 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).

2.4. MGPS should only be used to supply medical gases for clinical applications. Consideration can be given to the use of MGPS where a university theatre or room teaching medical procedures forms part of the healthcare facility.

2.5. 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 (SHTM) 08-06 refers and British Compressed Gases Association (BCGA) Code of Practice (CP) 4 provides further information.

Quality requirements for medical gases and air

2.6. 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.

2.7. 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 K.3. The medical air and synthetic air should also comply with the appropriate sections of the current edition of the Ph. Eur. (see Table K.3).

2.8. 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 K.3. Information on testing procedures is given in Section 13 and Appendix K .

2.9. 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.

2.10. 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 Section 13.

Sources of supply

2.11. British Standard (BS) EN International Standard (ISO) 7396-1 (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.

2.12. With respect to individual banks of a cylinder manifold installation, this SHTM refers to separate banks of an automatic manifold as primary and secondary supplies as prescribed within BS EN ISO 7396-1. This SHTM will classify an automatic manifold as a single source of supply, when used as a back-up for liquid oxygen, medical and surgical air systems.

2.13. 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.

2.14. 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 the IDP. Table 2.1 - 2.9 describe the various options for gas supply. For each, the primary, secondary and reserve sources are identified.

Table 2.1 - Compressed gas cylinder manifold systems

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 the IDP.

Table 2.2 - Bulk liquid oxygen Vacuum Insulated Evaporator (VIE) systems

Primary supply	Secondary supply	Reserve supply (third source of supply)
Simplex VIE 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 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) Note 7: 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	Type and capacity of supply to be determined by the IDP. (May not be required when remote dual supplies are connected to a ring main or to a mains (linked) pipeline distribution system.) Note 8: a ring main or distribution pipeline is not regarded as a reserve supply (third source of supply)

Primary supply	Secondary supply	Reserve supply (third source of supply)
	systems should be fitted with appropriate non-return valved connections to prevent gas loss in the event of one tank/ system failing.	

Table 2.3 - Liquid oxygen cylinder system

Primary supply	Secondary supply	Reserve supply (third source of supply)
Liquid cylinder or liquid cylinder manifold system Note 9: 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 2.4 - PSA plant

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 the IDP

Table 2.5 - Compressor-driven medical air systems

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 the IDP
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 2.6 - Synthetic air plant

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 the IDP

Table 2.7 - Combined medical/ surgical 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 (4bar) (MA4) system one dedicated to support surgical air (7bar) (SA7) system All to come on-line in the event of plant failure Type and capacity of supply to be determined by the IDP
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 Emergency Reserve Manifolds (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 2.8 - Compressor-driven surgical air systems

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 the IDP	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 2.9 - Central medical vacuum 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

Note 10: Notes to Table 2.1 - Table 2.9: General guidance on vacuum systems is contained in Section 8.

a. where duplex vacuum plant is currently installed, the system should be reviewed in line with Section 8 and the requirements determined during the IDP

b. 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

c. all plant is to be connected to circuits on the safety power supply

d. for vacuum provision during total electricity supply failure, cylinder - or medical-gas-system-powered vacuum generators can be used

e. 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) is used to protect the system from failure of either manifold

f. locations of manifolds supporting medical air and PSA systems should be determined by the IDP. Appropriate backflow protection should be provided, as above

g. a valved by-pass arrangement around compressor and VIE-plant non-return valves must be provided to facilitate valve replacement or servicing of the non-return valve to avoid disruption to the service without plant shutdown

h. 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

Design information for gas supply sources

Key lines of enquiry

2.15. Sizing of VIE systems, liquid cylinder storage systems, PSA plant and synthetic air plant should be based on historical consumption data, the IDP and appropriate risk assessments carried out with the medical gas supplier. 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 or for those of the existing cohort that the new facility will accommodate.

2.16. 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 C provides a conversion table for various units of measurement that may be encountered.

2.17. There are several aspects of gas flow to consider when completing the IDP for MGPS:

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)
2. the typical flow required at each terminal (this is the maximum flow likely to be required at any time in clinical use)
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 calculated flows to all similar departments and wards, plus individual or dissimilar departments

2.18. The pipeline system should be designed so that the flows determined during the IDP can be achieved at each terminal unit: the flows are expressed in free air. Peak and average flow rates will be calculated during stage three of the IDP. Pipe size selection shall be based on peak flow rates in normal use with the supply source sizing based on average continuous demand. Pandemic/ escalation alternative supply sources and peak demand shall be in line with procedures set out in BS EN ISO 7396-1 Annex H.

Note 11: When considering average continuous demand 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.

2.19. For existing systems and refurbishments, 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 vacuum, this should be 50mmHg pressure loss.

2.20. For delivery units (DUs) designed under an IDP, the pressure drop should be designed to be zero at the DU connection point under peak flow conditions.

Terminal unit flows

2.21. At the appropriate design stage during the IDP, the project team should define the individual room/ space requirements. Delivery units may comprise several ward units, treatment rooms and other spaces. At stage three of the IDP, the nomenclature for each clinical space should be clearly defined so that the appropriate gas flow requirements can be established during that stage.

Pipeline flows

2.22. 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.

2.23. The design of the pipework system is based on the IDP flowrates 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 meets the requirements of the IDP.

2.24. Table 2.10 provides indicative values for discussion during the IDP.

Table 2.10 - Gas flow - flows required at terminal units

Service	Location	Nominal pressure (400 kpa)	Design/ test flow (Litres/ min)	Typical flow required (Litres/ min)
Oxygen	Operating rooms and anaesthetic rooms in which Nitrous Oxide (N_2O) is provided for anaesthetic purposes	400	50	20
Oxygen	Continuous positive airway pressure (CPAP)	400	75	30
Oxygen	All other areas	400	25	6
Nitrous oxide	All areas	400	15	6
Nitrous oxide/ oxygen mixture	Labour, delivery, recovery, post-partum (LDRP) rooms	400[(a)]	275	20
Nitrous oxide/ oxygen mixture	All other areas	400	20	20
Medical air 400kpa	Operating rooms	400	40[(b)]	40
Medical air 400kpa	Critical care high dependency units (HDUs)	400	80[(b)]	80
Medical air 400kpa	Neonatal	400	40	40
Medical air 400kpa	Other areas	400	20	10[(b)]

Service	Location	Nominal pressure (400 kpa)	Design/ test flow (Litres/ min)	Typical flow required (Litres/ min)
Vacuum	Operating rooms and endoscopy	400mmHg - 47 kPa absolute (53 kPa below atmospheric pressure). All further figures will be in 'below atmospheric pressure'	40	40
Vacuum	All other areas	400mmHg – 47 kPa absolute (53 kPa below atmospheric pressure). All further figures will be in 'below atmospheric pressure'	25	5-10

Note 12: Notes applicable to Table 2.10:

a for nitrous oxide/oxygen mixture the pressure at the intermittent patient demand regulator should not be less than 310 kPa

b these flows are for certain types of gas-driven ventilators under specific operating conditions, and nebulisers and the like

c 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.

Oxygen

In-patient accommodation

2.25. 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 2.11, in case nebulisers or other respiratory equipment are used.

2.26. In post-anaesthesia recovery, it is possible that all bed spaces may be in use simultaneously.

2.27. In critical care, coronary care and high-dependency units, the flowrate should assume that all bed spaces may be in use simultaneously.

2.28. Most modern ventilators are servomotor operated or pneumatic. Oxygen should not be used as the driving gas for gas-powered ventilators if they are capable of being powered by medical air.

2.29. If under escalation procedures, 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 cognisance of during the IDP. 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. Consideration should be given to installation of systems to warn of ventilation failure and oxygen concentrations above 23%.

Maternity

2.30. For LDRP rooms, the flow can be based upon 10 litres/min for all terminal units. Two cot spaces may be provided, each with a terminal unit. Only one will be considered to be in use.

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

2.32. 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.

Hyperbaric oxygen chambers

2.33. 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. The individual design and operating procedures for hyperbaric chambers varies greatly. The equipment supplier should be consulted at Stage 2 of the IDP as individual clinical teams may not have the relevant experience of the design requirements for this type of equipment. This type of therapy can use large quantities of oxygen for sustained periods, a typical example of flows for a single patient chamber are as shown in Table 2.11.

Table 2.11 - Gas flow – hyperbaric chambers

Oxygen use	Max. time for one complete treatment	Total consumption for max. treatment time (litres)	Consumption for each additional minute (litres/min)
Oxygen (O_2) atmosphere and recirculation: On open circuit	2 hours	30,000	250
Oxygen (O_2) atmosphere and recirculation: 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

Note 13: Notes applicable to the gas flow in hyperbaric chambers:

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 supply source in accordance with Section 6

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

Conscious inhalation sedation (Dental)

2.34. All patients have the right to appropriate anxiety control for any dental procedure, the methods used must be considered for the individual patient having a specific treatment.

Behavioural management therapy, coupled with local anaesthesia may be insufficient for some patient cohorts and a holistic approach of anxiety management needs to be employed. This is a combination of behavioural therapy, a calm and peaceful environment and the use of conscious sedation.

What is conscious sedation?

2.35. The General Dental Council define conscious sedation as "a technique in which the use of a drug or drugs produces a state of depression of the central nervous system enabling treatment to be carried out, but during which verbal contact with the patient is maintained throughout the period of sedation. The drugs and techniques used to provide conscious sedation for dental treatment should carry a margin of safety wide enough to render unintended loss of consciousness unlikely. The level of sedation must be such that the patient remains conscious, retains protective reflexes, and is able to understand and to respond to verbal commands."

2.36. Since 1998 there have been significant changes in the provision of pain and anxiety management in UK dentistry. The results have been an increased emphasis on the safe provision of conscious sedation instead of a reliance on general anaesthesia. General anaesthesia should only be provided in response to clinical need. The publication of 'A Conscious Decision' in 2000 resulted in the cessation of general anaesthesia for dentistry in the primary care setting.

2.37. Inhalation sedation (IS), is a form of conscious sedation used in dentistry, it utilises a titrated dose of N_2O gas in O_2 The use of N_2O in healthcare has a wide margin of safety and IS is described as a standard technique for dentist-led sedation by the SDCEP and the Intercollegiate Advisory Committee for Sedation in Dentistry (IACSD) It has been found to be clinically successful for dental procedures in children and adults.

2.38. The way in which nitrous oxide is used in dentistry differs from both anaesthesia and maternity, and as such needs appropriately configured supply and disposal systems to control the environmental exposure and the potential environmental damage aspects. There are certain patient groups for which suitable alternatives are not available, or not practical. The way in which N_2O is administered by clinicians differs from both anaesthetics administration and maternity applications. Each dental service will have multifactorial combination of patient requirements which must be meet for a successful outcome for patient, practitioner and the global environment.

2.39. The average carbon footprint in a dental service for a week of clinical administration of N_2O, was 518.25kg CO^2e (range 38.88-1849). Per episode of IS, the average was 28.62kg CO^2e (range 10.74 - 40.67). This is a considerable sum when applied to the number of sites providing these services.

2.40. Approximately 40% use local cylinder supply sources and 24% from either a shared or dedicated manifold supply system. The remainder is a hybrid of the two.

2.41. The supply source and system for individual applications needs careful review through the IDP as the current Royal College of Anaesthetists (ROCA)/ Association of Anaesthetists of Great Britain & Ireland (AAGBI) joint statement on manifold removal for general anaesthesia applications may not provide the optimal solution for IS applications. Some adult interventions use large quantities of gas, and the resilience and convenience of a pipeline supply is needed. Likewise, because of the gas being a liquid supply type the pressure gauge is not an accurate means to determine remaining contents and many smaller individual cylinders are sent back still half full. Similarly, when larger quantities of gas are being consumed the larger cylinders are more economical and easier to secure.

Note 14: An E-size cylinder at 50% capacity has three times the amount of remaining gas as a G-size cylinder at the manifold changeover point, which equates to the standard manifold bank change over in one much smaller cylinder, so many small cylinders sent back for fear of running out can eclipse multiple banks of a more controlled manifold system.

2.42. All supply systems must be managed in a suitable and sufficient manner and be leak-tight.

2.43. Dental IS is administered through an Ori-nasal mask that is designed for the purpose, there are many proprietary types offering a broad range of sizes for a good fit to the patient. The masks, when correctly fitted, offer an efficient method of delivery of gaseous mixture to the patient. The mask will be configured to supply the gas and have a built-in scavenging opening and lumen to remove the expired gas away from the patient and practitioner.

Scavenging

2.44. Dental sedation clinical guidelines recommend that there is active scavenging equivalent to between 40- 45 litres/min attached to each nasal hood. This is occupational health-related, to ensure that the gas the patient breathes doesn't contaminate the dental operating environment.

2.45. Systems that are set up with higher scavenging rates have to compensate for this by manually increasing the flow rate of gas coming out of the dental sedation machine. For example, a 'normal' flow rate is expected to be 4-6 litres/min, but nationally it was found that 27% of services have an average flow rate of greater than 6 litres/min. Scavenging systems need to be specifically designed for dental service as either stand-alone portable units or as a central scavenging system for dental application without air break the use of BS EN ISO 7396-2 systems will give flow rates that unmodified are too high for Ori-nasal mask

applications and will increase the patient flow demand without having any benefit to the patient, but will increase the amount of gas used in the treatment process.

Nitrous oxide/ oxygen mixture

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

2.47. The flowrates for LDRP room use should be based on the criteria determined during the IDP. The peak inhalational '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.

2.48. Nitrous oxide/ oxygen mixture may be used in other areas for analgesic purposes. The flowrate for these areas should be based on the criteria determined during the IDP.

Air

2.49. 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 unless specifically recommended by the device manufacturer.

2.50. 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 400kPa

2.51. Medical air is 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.

2.52. 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 be considered where air-powered ventilators are to be used.

2.53. 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. Many modern devices have integrated compressors or turbines to supply the required air,

thus negating the need for an external source. Therefore, exact flow requirements will depend on the design of the ventilator and the equipment manufacturer or respiratory technicians should advise on any external medical air requirement.

2.54. Current models of anaesthetic ventilator are very similar to critical care models; almost all such units are pneumatically driven and electronically controlled.

2.55. 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.

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

2.57. Medical air should not be used to supply mechanical services.

2.58. Some medical gas pendants use the medical air supply for operating the control/ retraction system. This is not a preferred method of operation but may be permitted if there is no other design solution, 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 area valve service units (AVSU) arrangements are in place (see Section 3). (The surgical air supply should be used to provide the power source whenever possible)

2.59. The flow requirements should be ascertained and taken cognisance of prior to the installation of the equipment.

Vacuum

2.60. Second to oxygen, MV is the most prominent service from a medical gas perspective. Its use and availability is potentially the same as that of oxygen for preservation of life. How that vacuum is actually provided at the point of clinical use can vary and depending on the IDP can be delivered in many ways, other than from the traditional approach of having a centralised piped system. The primary aims of ‘net- zero’ in healthcare cannot be met unless the critical assessment of the actual requirements that are needed for safe clinical care are developed and shared during the IDP.

Anaesthetic gas scavenging systems

2.61. For anaesthetic gas scavenging systems (AGSS), it is possible that more than one Anaesthetic gas scavenging (AGS) terminal unit may be installed in an operating room or anaesthetic room for convenience. It should be assumed that only one terminal unit in each

room will be in use at any given time. The theatre suite configuration and mode of operation should be considered in the IDP as anaesthetic rooms are not always specified or used in modern anaesthesia. However, should there be a requirement for simultaneous use, the plant should be sized for two AGS terminal units in dual operation for each theatre suite with that mode of operation. Otherwise, a flow rate for a single outlet should be the design criteria (see Section 9). For other areas where AGSS might be required as identified in the IDP, for flowrates refer to Section 9.

2.62. The current standard for AGS systems, BS EN ISO 7396-2, recognises the reduction in overall and fresh gas flows that have resulted from changes in clinical practice, and the resultant reduced flowrates required to control this. Low-flow anaesthesia are techniques that employ a fresh gas flow that is less than the alveolar ventilation (see Section 9).

Safety

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

- identity
- adequacy
- continuity
- quality of supply

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

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

2.66. **Continuity** of supply is achieved by:

- in accordance with BS EN ISO 7396-1, has three sources of supply
- the provision of alarm systems
- connection to the safety power supply system

2.67. **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

2.68. The installation of an MGPS should be carried out only by specialist firms who are registered to BS EN ISO 9001/ BS EN ISO 13485 with an appropriate scope of registration to specifically cover the work that they are undertaking.

Modifications

2.69. 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 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, a risk assessment must be undertaken as to the most appropriate means of complying with this requirement. If complete physical separation cannot be achieved an individual safety risk and reliability assessment should be undertaken for specific isolation element in line with the question set in the IDP risk assessment.

2.70. 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 the IDP to ensure the system has sufficient capacity for adequacy of performance.

2.71. Any work involving alteration, extension or maintenance work on an existing system should be controlled under the appropriate functional safety documentation (see Part B of SHTM 02-01, Section 8).

Removal of pipework

2.72. 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, capping off and removal of redundant pipework and equipment) should be carried out by specialist medical gas contractors only and the IDP risk assessment template applied to all relevant elements of this process.

Note 15: 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 healthcare organisation'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 healthcare organisation's Infection Prevention and Control Team (IPCT).

Validation and verification

2.73. The objective of validation and verification is to ensure that all the necessary safety and performance requirements of the MGPS will be met as determined in the IDP. Validation and verification procedures will be required for new installations, additions to existing installations and modifications to existing installations. The IDP will dictate the specific programme required. This is described in Section 13.

General fire precautions

General

2.74. The siting and general structural principles for the design of liquid oxygen storage accommodation are given in Section 5, and the requirements for plantrooms and gas manifold rooms in Section 12. BCGA Code of Practice CP 36 provides further information on the requirements for liquid storage and BCGA Code of Practice CP 44 provides further information on the requirements for cylinder storage areas.

2.75. Guidance on cylinder storage and handling is given in SHTM 02-01 Part B.

Fire detection system

2.76. 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 SHTM 85: 'Firecode: alarm and detection systems'. External stores may also require fire detection systems.

Electricity supply to medical gas installations

General

2.77. Electrical installations should be carried out in accordance with the current edition of BS 7671 'Requirements for Electrical Installations', including all current amendments and associated guidance documents.

2.78. Provision of electrical supply and distribution should take cognisance of guidance issued in SHTM 06-01: 'Electrical services: supply and distribution'.

Resilience of supply

2.79. MGPS, associated equipment and alarms are a critical service within a healthcare facility. Consideration should be given to ensure the continuity of the medical gas service under mains power supply failure conditions in accordance with BS 7671 'Requirements for Electrical Installations' Chapter 56 'Safety Service'.

2.80. Each item of plant with respect to medical/ surgical air and MV should be supplied from a dedicated, final sub-circuit that is connected to the safety power supply. Alternative means of supply should be considered in the event that internal sub-distribution arrangement is compromised.

2.81. 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 and the like, the same compressor and dryer (or vacuum pump) set should be on-line, and for manifold systems the same bank should be running.

2.82. All electrical systems, including plant control systems, alarm interfaces and the like, should be designed in accordance with electromagnetic compatibility (EMC) directives. For further details, see the 'Electromagnetic Compatibility' section within SHTM 06-01: 'Electrical services: supply and distribution'.

2.83. It is important that operational managers and designers are fully aware of safety power supply arrangements and availability and that plans are available to deal with the total loss of power under adverse circumstances.

Electrical installation

2.84. Wiring systems for medical gas installations should be selected in accordance with the current edition of BS 7671 'Requirements for Electrical Installations' with particular regard to the environment and risk from mechanical damage.

2.85. Care should be taken when installing both electrical systems and MGPS to avoid occasional contact between pipework and electrical cables and containment systems. 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 the current edition of BS 7671 'Requirements for Electrical Installations'.

2.86. 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 to only permit authorised isolation of the equipment.

2.87. Where electrical systems and MGPS 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 'Medical Supply Units' which gives clear guidance on the requirements for such separation and segregation.

Earthing

2.88. Medical gas pipelines should be bonded together and bonded to the local electrical distribution board in accordance with the current edition of BS 7671 'Requirements for Electrical Installations'. The pipelines should not, in themselves, be used for earthing electrical equipment.

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

2.90. Where a medical gas outlet or pipeline system is present within Group 1 or Group 2 Medical Locations, as defined by BS 7671 'Requirements for Electrical Installations' Section 710: 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

Terminal units

3.1. 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 and the like. 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.

3.2. 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. This may be advantageous if the design solution incorporates surgical air systems as rigid pipework can be used, thus avoiding pressure-loss problems that can occur with flexible assemblies used within pendant fittings.

3.3. Floor-mounted terminal units are not permitted.

3.4. All terminal units should conform to British Standard (BS) EN International Standard (ISO) 9170-1. 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 and materials for manufacture are given in BS 5682.

3.5. Wherever nitrous oxide (N_2O) and anaesthetic agents are available for anaesthetic procedures the informed design process (IDP) will need to be followed to determine the requirements for the Control of Substances Hazardous to Health (COSHH) compliance. As with certain low-flow and total intravenous anaesthesia (TIVA) applications this may not be required as a piped service. If Anaesthetic gas capture technology and destruction units cannot assure the relevant levels of exposure, a local exhaust ventilation (LEV) system would be the next option in the hierarchy of controls. In recovery areas, where N_2O 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 N_2O mixed with oxygen is provided for analgesic purposes, the IDP should be followed to determine the most suitable method of environmental control in line with COSHH requirements. Certain dental techniques and pain management procedures where oxygen and N_2O are blended before patient administration may utilise active gas scavenging, these are tailored solutions and may use an alternative extraction system to BS EN ISO 7396-2 (see Section 9).

3.6. The terminal unit (Anaesthetic gas scavenging (AGS)) is specified in BS EN ISO 9170-2. AGS systems are covered in Section 9.

Note 16: Reference should be made to the Department of Health's (1996) 'Advice on the implementation of the Health & Safety Commission's occupational exposure standards (OES) for anaesthetic agents'. Further guidance is given in the Health & Safety Executive's (HSE) (1996) 'Anaesthetic agents: controlling exposure under COSHH'.

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

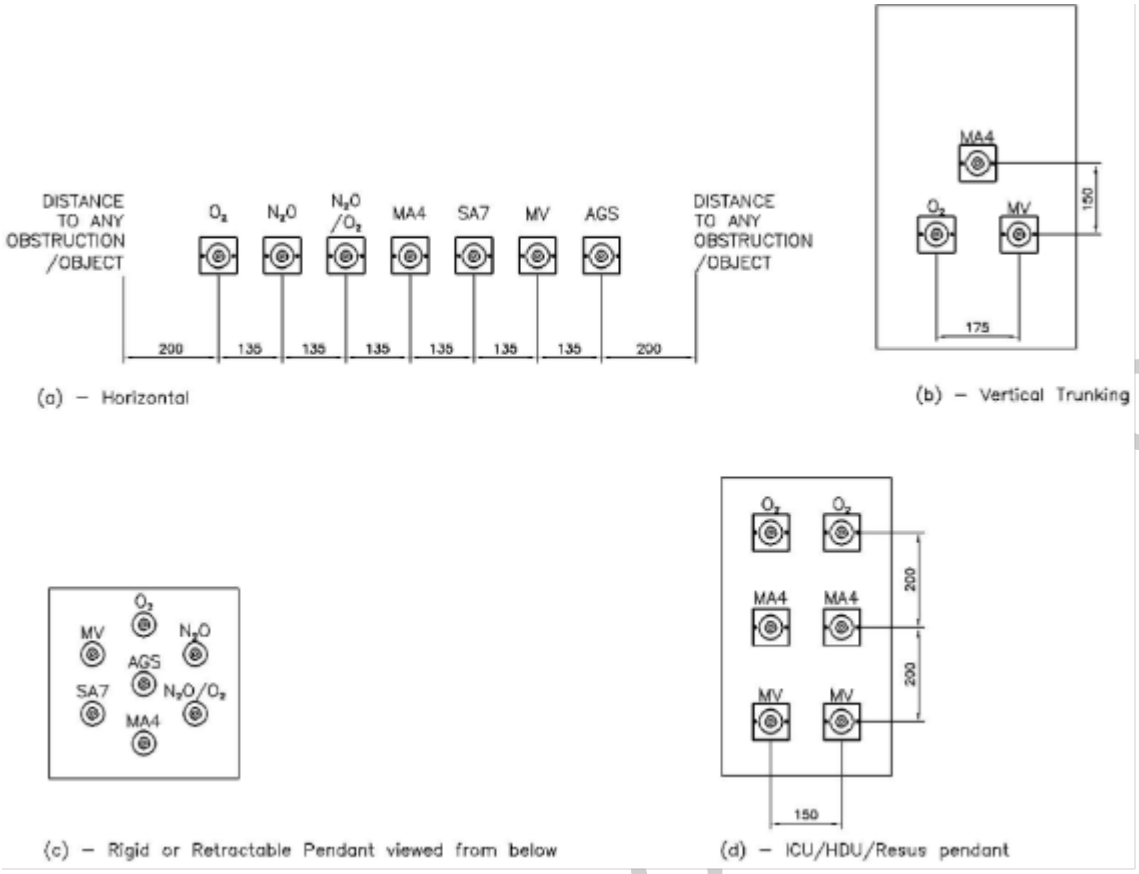
3.8. The fixing of terminal units into medical supply systems or to wall surfaces and the like, should be such that the following forces can be applied:

- a lateral force of 20 Newton (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

3.9. Where an array of terminal units is provided at a location based on the IDP, they should be arranged as follows (see Figure 3.1) with non-utilised gases being omitted from the sequence:

- for a horizontal array, when viewed from the front, left to right: oxygen, N_2O, N_2O/ 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 3.1 (a to d), however, this should be agreed in line with contractual requirements

Figure 3.1 - Terminal unit mounting order



3.10. 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 or as defined by the IDP (see Figure 3.2). 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, for example below worktops in some dental surgery configurations, this would be determined as part of the IDP.

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

3.12. Pressure losses across terminal units should be in accordance with BS EN ISO 9170-1.

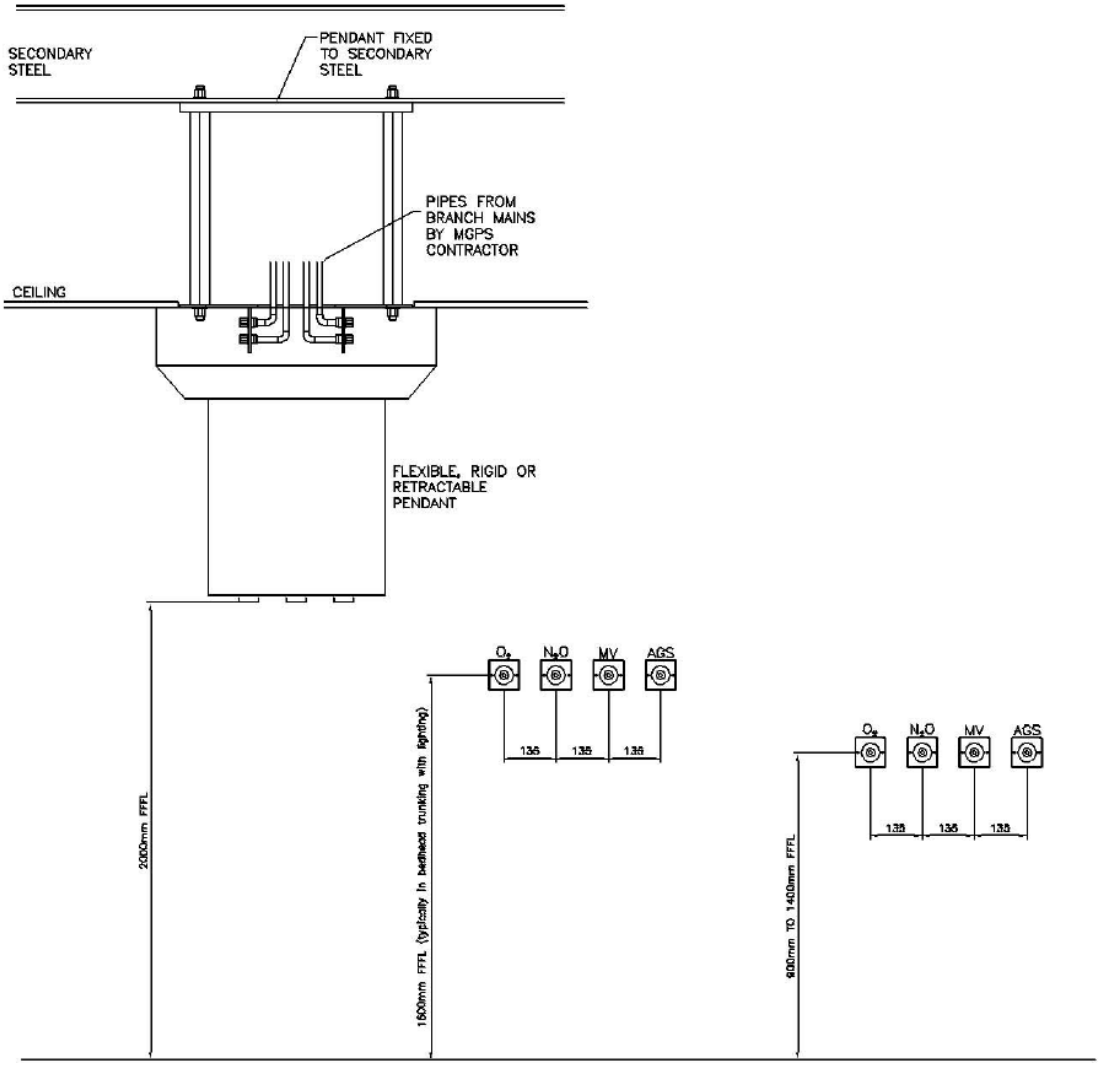
3.13. Terminal units that are wall mounted should be located as follows (Figure 3.2 refers):

- 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. Consideration should be given to terminal unit positioning with respect to worktops, electrical sockets, cupboards, equipment rails, ventilation 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 17: To promote a more 'domestic' environment, some in-patient accommodation is provided with terminal units installed in recesses behind covers/ decorative panels and the like. 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 3.2 - Terminal unit mounting heights



Area valve service units

General

3.14. Normally, departmental area valve service units (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. The IDP and associated Firecode guidance will inform the number and location of AVSUs required to assist progressive horizontal evacuation away from the compartment of origin.

3.15. If a department includes one or more floors, a set of AVSUs should be provided for each floor, which will act as emergency shut-off valves in the event of fire.

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

3.17. Area alarms within critical care areas should be provided for the individual space; that is, if for example, a critical care area of 18 beds is sub-divided into three separate six-bed wards, there should be one alarm only for each 6-bedded space and for each individual supply circuit.

3.18. 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.

3.19. When an anaesthetic room forms part of a special procedures' suite then one set of AVSUs serving both rooms is permissible.

3.20. AVSUs should be mounted at a convenient height (typically between 1,000 – 1,800mm) such that they can be operated comfortably by staff (see Figure 3.3 and Figure 3.4). The order of the location of individual valves in an array should follow that for terminal units, for example: oxygen (O_2), nitrous oxide (N_2O) and/ or N_2O/O_2, medical air (4bar) (MA4), surgical air (7bar) (SA7), Medical Vacuum (MV). If the array exceeds 1,000mm in height from top to bottom, it may be preferable to arrange them in two columns. AVSUs should be positioned where they are free of obstruction. Details of the design of AVSUs are given in Section 11.

Note 18: 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.

Specific labelling requirements

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

3.22. 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.

Figure 3.3 - AVSU and alarm panel mounting heights

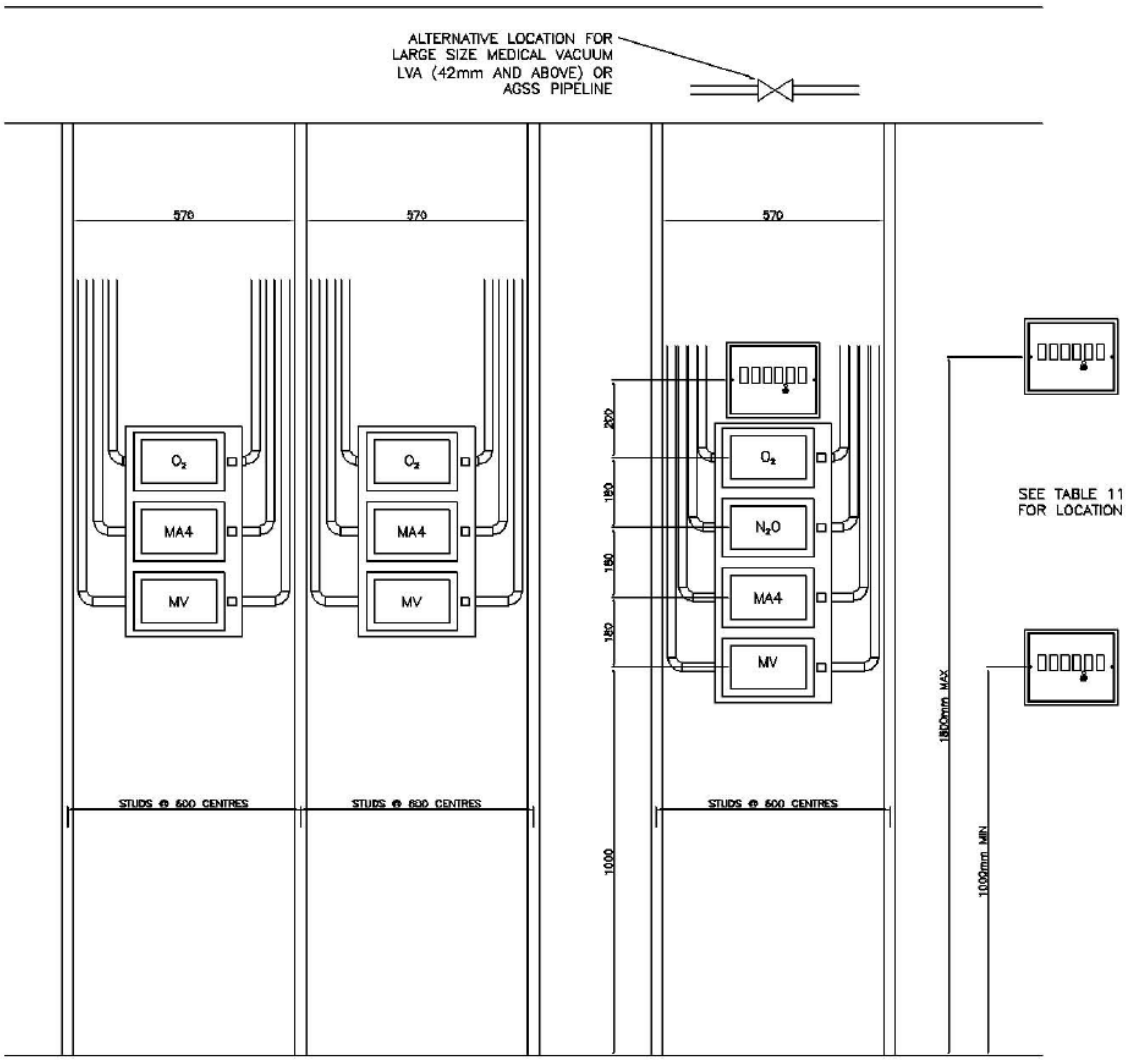
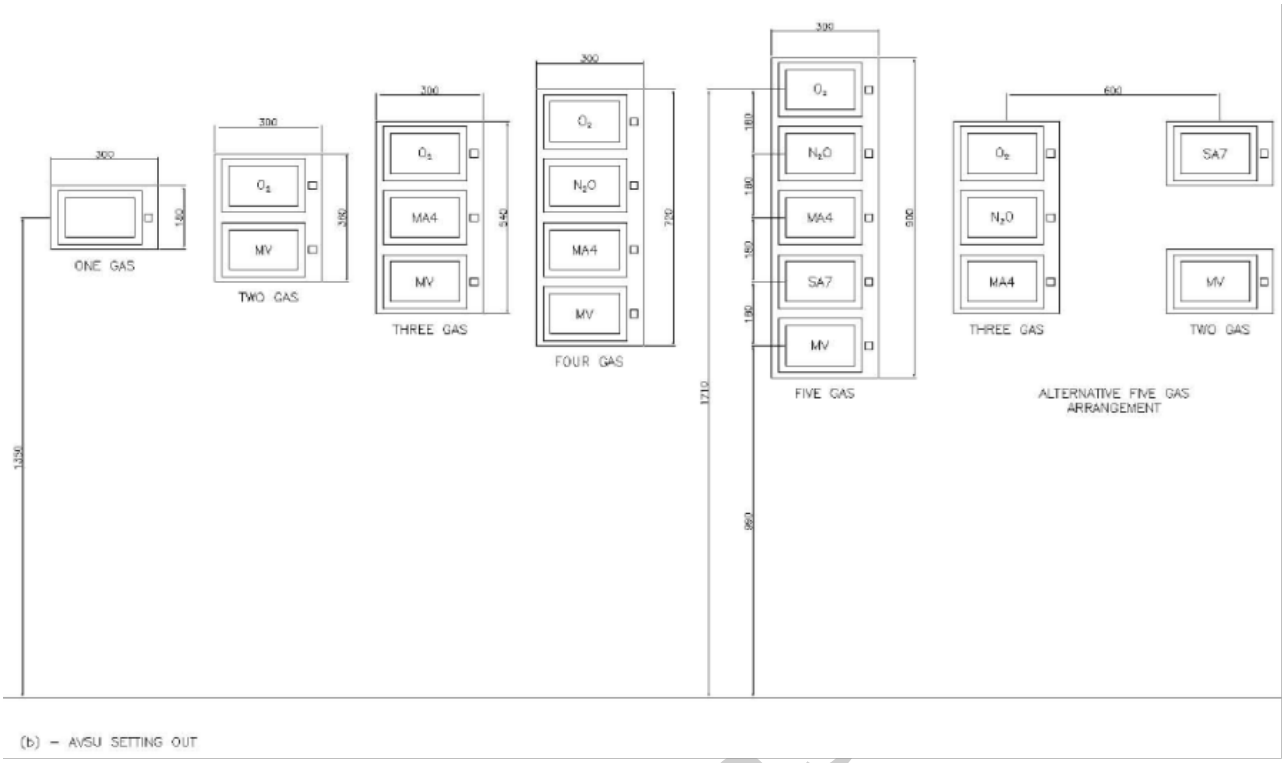


Figure 3.4 - AVSU mounting heights



Area alarm indicator panels

3.23. The placing of area alarm indicator panels should be at locations such as nurse stations and be such that they are readily visible by staff. Notices, partitioning, screens, and the like 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, and be a maximum 1,800mm above FFL (see Figure 3.3 and Figure 3.4).

Line valve assemblies

3.24. Line Valve Assemblies (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 Section 11. At ‘ring-main’ branch connections, a ‘triple tree’ arrangement is required to facilitate the branch flow from either direction. In normal operation all the valves in the ‘triple tree’ arrangement would be open.

4. Cylinder manifold installations

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

Automatic manifold control system

4.2. 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.

4.3. A schematic layout for a typical cylinder manifold system is shown in Figure 4.1. Total storage is usually provided on the basis of a risk assessment. The quantity of cylinders required on each bank of the manifold should be determined by undertaking a risk assessment as part of the informed design process (IDP) taking cognisance of flow rates and peak demand. Additional cylinders for one complete bank change should be held in the manifold room; for nitrous oxide (N_2O)/ oxygen (O_2) 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 British Standard (BS) EN International Standard (ISO) 7396-1. Each cylinder bank should be capable of independent selection to facilitate maintenance activity, for example, via a control switch.

4.4. The nominal and usable capacities of the cylinders commonly used on manifolds are given in medical gas cylinder data charts provided by the medical gas supplier.

4.5. 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 electrical power supply, the design should be such that failure of the electrical power 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, for example for N_2O/O_2 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 19: All systems should be designed so that both banks (duty and stand-by) supply gas in the event of an electrical power supply failure.

4.6. In the event of power failure, when the power is restored, the original 'duty bank' should be on-line, that is, the same bank that was the 'duty bank' prior to interruption of the supply.

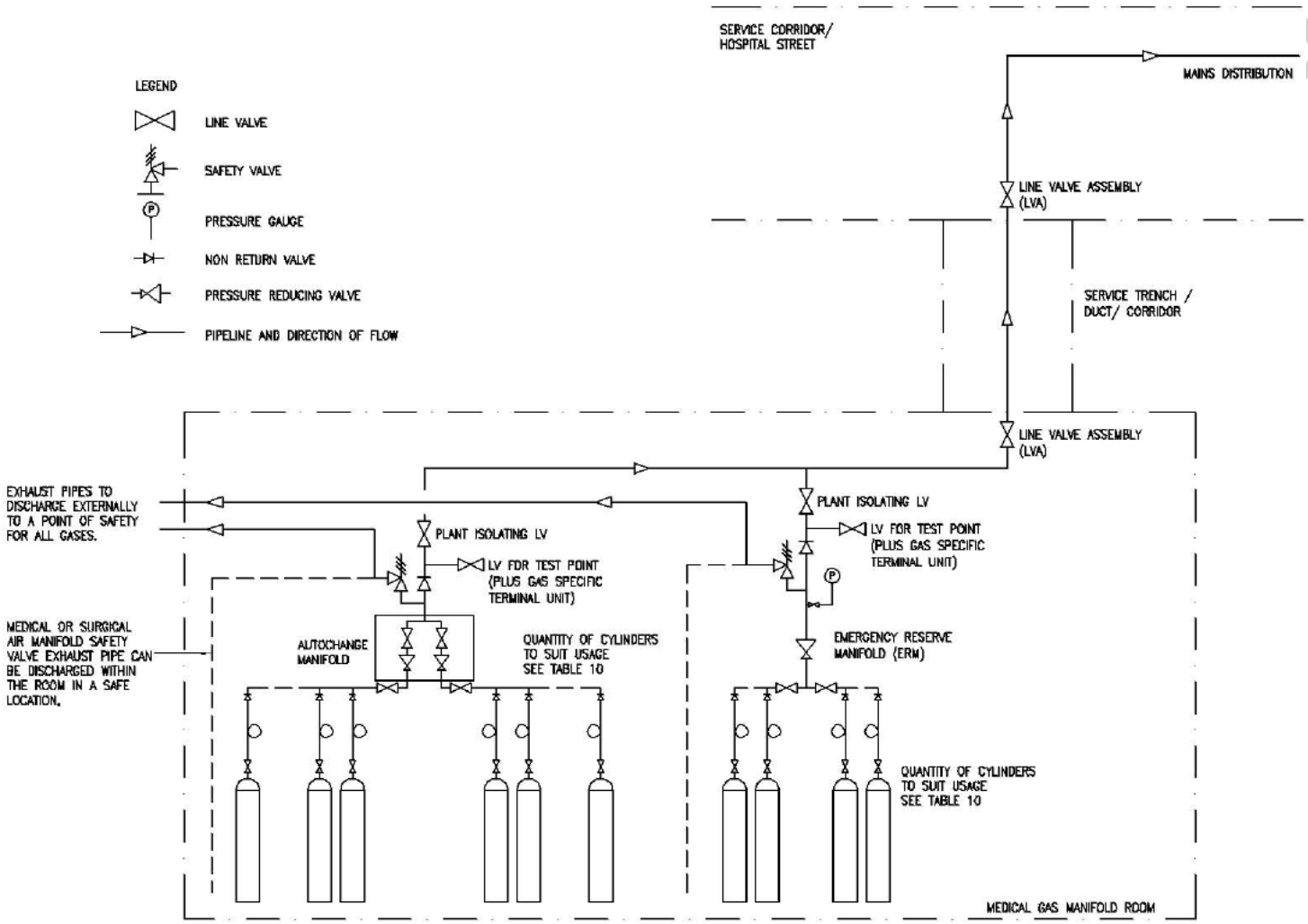
4.7. Manifolds and control panels should be designed and certificated for use with 230 bar cylinders. The manifold headers should incorporate a renewable non-return valve to prevent the discharge of a complete bank of cylinders in the event of 'tailpipe' rupture.

4.8. The tail-pipe cylinder connector must be a pin-index yoke connector in accordance with either BS EN ISO 407 or BS ISO 5145 for oxygen, nitrous oxide/oxygen mixture (50% v/v) and medical air. Non-metallic flexible connectors shall not be used. The manifold connectors should be in accordance with Table 4.1.

Table 4.1 – Cylinder thread sizes

Thread	Medical Gas
M24 x 2	Medical air
M22 x 2	N_2O/ O_2
M20 x 2	O_2

Figure 4.1 - Typical automatic manifold arrangement with manual Emergency Reserve Manifold (ERM)



4.9. In the event of power failure, when the power is restored, the original ‘duty bank’ should be on-line, that is, the same bank that was the ‘duty bank’ prior to interruption of the supply.

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4.11. The tail-pipe cylinder connector must be a pin-index yoke connector in accordance with either BS EN ISO 407 or BS ISO 5145 for oxygen, nitrous oxide/oxygen mixture (50% v/v) and medical air. Non-metallic flexible connectors shall not be used. The manifold connectors should be in accordance with Table 4.1.

4.12. 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 kilo Pascal (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.

Note 20: Studies have shown that inadvertent ignition of halogenated polymers can lead to highly toxic by-products being delivered to the gas stream.

4.13. Pressure indication should be provided to indicate pressure in each cylinder bank and in the medical gas pipeline system (MGPS).

4.14. 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

4.15. The pressure control should maintain the nominal pipeline pressure within the limits given in Section 2. High-pressure regulators should comply with BS EN ISO 10524-2 and be supplied with auto-ignition test results and regulator performance curves for each gas.

4.16. 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 Figure 4.1 and Figure 4.2 for provision of isolating valves.

4.17. 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. There should be a separate discharge pipe for each safety valve. Discharge pipes from each safety valve should not be connected to a common discharge pipe. No other valves of any type should be installed in the discharge pipe.

4.18. This discharge pipeline should be vented to atmosphere, outside the building, in an area where the discharge of oxygen or N_2O/O_2 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 (FFL). Warning signs should be posted at the discharge positions; access for inspection should be provided.

4.19. 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.

Manifold monitoring and indicating system

4.20. The monitoring and indicating system should perform the following functions:

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

4.21. 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.

4.22. Manifold monitoring, indicating and alarm systems should be connected to the safety power supply.

Manifold control unit

4.23. The control unit should include a green ‘mains power supply on’ indicator.

Manifold monitoring

4.24. 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 the nominal pressure for 50% of the cylinder contents

E. pipeline pressure faults outside the normal range

Manifold indicator unit

4.25. There should be indicators to show the following conditions:

A. for each automatic manifold:

- **a.** a green ‘running’ indicator for each bank. This should display when the bank is supplying gas, irrespective of the pressure
- **b.** a yellow ‘empty’ indicator for each bank when the running bank is empty and changeover has occurred
- **c.** 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

B. for each emergency reserve bank, a yellow indicator to be illuminated when the pressure in the bank falls below the nominal pressure for 50% of the cylinder contents- this will require the use of separate pressure sensors - one for each bank)

C. 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

4.26. 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

4.27. Conditions (a) and (b) in paragraph 4.22 should be transmitted to the central alarm system.

4.28. The panel should be incorporated into the manifold control unit.

Manifold management

4.29. Connections should be provided that allow monitoring of manifold alarm conditions (b) to (e) and manifold running for each ‘bank’.

Emergency reserve manifold

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

4.31. The supply should be designed to provide the design flow of the primary system. If the IDP indicates such a provision would result in more than ten cylinders on each bank, zoning of the ERM should be reviewed and area-specific local emergency supply sources (mini and portable manifold systems) considered. A non-return valve and isolating valve should be installed immediately upstream of the reserve manifold connection to the pipeline distribution system.

4.32. 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. This should be determined by risk assessment in consultation with the medical gas supplier.

4.33. The specific requirements will depend on the method of primary supply and will be determined by risk assessment as referred to in paragraph 4.29. 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.

4.34. For large installations, it may be impractical to rely on a cylinder manifold system therefore it may be appropriate to consider segregated local re-supply systems for business continuity or major incident planning as defined by the IDP.

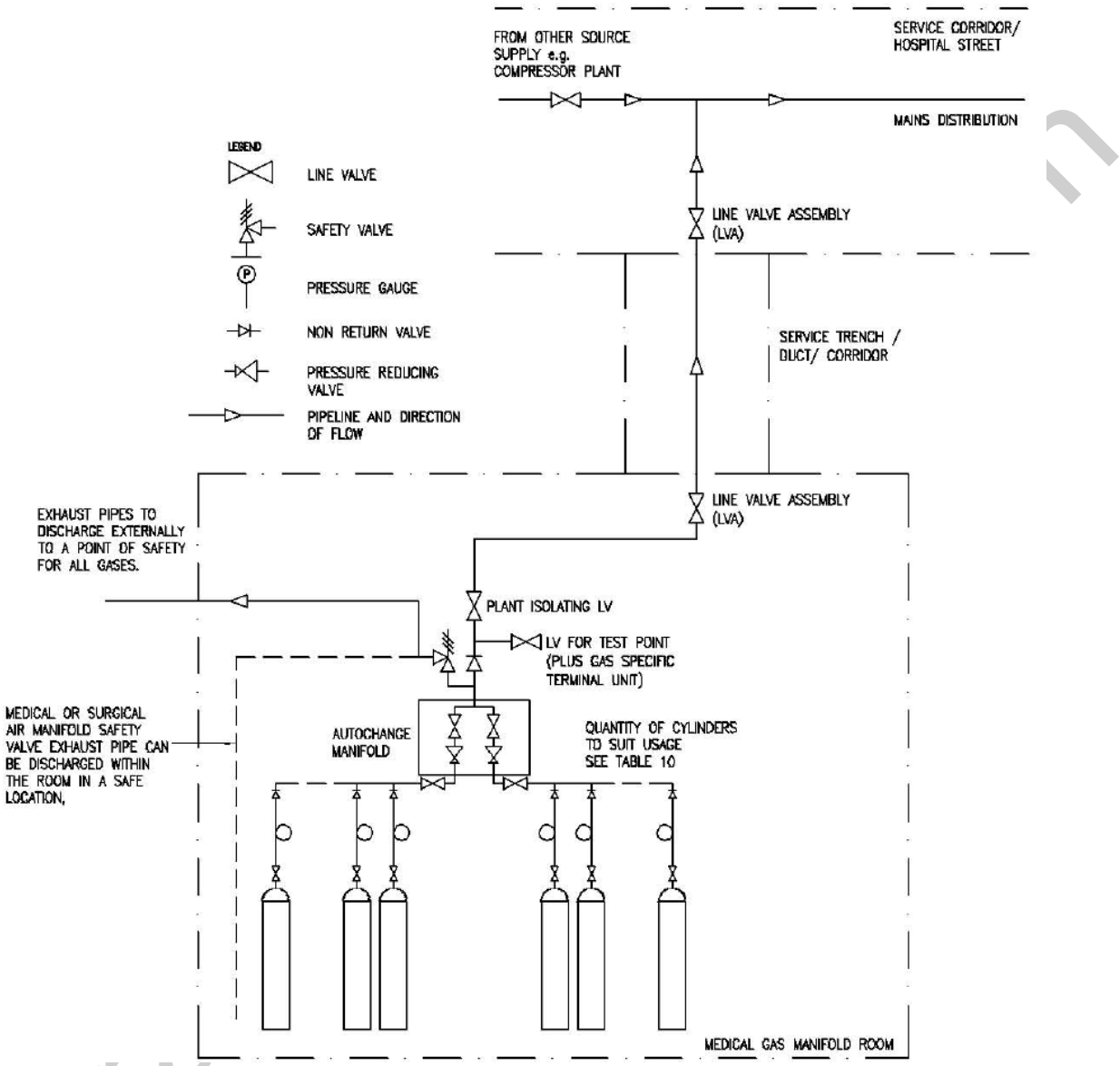
4.35. The risk assessment should inform the operational policy and set out the location of emergency manifolds, cylinders and the like. These may be fixed systems, emergency inlet ports or portable manifold arrangements. The operational policy should detail the action to be taken in the event of loss of the primary source of supply.

Emergency reserve supply for manifold installations

4.36. The reserve supply system for cylinder manifold systems should normally be located in the manifold room adjacent to the automatic manifold or the discreet area of re-supply/ emergency inlet port. 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 4.1.

Figure 4.2 - Typical automatic changeover emergency reserve manifold for liquid oxygen and medical/ surgical air plant



4.37. The supply system should go into operation automatically via a non-return valve, and the ERM isolating valve should remain open.

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

4.38. The supply should comprise a two-bank fully-automatic manifold system as described in paragraphs 4.1 - 4.23 (except for (d) in paragraph 4.21; (b) in paragraph 4.22; and (d) in paragraph 4.23, 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 4.2.

5. Oxygen systems

General

5.1. The medical gas most commonly used for administration to patients in healthcare facilities is medical oxygen, being almost an order of magnitude higher than any other medical gas. A medical oxygen medical gas pipeline system (MGPS) supplies a medical gas that is an essential requirement for life. Its use has increased, not only due of the number of patients being treated but also from the changes in clinical practice for some indications, where the administration rates used have increased. Due to the demand, a MGPS is the preferred way of supplying the medical oxygen to patients within the healthcare facility. Experience gained during the COVID-19 pandemic has shown that under extreme conditions, the overall use of medical oxygen will increase leading to shortfalls in the ability to supply patients from the MGPS. To ensure that the MGPS system is designed to meet the potential requirements for all patients within the healthcare facility, the type of supply sources need to be selected, and the pipeline system appropriately sized to ensure that the design flowrates can be achieved.

5.2. The purpose of this section is to ensure that the most appropriate supply sources for medical oxygen for the MGPS are selected and to ensure that the output capacity of each supply system is capable of meeting the criteria established. It does not cover the sizing of the MGPS pipework (see Section 2), though it refers to the routing and integrity of pipework.

5.3. The basic requirements for the design and construction of a medical oxygen MGPS is described in British Standard (BS) EN International Standard (ISO) 7396-1 (Medical gas pipeline systems Part 1: Pipeline systems for compressed medical gases and vacuum), requiring a documented risk assessment approach to the design and installation of the overall system.

5.4. When designing new installations or revising existing systems, the principles set out in BS EN ISO 7396-1 should be followed, using the informed design process (IDP) methodology (see Section 1).

5.5. One of the prerequisites of BS EN ISO 7396-1 for the MGPS is that it shall maintain the medical oxygen supply to the patients should a single fault condition arise.

5.6. Single fault condition assumes that maintenance is a normal condition and that any fault that occurs whilst one system is being maintained will not affect the ability to supply patients. Hence the need for three sources of supply. However, the system design should ensure that two out of the three supply sources are available, should a single fault condition occur whilst a supply source is being maintained. Where possible, suitable bypass

arrangements can be used to enable maintenance of a supply source without impacting on the other two sources.

5.7. Single fault failure also applies to components of the MGPS, such as automated valves and pressure regulators. Provided essential spares are held on site and faulty components can be replaced quickly then duplication may not be required.

5.8. The need to comply with the principles of control of single fault conditions needs to be addressed by the risk management process adopted in the IDP (see Section 1).

5.9. Since the publication of the Scottish Health Technical Memorandum (SHTM) 02-01, apart from the requirements described in BS EN ISO 7396-1, there have been a number of changes relating to the supply of medical oxygen in compressed gas cylinders. These include:

- the introduction of higher-pressure cylinders, providing a more efficient package and reducing the environmental impact of cylinder supplies
- the use of palletised cylinder bundles, where high pressure cylinders are manifolded together providing a high-volume package for use as a supply source for the MGPS
- the introduction of small mobile emergency supply systems to be used to supplement supplies in a High Dependency Unit (HDU) or as a back feed source to address an adverse event with the MGPS
- the increased use of medical oxygen cylinders fitted with a valve with an integral pressure regulator (VIPR). The VIPR cylinder is fitted with a terminal outlet to allow it to be used as a reserve supply source for individual patient use, where the medical oxygen is not considered as critical

The use of these packages can impact on the decision when selecting a supply source for the MGPS.

5.10. Although previous versions of SHTM 02-01 indicated that the supply source storage systems could contain product identified for more than one supply source, it is now recommended that the primary, secondary and reserve supply sources should be held in separate storage systems, to comply with the requirements of single fault conditions.

5.11. Automatic manifolds should normally be considered as a single supply source for medical oxygen if they are intended as the primary supply source for the MGPS. Where the medical oxygen demand is low, and one bank of the automatic manifold will maintain supplies for at least 48 hours, it may be considered as two sources of supply (primary and secondary), based on the IDP and an appropriate risk assessment.

5.12. Other than to address the location and any arrangements that impact on the use of each supply source, the design, layout, routing and sizing requirements of the medical oxygen MGPS pipework are covered in Section 2.

5.13. The IDP risk assessment process should address the key requirement for each MGPS supply source to ensure that:

- they are sized to provide sufficient storage of product, which is always available for supply under single fault conditions
- the associated control panels are capable of supplying product from each supply source to deliver the maximum design flowrate to maintain supplies at all outlets

Medical Oxygen Supply Sources

5.14. The scope of this section covers the supply of medical oxygen from all types of supply sources. The type of supply systems used for the MGPS are dependent on the availability of licenced product from the medical gas supplier and the overall demand for the system. There are a number of options that may be considered as the supply source for an MGPS, including:

- compressed medical oxygen, (using a full for empty exchange system), supplied in:
  - high pressure cylinders
  - high pressure cylinder packs, where the cylinders are manifolded together and supplied in a palletised frame (manifolded cylinder pack (MCP))
- liquid medical oxygen storage tank, (refilled by a liquid oxygen cryogenic tanker) supplied into:
  - vacuum insulated evaporator (VIE)
  - permanently installed liquid cylinders connected to the MGPS
  - cryogenic liquid mini tanks
- on-site medical oxygen manufacturing plants, such as pressure swing adsorption (PSA) or electrolytic plants, produced as a by-product of a hydrogen production facility

5.15. Figure 5.2, Figure 5.3 and Figure 5.4 provides some guidance about the type of supply system that will support the design annual usage.

5.16. The table provides some indication of the allowances needed for the boil-off rate where liquid oxygen systems are installed as secondary or emergency systems. Economiser systems should be included in the design of liquid oxygen secondary supply systems to utilise any boil-off from the vessels caused by heat inleak.

5.17. Due to the boiling point of liquid oxygen and that it will continuously ‘boil off’ from the cryogenic storage tank when not in use, it should never be considered as suitable for the reserve supply source.

Note 21: Other considerations:

a. portable oxygen concentrators and liquid cylinders intended to be used by homecare patients are not seen as suitable sources of supply for the MGPS.

b. the information concerning cryogenic liquid supply source installations does not apply to bulk liquid nitrogen, as the product supplied is intended to be used at cryogenic temperatures. However, the principles of where the storage tanks are located, and their management may be applied to their use on a healthcare facility.

5.18. Of the types of product available, compressed medical oxygen is the most sustainable supply source, as the product stored in the high-pressure cylinder is secure and retained for use whilst the cylinders are stored on site.

5.19. However, as the usage increases, medical liquid oxygen stored in a VIE becomes the most appropriate supply source as it requires significantly less space on site, due to the gas to liquid volume ratio (850:1).

5.20. It is also more flexible, as the medical gas supplier has the ability to adjust the frequency of delivery to accommodate increases in daily demand and to reset minimum stock levels to manage any potential delivery delays or failures.

5.21. It is recommended that on-site manufacture should only be considered when there is no alternative reliable supply source that is readily available.

5.22. Currently, only PSA plants (producing ‘Oxygen 93’, covered by the European Pharmacopoeia (Ph. Eur.) monograph (2433)) have been used as an on-site manufacturing supply system.

5.23. As medicinal products manufactured on-site are considered as a Pharmaceutical Preparation, it requires them to be manufactured in compliance with the Ph. Eur. monograph (2619), which details the batch management and quality control of the manufacturing process. These requirements are specified as being under the control of the healthcare facility’s Responsible Pharmacist.

5.24. This requirement is complicated by the fact that medical oxygen manufactured on-site is fed directly to the MGPS, without any form of batch management to allow the product to be prospectively released by the Pharmacist. To compensate for this, the on-site manufacturing system requires additional controls to demonstrate compliance of the product as it is fed to the MGPS.

5.25. When selecting the supply sources for a medical oxygen MGPS, having systems that deliver medical oxygen to a different quality standard is also not recommended.

5.26. Although ‘Oxygen 93’ is considered suitable for patient treatment for most indications, as changing the supply source (following a single fault condition) can result in a change of 10% oxygen content, this may introduce serious consequences for patient outcomes, where high flowrates are prescribed.

5.27. In addition, as the medical oxygen from the MGPS is used to calibrate medical devices (such as anaesthetic workstations), a large change to the product quality delivered to these devices is likely to raise alarms on these devices.

5.28. This means that a PSA plant should not be used as a secondary or emergency supply source, where the primary supply source uses liquid or compressed medical oxygen, and liquid or compressed medical oxygen cannot be used as the secondary or reserve supply source for a PSA plant.

5.29. Consideration needs to be given to the operational management consequences where medical oxygen from different suppliers is used for supplying the gas to the MGPS.

5.30. This can create confusion from a pharmacovigilance perspective, in the event of an adverse event being reported.

5.31. Where different suppliers are contracted to supply medical oxygen, their responsibilities and limits of liabilities of each party shall be defined in the Facilities Management (FM) agreement between the healthcare facility and the medical gas supplier.

Product quality

5.32. The quality of the gas used for each supply source shall be based on the relevant pharmacopoeia monograph. For medical oxygen that is supplied by a third party:

- the manufacturer should hold a Manufacturing and Importation Licence (MIA) issued by the Medicines & Healthcare products Regulatory Agency (MHRA), which requires the manufacturing procedures to be compliant with the Good Manufacturing Practice (GMP) requirements, specified in the EU GMP Guide, and specifically with Anne VI covering medicinal gases
- the supplier should hold a Marketing Authorisation (MA) issued by the MHRA, detailing the specification of the gas, indications and contraindications for its use and basic safety information how to handle, store and administer the product. The Ph. Eur. monograph for medical oxygen manufactured by cryogenic distillation of ambient air should comply with the medical oxygen monograph (0417)
- medical oxygen may also be manufactured on-site at the healthcare facility. However, it is recommended that on-site manufacture should only be considered when there is no alternative licenced product supply that is readily available.

5.33. Currently, the only on-site manufacturing system uses a PSA plant to produce Oxygen 93, covered by the Ph. Eur. monograph (2433).

5.34. Medicinal products manufactured on site are considered as a Pharmaceutical Preparation, requiring them to be manufactured in compliance with the Ph. Eur. (2619), which details the batch management and quality control of the manufacturing process. These requirements are specified as being under the control of the healthcare facility's Responsible Pharmacist. For medical oxygen manufactured on-site and fed directly to the MGPS without any form of batch management, additional controls would be required to demonstrate compliance.

5.35. When considering the use of an on-site generation plant as the Medical Oxygen Supply Source for the MGPS, it should be noted that the quality of the gas delivered to the MGPS is the responsibility of the Responsible Pharmacist for the healthcare facility. The design of the plant should consider the need to formally release the product for patient use, whilst the plant is continuously operating. The plant should be operated under a Quality Management System (QMS) that is compliant with the principles of GMP, as specified in the EU Guide.

5.36. The current position in healthcare facilities references the Ph. Eur. medical oxygen monograph (0417), as the medical devices use the gas delivered from the MGPS to calibrate the device mixing the gas such as anaesthetic workstations and patient ventilators.

Supply system design

5.37. The design process for the medical oxygen supply source(s) should follow the principles of the IDP, as described in Section 1. To assist the process, the relevant design question sets provided in Appendix I should be used to assist the design process.

5.38. For supply systems utilising liquid medical oxygen, it is essential that the medical gas supplier should be involved in the IDP, as they will be responsible for providing the validated equipment for the medical liquid oxygen supply system(s) at the appropriate flowrate, pressure and product quality. They also need to recommend the size of the cryogenic storage tank(s) and agree the delivery frequency to ensure that there is always sufficient product to maintain supplied to the MGPS, even under single fault delivery conditions.

5.39. Where high pressure cylinders are used as a supply source for the MGPS, the gas supplier will provide advice about the types of cylinder packages available and the number of cylinders that would need to be held on site to maintain supplies. However, the gas supplier may not be responsible for the supply and installation of the automatic manifold systems, or the control panel used to manage the changeover process and control the pressure of the gas delivered to the MGPS.

5.40. Although it is not recommended that on-site generation of the medical oxygen is used, where there is no alternative, the manufacturer/ supplier of the plant and the healthcare facility's Responsible Pharmacist (or their nominated deputy) need to have a prominent role in the IDP risk assessment team as the drug manufacturing risk is to the healthcare facility.

5.41. All supply source systems shall be included in the scope of the IDP risk management process.

5.42. An important decision within the IDP is to determine the size of each supply source and flowrate capacity of the associated equipment and control panel.

5.43. Where the MGPS is being designed for a new healthcare facility, the primary requirements for the MGPS need to be established from existing patient cohort information and supplier delivery data to prepare a basic design that can be subjected to the risk management process as part of the IDP. If the new facility is being built as a replacement for an existing facility, the throughput and the maximum flowrate can be based on the figures for the facility being replaced, making allowances for the planned differences in patient numbers and clinical practices that are discussed in the IDP.

5.44. For existing MGPS systems, the average continuous demand of the MGPS can be determined by the medical gas supplier, based on the delivery volumes over the defined period and any available individual telemetry or metering.

5.45. Where the MGPS uses medical liquid oxygen as the primary supply source, and the VIE is fitted with a telemetry system, variations in daily and weekly demand can be evaluated.

5.46. Maximum flowrates within the MGPS can only be determined using appropriately positioned flowmeters.

5.47. The control panels and the liquid oxygen vaporisers are supplied as predesigned equipment, where the panel or vaporiser is designed for a continuous maximum flow, delivered at the required pressure. If the design flowrate is close to the maximum design capacity of the system, the IDP will need to consider any potential planned increases in demand to ensure that the chosen equipment will be able to manage the increased demands or flowrates.

5.48. Although the supply systems need to be capable of supplying the peak flowrates, to ensure that the MGPS is capable of maintaining the flowrates at the supply pressure at the terminal outlet is dependent on the size of the installed pipework, which may restrict flows to specific sections of the MGPS.

5.49. Figure 5.2, Figure 5.3 and Figure 5.4 provides some guidance as to the correct type of supply source, dependent on the usage and maximum flowrate requirements.

5.50. For smaller systems, high pressure cylinders offer the most economical way of providing the medical oxygen. The use of cylinders filled to a higher pressure provide a means to increase the volume of gas stored on site and reducing the manual workload in changing cylinders on a changeover manifold. Upgrading cylinder manifolds to a higher pressure requires the use of tailpipes designed to the correct pressure, with the appropriate fittings to connect to the cylinder valve on the higher-pressure cylinders.

5.51. The ideal maximum automatic cylinder manifold size is a 2 x 10, with each bank ideally lasting at least 7 days, but providing the labour is available, the minimum changeover period can be as low as 48 hours.

5.52. Compressed cylinders can also be used as a supply source when supplied in an MCP. As an example, MCPs, filled to 230 bar(g), provide approximately 150m^3 of useable medical oxygen per unit (allowing for a 20 bar(g) changeover pressure). Although the manifolded pallet requires significantly less manual input, there is a requirement for the healthcare facility to have suitable mechanical handling equipment available to remove them from the delivery vehicle and exchange them on the changeover manifold system. MCPs are recommended for supply systems with an annual demand of up to 24,000m^3.

5.53. As the healthcare facility's demand increases, permanently installed liquid cylinders can be used as the MGPS supply source. Although it is possible to transport these liquid cylinders full to the healthcare facility, they are susceptible to damage when being transported and are required to be permanently installed and manifolded together as an MGPS supply system and filled on-site using a smaller liquid oxygen cryogenic tanker.

5.54. Liquid cylinders are supplied up to 240 litres capacity, with up to 12 cylinders manifolded together, being able to supply the medical oxygen MGPS up to an annual demand of 20,000 m^3. They are designed with an internal vapouriser and pressure raising coil inside the vacuum jacket. The integral vaporiser is limited to 10 m^3/hour for each liquid cylinder.

5.55. The heat inleak into the liquid cylinder will cause the liquid oxygen to boil, generating approximately 2% of the cylinder's contents per day. This gas is used as part of the economiser circuit for the supply source to the MGPS, indicating that the minimum throughput per liquid cylinder is 4m^3 per day.

5.56. The mini bulk tank (which can have a storage capacity of up to 3000 litres) can be used as an interim choice for a medical oxygen supply source between liquid cylinders and VIEs. Mini bulk tanks are normally skid mounted (making them easier to install), have a separate external vapouriser and are refilled using a small cryogenic liquid oxygen tanker. It has the ability to deliver medical oxygen to the MGPS at a rate of 20 m^3/hour.

5.57. The heat inleak into the mini tank will generate approximately 1% of the tank's contents per day. This gas is used as part of the economiser circuit the Supply Source to the MGPS, indicating that the minimum throughput per liquid cylinder is 8 m^3 per tank/ day. Mini bulk tanks due to their construction and size are more flexible for siting than traditional VIEs and can offer advantages where external siting and safety distances may cause a problem for a traditional application.

5.58. Although it is preferable to use a VIE primary supply source, liquid cylinders and mini tank systems are seen as a useful supply source for inner-city healthcare facilities. They can increase the volume delivered by compressed gas supply sources but require less space for refilling, where space is limited. They are also filled by pressure decant rather than the traditional pumped rigid or articulated tanker, therefore environmental noise for out-of-hours refilling can be managed.

5.59. For larger healthcare facilities, the use of a VIE is the most suitable choice for the medical oxygen primary and secondary supply sources.

5.60. VIE tanks are available with capacities from 1000 litres up to 100,000 litres and are refilled on-site by liquid oxygen cryogenic road tankers. The VIE and the tankers have a product specific filling connection, ensuring that only liquid oxygen can be transferred into the storage tank.

5.61. The VIE is the most common choice for the primary and secondary source of supply to the MGPS, primarily due to the ability to store significant volumes of medical oxygen in a relatively small space (due to the liquid to gas ratio being 850:1).

5.62. The VIE utilises a pressure raising coil to maintain tank pressure and a separate ambient air heated vapouriser system to convert the medical liquid oxygen to a gas supply for the MGPS (at ambient temperature).

5.63. Any heat inleak to the vacuum insulated vessel will cause the liquid to boil generating between 0.25% and 0.5% boil off per day, dependent on the capacity of the tank. The VIE pressure control system utilises this gas generated to maintain the tank pressure, with any excess gas being supplied to the MGPS via an economiser circuit.

5.64. To prevent the liquid medical oxygen vapourisers from icing up, two sets of vapourisers can be used, with a changeover system to allow one set of vapourisers to convert the liquid to gas, whilst the other set is allowed to defrost to allow for continuous supply. This avoids the vapourisers from becoming iced up, which reduces the vapourising capacity of the system.

5.65. For larger hospitals, multiple VIEs can be used, acting as multiple primary supply sources. These should be sited at diverse locations, providing a level of security for the overall system should there be any restriction to get access to the VIEs with the road tanker. It should also be noted the location of VIE plants due to their size may be a planning issue.

5.66. Where automatic changeover systems are utilised, multiple primary supply sources can be used, avoiding the need for a secondary supply source, providing that the capacity of the primary supply sources are large enough to provide the medical oxygen to the complete MGPS under single fault conditions.

Sizing medical oxygen supply systems

5.67. BS EN ISO 7396-1 specifies that the MGPS should have three sources of supply to maintain medical oxygen supplies for patient use during a single fault condition.

5.68. Having determined the appropriate types of supply sources to be used, it is necessary to determine the size and flowrate capacity for each system and the time that they are expected to maintain supplies until the single fault condition can be rectified.

5.69. The primary supply source must be designed so that it is capable of continually supplying the design throughput to the MGPS at the design flowrate. Agreement from the medical gas supplier is required to ensure that they have the capability to maintain a minimum stock of medical oxygen on site, based on the annual usage and the delivery frequency. Where multiple primary supply sources are used to supply specific sections of the MGPS, each supply source should be sized as if they were the only source available for use.

5.70. The secondary supply source should also be capable of supplying the MGPS with the design throughput at the maximum design flowrate whilst the primary system is being maintained, repaired or replaced. The size and the minimum stock for the secondary Supply source is determined by risk assessment based on the time to get the primary supply source back online. It may also be reduced if the gas supplier can maintain a shorter delivery frequency during the time it is in use.

5.71. Where a single reserve supply source is used, it should be sized to maintain the design throughput at the maximum design flowrate when the primary and secondary supply sources are not available. The duration for which the reserve supply source must be able to supply the MGPS should be determined by the risk management procedures, based upon the estimated time to get one of the systems back in operation.

5.72. The reserve supply systems need to utilise cylinders, normally using automatic cylinder manifold systems. The size and flowrate capacity of each system should be determined by the IDP and risk management procedures based on the requirements of the specific areas of the healthcare facility they are designed to supply. Design for single fault conditions also includes the failure of any key components of the MGPS control system, including actuated valve and regulators used in the control panels.

5.73. Where it is necessary to install an on-site PSA supply system, the electrical power source for the plant must be connected to the safety power supply. Any on-line analysis equipment

(as required by the Pharmacopoeia monograph) will require an uninterruptible power supply (UPS) system to ensure that the gas delivered to the MGPS remains within specification.

5.74. When designing the pipeline system, care is needed to ensure that the supplies of medical oxygen to critical areas within the healthcare facility are appropriately protected, irrespective of any fault condition, identified by risk management.

5.75. Although on-site manufacturing plant are not recommended, where there is a requirement to use them, the reserve supply source shall be designed to provide the design throughput and the maximum flowrate to the MGPS due to the fact that the plant supplies directly into the MGPS without any batch storage.

5.76. The average flow requirements (based, where possible, on the historic consumption) will determine the type and size of the supply source(s) to be used.

5.77. When determining the size of the supply source, consideration needs to be given to where the healthcare facility is located relative to the medical gas supplier. It will depend on how far the medical gas manufacturing plant is located and the agreed delivery frequency.

5.78. Using the information provided in Table 5.1, the minimum stock level (for either liquid or compressed gas) can be determined to address any delivery issues that the medical gas supplier's distribution system may experience.

5.79. Where the demand is high enough to require medical liquid oxygen to be the preferred supply source, the size of the VIE will be determined by the medical gas supplier to ensure that there is sufficient storage capacity on site to continue to meet demands when the VIE needs to be refilled. Seasonal variations should be taken into consideration, where the demand is likely to be higher than the annual average flowrate. It is recommended to use telemetry to provide remote access for the medical gas supplier and the healthcare facility to monitor the level of gas in the VIE. Although the medical gas supplier may take the responsibility for scheduling the next delivery (using either telemetry or the 'predicted consumption' from recent history), the healthcare facility still has a responsibility for checking stock levels on an agreed frequency.

5.80. Where the demand can be met by high pressure cylinders, the size of the automatic cylinder manifolds will be determined by the IDP risk assessment, including the ability for the healthcare facility to change the cylinders on the manifold, whilst maintaining supply to the MGPS using the in-use bank of cylinders. The number of cylinders held on site, for use on the changeover manifold should be agreed with the medical gas supplier to manage normal use and to cover any adverse conditions so as to ensure continuous availability of product for MGPS use. At least one week's supply should be held on site in the main cylinder store.

5.81. Having determined the actual throughput for the medical oxygen MGPS and taken account of both seasonal variation (due to the increase in the number of patients during winter periods) and any planned increase in the demand, the type of system can be selected for the primary, secondary and reserve supply source.

5.82. For supply sources using high pressure cylinder packages, the number of connections on the automatic cylinder manifold and the number of cylinder packages required to be held on site need to be agreed.

5.83. The healthcare facility is responsible for confirming that they have the capability to undertake the cylinder manifold changeover procedures to maintain supplies to the MGPS.

5.84. For liquid cylinder/ VIE supply sources, the capacity of the vessels, the minimum stock levels to be maintained and the delivery frequency need to be agreed with the medical gas supplier. The minimum stock levels in each vessel need to be determined as part of the risk management procedures and capacity of the tank determined by the capacity of the delivery tanker and whether the storage tank is fitted with a telemetry system. Figure 5.2 details the recommended storage supply to cover the delivery risk assessment.

5.85. The maximum flowrate capacity is dependent on the type of supply source and the control panel that manages the supply system.

5.86. For compressed cylinder supply sources, the maximum flow capacity is limited by the size of the orifice through the cylinder valve and the maximum flowrate that can be expected when the pressure falls to the changeover setting.

5.87. Generally, the maximum flowrate will be dependent on the design of the control panel and the capacity of the regulators used to control the pressure of the gas delivered to the MGPS.

5.88. The medical oxygen supply sources need to be sized to provide sufficient storage of medical oxygen on site, as well as being able to continuously deliver the maximum system demand, as defined by the risk management process, at the correct pressure and flowrate at all terminal outlets. This requirement needs to be assessed in conjunction with the pipework design process to ensure that the supply source control panel is capable of delivering the gas at the appropriate flowrate and pressure and the pipeline sized so that it can deliver the correct flowrates to all terminal outlets.

5.89. In respiratory wards where the supply of medical oxygen is not considered critical for life, the reserve supply source can be individual portable cylinders to ensure that patients receive medical oxygen.

5.90. If this is documented as the reserve supply source for the section of the MGPS, it is important to hold sufficient portable cylinders within the ward area to ensure that medical oxygen will be available to maintain supplies to all patients.

5.91. Where a supply system consists of three PSA plants, the flowrate and outlet pressure can be determined from the specification of each plant, recognising the values are dependent on the design of each plant. Assessment of the flowrate shall not consider running more than one plant at a time, in order to ensure that the supply system is capable of supplying the design flowrates under single fault condition.

5.92. Each plant should have an air receiver after the compressor to enable an increase in flow requirements in excess of the air compressor output.

5.93. Each plant should have a PSA oxygen buffer tank to allow excess gas to be stored during periods where the required flowrate is less than the demand.

5.94. When designing the medical oxygen supply source for a new-build healthcare facility and historic data is not available, the average daily demand can be estimated either by:

- taking the information from the current facility (to be replaced), allowing for any planned changes in the number and type of patients to be treated in the new facility
- using information from another healthcare facility where the patient cohort is similar to those planned, taking account of any specific changes to clinical practice that may impact on demand

5.95. The information concerning pipework design and sizing is determined from first principles based on the planned location of the supply sources and the layout of individual wards within the healthcare facility.

5.96. In order to ensure that the MGPS supply systems are capable of continually supplying medical oxygen to the terminal outlets throughout the healthcare facility, an annual risk management programme should be undertaken to determine the usage and the peak flowrate requirements and to ensure that the MGPS have not exceeded the previous design criteria. The risk management process should involve the relevant personnel and contractors responsible for running and maintaining the system, representatives from Pharmacy and clinical staff and the suppliers of the medical oxygen.

5.97. If it is determined that the demand has exceeded the design throughput for the system, a review of the supply source(s) is required to ensure that adequate stocks are maintained on site.

5.98. For liquid oxygen supplies, it may be acceptable to manage the additional throughput by changing the frequency of delivery and increasing the minimum stock levels for re-delivery. This change must be agreed with the medical gas supplier to ensure that they have

sufficient resource to manage the increased delivery frequency. If this cannot be met, then consideration should be given to installing a larger VIE to manage the increase in demand.

5.99. Where a telemetry system is used with medical liquid oxygen storage systems, the medical gas supplier will recognise any significant changes in the demand and adapt the delivery schedules to suit.

5.100. For automatic cylinder manifolds, the number of cylinders held on site as the backup supply should be reassessed. A review is required to ensure that the healthcare facility can manage the changeover procedure without impacting on the supply system's ability to maintain the supplies to the MGPS. If this cannot be maintained, then consideration should be given to changing the supply source to a liquid cylinder manifold system.

5.101. For systems using high pressure oxygen cylinders, the assessment should consider the size of the automatic cylinder manifolds (and the healthcare facility's capability to change cylinders to enable continuous supply) and the number of cylinders held in store to ensure availability of cylinders to replace on the manifold.

Medical oxygen supply system stock control

5.102. The principle of stock control for all types of supply systems is the same as it provides the information as to when the stocks need to be reordered/ replenished and how much available product is available at the healthcare facility.

5.103. In addition, there is a requirement to specify the alarm limits for the supply systems to indicate when the supply systems are approaching their changeover pressure or when the liquid oxygen systems are approaching their minimum refill condition.

5.104. Although arrangements may be agreed with the medical gas supplier as to when cylinders are replenished (full for empty) or when the VIEs/ liquid cylinders are refilled, the healthcare facility still has a responsibility to monitor product stock on site and to notify the medical gas supplier when there are any unusual demand requirements that would increase the usage of the gas supplied to the MGPS.

5.105. For liquid medical oxygen supply systems, where the stock held at the healthcare facility is contained in the vacuum insulated tanks, the stock control relates to when the medical liquid oxygen should be ordered, and the storage tanks refilled.

5.106. For compressed medical oxygen supply systems, the stock requirements relate to the size and filling pressure of the cylinder packages used and the number of cylinders held on site available for connection to the automatic cylinder manifolds. Hence, the use of higher-pressure cylinders means that less cylinders can be held on site, due to their increased capacity.

5.107. As the flowrate capability of the cylinder package is dependent on the pressure in the cylinder, the changeover pressure needs to be set at the pressure where the maximum flowrate can be achieved. When calculating the available stock on site, the cylinder package volume should take account of the unavailable product retained in the cylinder.

Medical Liquid Oxygen Primary Supply Systems

5.108. Having determined the size of the VIEs or mini tank used for the primary supply source, it is necessary to identify the content levels within the storage tank used to ensure that there is always sufficient product on site to manage a single fault condition with the scheduled delivery to the primary supply system.

5.109. For the primary supply system, the design operational stock volume is calculated using the demand throughput, based on IDP risk management process, using the historic information and any planned increases in demand. The VIE operational stock volume is then calculated using the delivery frequency, agreed with the medical gas supplier.

5.110. A delivery risk assessment should also be conducted with the medical gas supplier to determine the delivery risk assessment operational stock volume. The output from the delivery risk assessment should take cognisance of the potential delay in refilling the tank due to single fault conditions with the delivery process. This should take account of the distance between the medical gas suppliers manufacturing plant and the healthcare facility and the availability of cryogenic tankers available for supply.

5.111. Table 5.1 gives the recommended volumes (based on the daily consumption identified in the IDP) and the distance from the manufacturing plant and the healthcare facility.

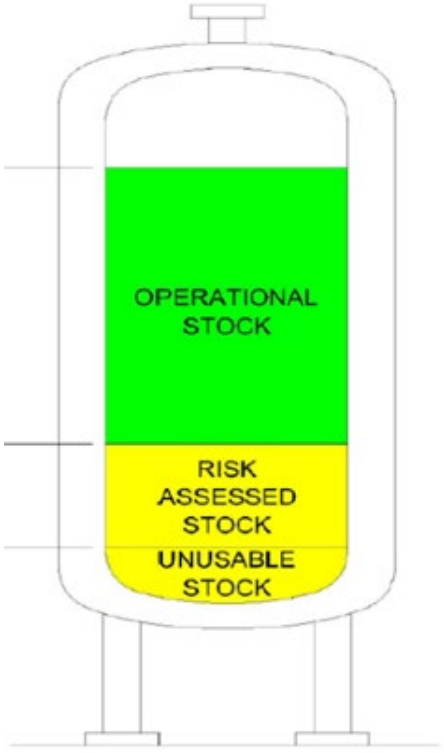
Table 5.1 - Delivery Risk Managed Stock

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

5.112. The illustration below indicates the basic requirements for stock in the primary supply system, which is split into four sections:

- the top space, above the tank's trycock (the level to which the tank is filled) is used to provide space for the expansion of the liquid oxygen as it warms due to heat inleak. This is part of the tank design, which relates to the safety of the system
- the ullage at the bottom of the tank, where the remaining product does not have the capability to provide product to the MGPS at the design flowrate and pressure
- the operational stock, which is split into two sections:
    - the stock level based on the throughput used in the IDP and the maximum deliver frequency agreed with the medical gas supplier
    - this is defined as the minimum level when the tank should be scheduled for redelivery and is based on the delivery risk assessment

Figure 5.1 - Primary supply system VIE storage tank



5.113. For VIEs, the use of telemetry systems allows the medical gas supplier to see the stock levels at each facility and schedule tankers so that they can refill tanks. Although systems are available for using telemetry with liquid cylinders and mini tanks, these are not always used and the healthcare facility is responsible for monitoring retained stocks in each supply system and notifying the gas supplier when the tank levels are approaching the refill point. The reorder level set for the operational stock should be used for the alarms and linked to the telemetry system.

Medical Liquid Oxygen Secondary Supply Systems

5.114. The stock requirements for the medical liquid oxygen secondary supply systems are subtly different to the primary VIE.

5.115. The top gas space and the ullage space at the bottom of the tank will be the same percentage of the VIE's capacity as the primary VIE, but the operational stock is dependent on the outcome of the risk management process used for developing the design using the IDP.

5.116. As the stock in the secondary supply source is continually boiling off, the minimum tank level for the alarm setting needs to be when the remaining usable content equates to the throughput that will be consumed for the period when the primary VIE will be out of service for maintenance or repair. The delivery risk management volume used for the primary VIE will need to be added to the operational stock volume to ensure that there is no interruption to the supply of gas to the MGPS. The secondary VIE should be added to the telemetry system to give the medical gas supplier adequate warning as to when the tank should be refilled.

Supply System Flowrates and Design Features

5.117. Although the design flowrates for the individual healthcare facilities may be different, the equipment is design and supplied for specific flowrates to simplify the number of available.

5.118. The regulator panels for compressed cylinder manifolds are typically provided for the following flowrate ranges:

- 500 litres/ min
- 1,000 litres/ min
- 1,200 litres/ min
- 1,333 litres/ min
- 1,500 litres/ min

5.119. Higher flowrates may be supplied (up to 3,000 litres/min) for specialised installations.

5.120. The design flowrate is primarily dependent on the pressure regulators used in the installation. The maximum flows from the cylinder manifold system will be provided when the cylinders are at full pressure, but the flow when the cylinders are nominally empty (at around 20 bar(g)) will be significantly lower. When specifying the regulator panel flowrate, the design flowrate should be calculated at the nominally empty cylinder changeover pressure. To obtain the design flowrates at the changeover pressure may result in the outlet pressure dropping from 4.1 bar(g) to 3.7 bar(g).

5.121. Cylinder manifold tailpipes, manufactured to ISO 21969 will provide a flow of 83 litres/min when the cylinders are nominally empty (20 bar(g)).

5.122. Hence, a 2x10 changeover manifold will provide a flow of 830 litres/min at changeover pressure but will provide a significantly higher flowrate when the cylinders are full. A benefit of using cylinders filled to a higher pressure is that changeover pressure will remain the same for all filling pressure, but the useable gas in each cylinder will be an increased percentage of the full contents.

5.123. A 137 bar(g) J size cylinder will deliver approximately 85% of the cylinder content. A 300 bar(g) cylinder will deliver 93% of its full content.

5.124. The minimum duration for a 2x10 cylinder manifold is four hours for reserve use, which equates to only a flow of 242 litres/min.

5.125. When risk assessing the size of the automatic cylinder manifold, it is important to understand the limitations of the flowrate from the manifold to determine whether it will meet the maximum design flowrate when used under single fault condition.

5.126. The automatic cylinder manifold systems for high pressure cylinder packs are the same as those used for single cylinders. ISO 21969 specifies that the flexible hose for cylinder packs should be rated at 1245 litres/min, when the pressure in the cylinder pack drops to the nominally empty contents. This indicates that the benefits of a cylinder pack over a 2x10 changeover system, compared to a 2x10 cylinder manifold relate to the volume of gas held/ duration of use, rather than achievable flowrate.

5.127. Flowrates available from liquid cylinders are limited by the capacity of the integral vaporiser, which are sized to supply gas at 10 m^3/hour, which is equivalent to a peak flow of 167 liquid from each liquid cylinder. At this peak flow they may require de-icing on a regular basis.

5.128. The typical average flow of a 200-litre liquid cylinder is only 0.5 m^3/hour (8 litres/min) based on a delivery frequency of 10 to 14 days.

5.129. Multiple liquid cylinders may be connected together by a manifold on a supply system to provide a higher flowrate, but more importantly, provide the required storage volume of liquid oxygen.

5.130. The liquid cylinder system regulator panel is typically rated at 30 m^3/hour (500 litres/min) with a peak flow of typically 80 m^3/hour (1,333 litres/ min).

5.131. The flowrates from a mini tank are limited by the capacity of the skid mounted vaporiser, which are typically sized with a peak flowrate of between 60 to 100 m^3/ hour (1,000 to 1,667 litres/ min). At this flowrate the vapouriser would require de-icing on a regular basis, unless two mini tanks were used on a timed changeover (TCO) system.

5.132. The typical average flow of a 1000 litre liquid cylinder is typically 2.5 m^3/ hour (40 litres/min) based on a delivery frequency of 10 to 14 days.

5.133. The mini tank regulator panel is typically rated at 30 m^3/hour (500 litres/ min) with a peak flow of 100 m^3/hour (1,667 litres/min).

5.134. The regulator control panels for VIE supply systems are split into two ranges of 3,000 litres/min and 5,000 litres/ min, although on smaller healthcare facilities a smaller 1,500 litres/min control panel would be more appropriate. The control panel specification requires the panel to achieve these flows whilst maintaining the 4.1 bar(g) outlet pressure to supply the MGPS.

5.135. The flowrate from VIE systems is also impacted by the ambient vaporiser flowrate capabilities when being used on a continuous basis.

5.136. The vaporisers are specified to achieve the design flowrates to match the output from the regulator panels, with an outlet temperature difference of 5°C below the ambient temperature. At average flowrates, the outlet temperature difference will only be about 1°C below the ambient temperature.

5.137. On primary supply source systems, best practice is to use two vaporisers on a TCO basis, to allow one vaporiser to be online whilst the other one is defrosting. This system requires the control valves to fail open under single fault conditions (loss of power), allowing both vapourisers to be online, reducing the throughput of each vaporiser by 50%. The vapourisers can cope with this condition, not changing over for prolonged periods without ice building up.

5.138. The healthcare facility should carry out routine checks on the vaporisers for ice build-up but with the use changeover vapourisers, de-icing should never be necessary.

5.139. As secondary supply source systems are only used under single fault conditions, it is normal for an only single vaporiser to be installed to provide the required flow for a period the period when the primary supply source is unavailable.

5.140. Typically, the average flowrates for a large healthcare facility primary supply system VIE is a maximum of 1,700 litres/min. This is well below the design capability of the 3,000 litres/min or 5,000 litres/min regulators panels and vaporisers. Depending on the output from the IDP, the vaporisers and regulators will be specified for one of the two flow ranges, which will be well in excess for the actual flowrates.

5.141. If flowrates higher than 5,000 litres/min are required, the requirement will be met by installing a second 5,000 litres/min control panel, providing a maximum flowrate of 10,000 litres/min, with duplicate vaporisers. However, based on historical data, flowrates higher than 5,000 litres/min are not foreseen.

5.142. If an average flow, greater than 2500 litres/min and a peak flow greater than 5,000 litres/min is selected by the IDP, specialist advice should be requested from the medical gas supplier.

5.143. A potential option is to use two 5,000 litres/min control panels and vapouriser system, where the MGPS is fed from two primary supply sources, installed at remote locations and feeding half of the healthcare facility's MGPS system. Using a central switching valve to cater for single fault conditions of either primary system, the other primary system would feed the complete facility.

5.144. Under fault conditions and with the central valve open, the operational primary supply source would require 10,000 litres/min, supplied from two 5,000 litre/min control panels.

Supply system configuration

Oxygen supply sources

5.145. All medical oxygen supply systems must be built to recognised codes and standards. they should be designed so that they can be maintained easily, and any envisaged routine maintenance should be possible without interrupting the supply of medical oxygen. Where unforeseen maintenance, such as a VIE replacement is required, then an alternative temporary supply source(s) shall be implemented in a planned approach and connected to designated points on the MGPS.

5.146. Although some existing automatic cylinder manifolds and regulators panels allow a liquid oxygen supply source to be incorporated and also have temporary supply source inlet ports. they can suffer from the single fault failure conditions. Best practice is to use dedicated dual regulator panels on each supply source, with diverse supply lines and temporary supply inlet points for high dependency wards is a requirement.

5.147. Where dome loaded regulators are used for changeover systems, as they fail closed on loss of dame pressure, it is advisable that a spring-loaded regulator is employed in parallel.

5.148. Automatically operating mechanical bypass systems are designed using pressure regulators, the lead regulator shall be associated with an actuated valve.

5.149. The functionality of any fail-safe system should be validated when commissioning the system and when carrying out any planned preventative maintenance scheme.

5.150. The three supply sources, together with the emergency supply are shown in overview in Figure 5.2, Figure 5.3 and Figure 5.4.

5.151. The following schematic diagrams give an overview of the nine combinations of medical oxygen supply systems, showing the primary, secondary and reserve supply sources, and

including the emergency supply source options used to maintain supplies to critical care areas.

5.152. The detailed piping and instrumentation diagrams (P&ID) should be used in the risk management procedure during the IDP.

5.153. The systems should be risk assessed to ensure that the overall system will maintain supplies to the medical oxygen MGPS under a single fault condition, including a failure of the electrical supply.

Figure 5.2 - Configurations schematics for medical oxygen supply systems

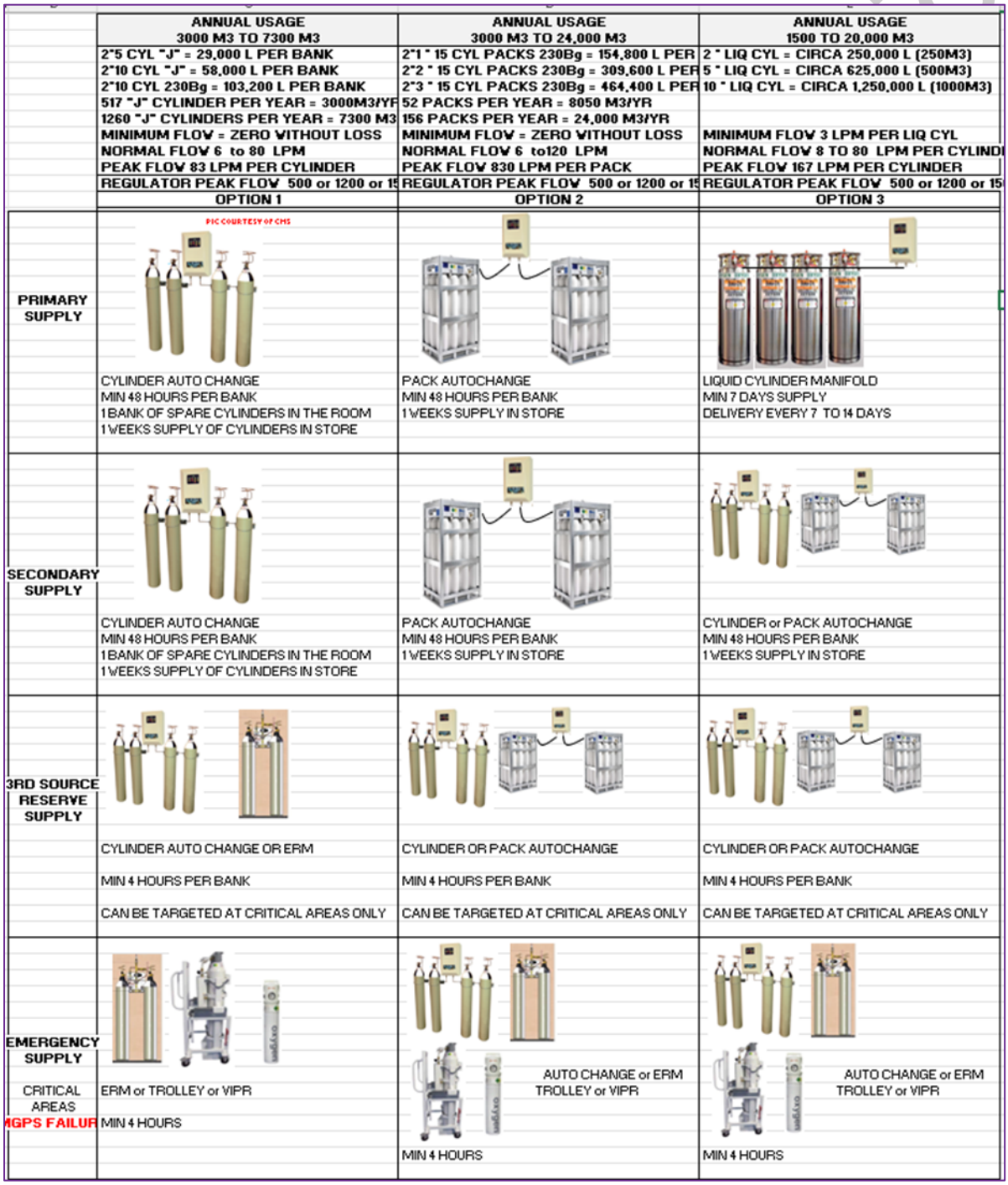
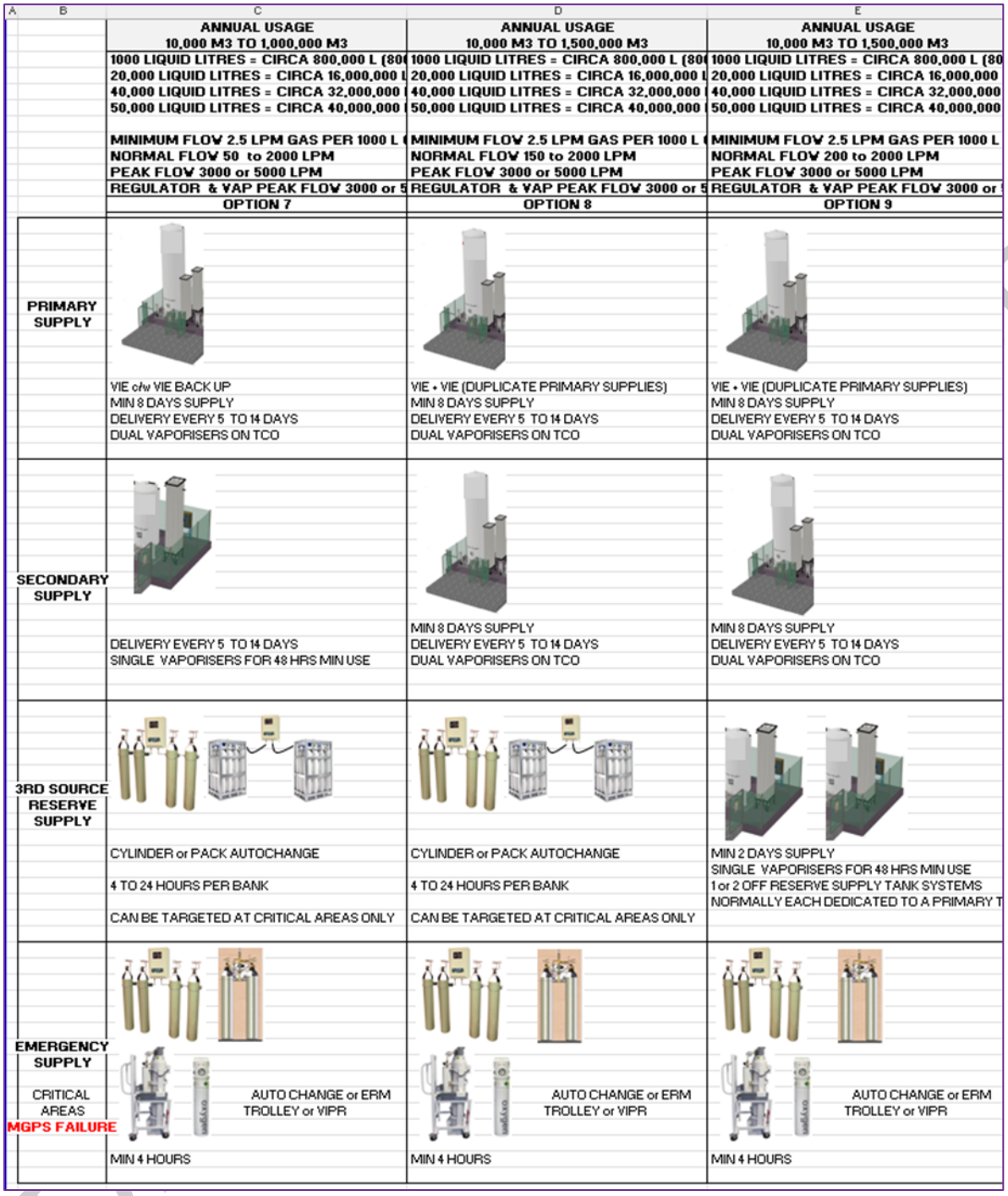


Figure 5.3 - Configurations schematics for medical oxygen supply systems

	ANNUAL USAGE 3000 TO 100,000 M3	ANNUAL USAGE 7000 TO 100,000 M3	ANNUAL USAGE 5000 TO 250,000 M3
	1000 LIQUID LITRES = CIRCA 800,000 L (80 3000 LIQUID LITRES = CIRCA 2,400,000 L (2	1000 LIQUID LITRES = CIRCA 800,000 L (80 3000 LIQUID LITRES = CIRCA 2,400,000 L (2 6000 LIQUID LITRES = CIRCA 4,800,000 L (4	1000 LIQUID LITRES = CIRCA 800,000 L (800 10,000 LIQUID LITRES = CIRCA 8,000,000 L (8 20,000 LIQUID LITRES = CIRCA 16,000,000 L
	MINIMUM FLOW 5 LPM GAS PER 1000 L OF NORMAL FLOW 40 TO 350 LPM PEAK FLOW 1500 LPM REGULATOR & VAPORISER PEAK FLOW 1	MINIMUM FLOW 5 LPM GAS PER 1000 L OF NORMAL FLOW 40 TO 350 LPM PEAK FLOW 1500 LPM REGULATOR & VAPORISER PEAK FLOW 1	MINIMUM FLOW 2.5 LPM GAS PER 1000 L O NORMAL FLOW 25 to 400 LPM PEAK FLOW 1500 TO 3000 LPM REGULATOR & VAP PEAK FLOW 1500 TO
	OPTION 4	OPTION 5	OPTION 6
PRIMARY SUPPLY			
	MINI BULK TANK 800 TO 3000 LIQUID LITRES MIN 7 DAYS SUPPLY DELIVERY EVERY 7 TO 14 DAYS	MINI BULK TANK 800 TO 3000 LIQUID LITRES MIN 7 DAYS SUPPLY DELIVERY EVERY 7 TO 14 DAYS 2 OR MORE TANKS ON TIMED CHANGEOVER	VIE c/w CYLINDER BACK UP MIN 7 DAYS SUPPLY DELIVERY EVERY 7 TO 14 DAYS IDEALLY DUAL VAPORISERS ON TCO
SECONDARY SUPPLY			
	CYLINDER or PACK AUTOCHANGE MIN 24 HOURS PER BANK 1 WEEKS SUPPLY IN STORE	MINI BULK TANK 800 TO 300 LIQUID LITRES MIN 7 DAYS SUPPLY DELIVERY EVERY 7 TO 14 DAYS 2 OR MORE TANKS ON TIMED CHANGEOVER	CYLINDER or PACK MANUAL OR AUTOCHANGE MIN 24 HOURS PER BANK 1 WEEKS SUPPLY IN STORE
3RD SOURCE RESERVE SUPPLY			
	CYLINDER OR PACK AUTOCHANGE MIN 4 HOURS PER BANK CAN BE TARGETED AT CRITICAL AREAS ONLY	CYLINDER or PACK AUTOCHANGE 4 TO 24 HOURS PER BANK CAN BE TARGETED AT CRITICAL AREAS ONLY	CYLINDER or PACK AUTOCHANGE 4 TO 24 HOURS PER BANK CAN BE TARGETED AT CRITICAL AREAS ONLY
EMERGENCY SUPPLY CRITICAL AREAS MGPS FAILURE	 AUTO CHANGE or ERM TROLLEY or VIPR	 AUTO CHANGE or ERM TROLLEY or VIPR	 AUTO CHANGE or ERM TROLLEY or VIPR
	MIN 4 HOURS	MIN 4 HOURS	MIN 4 HOURS

Figure 5.4 - Configurations schematics for medical oxygen supply systems

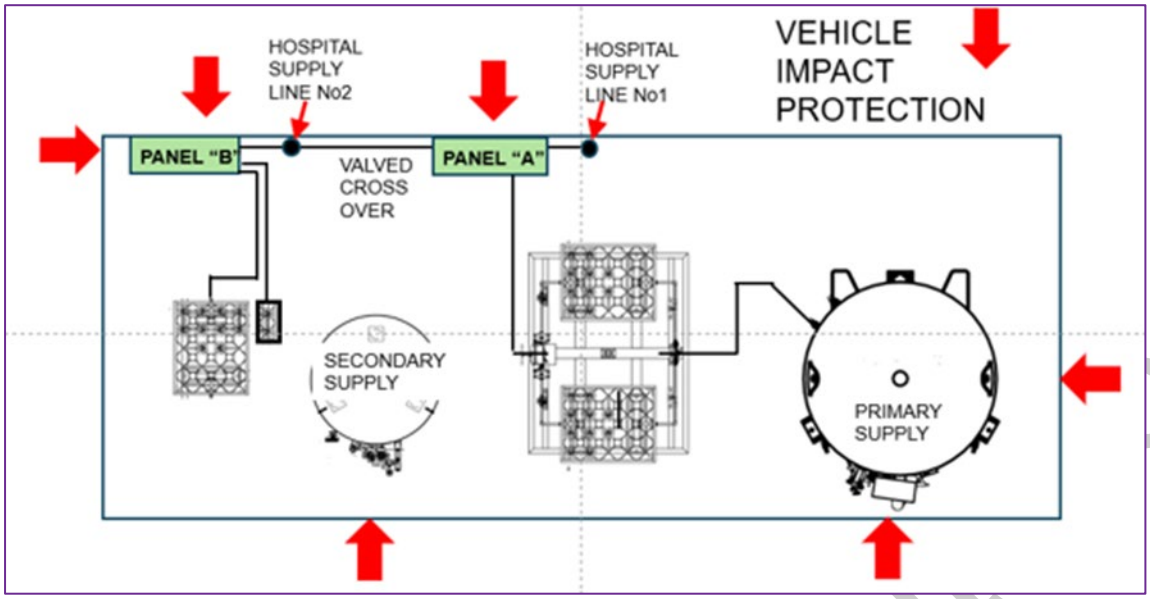


	ANNUAL USAGE 10,000 M3 TO 1,000,000 M3	ANNUAL USAGE 10,000 M3 TO 1,500,000 M3	ANNUAL USAGE 10,000 M3 TO 1,500,000 M3
	1000 LIQUID LITRES = CIRCA 800,000 L (80 20,000 LIQUID LITRES = CIRCA 16,000,000 L 40,000 LIQUID LITRES = CIRCA 32,000,000 50,000 LIQUID LITRES = CIRCA 40,000,000 MINIMUM FLOW 2.5 LPM GAS PER 1000 L NORMAL FLOW 50 to 2000 LPM PEAK FLOW 3000 or 5000 LPM REGULATOR & VAP PEAK FLOW 3000 or 5	1000 LIQUID LITRES = CIRCA 800,000 L (80 20,000 LIQUID LITRES = CIRCA 16,000,000 L 40,000 LIQUID LITRES = CIRCA 32,000,000 50,000 LIQUID LITRES = CIRCA 40,000,000 MINIMUM FLOW 2.5 LPM GAS PER 1000 L NORMAL FLOW 150 to 2000 LPM PEAK FLOW 3000 or 5000 LPM REGULATOR & VAP PEAK FLOW 3000 or 5	1000 LIQUID LITRES = CIRCA 800,000 L (80 20,000 LIQUID LITRES = CIRCA 16,000,000 40,000 LIQUID LITRES = CIRCA 32,000,000 50,000 LIQUID LITRES = CIRCA 40,000,000 MINIMUM FLOW 2.5 LPM GAS PER 1000 L NORMAL FLOW 200 to 2000 LPM PEAK FLOW 3000 or 5000 LPM REGULATOR & VAP PEAK FLOW 3000 or
	OPTION 7	OPTION 8	OPTION 9
PRIMARY SUPPLY	VIE c/w VIE BACK UP MIN 8 DAYS SUPPLY DELIVERY EVERY 5 TO 14 DAYS DUAL VAPORISERS ON TCO	VIE + VIE (DUPLICATE PRIMARY SUPPLIES) MIN 8 DAYS SUPPLY DELIVERY EVERY 5 TO 14 DAYS DUAL VAPORISERS ON TCO	VIE + VIE (DUPLICATE PRIMARY SUPPLIES) MIN 8 DAYS SUPPLY DELIVERY EVERY 5 TO 14 DAYS DUAL VAPORISERS ON TCO
SECONDARY SUPPLY	DELIVERY EVERY 5 TO 14 DAYS SINGLE VAPORISERS FOR 48 HRS MIN USE	MIN 8 DAYS SUPPLY DELIVERY EVERY 5 TO 14 DAYS DUAL VAPORISERS ON TCO	MIN 8 DAYS SUPPLY DELIVERY EVERY 5 TO 14 DAYS DUAL VAPORISERS ON TCO
3RD SOURCE RESERVE SUPPLY	CYLINDER or PACK AUTOCHANGE 4 TO 24 HOURS PER BANK CAN BE TARGETED AT CRITICAL AREAS ONLY	CYLINDER or PACK AUTOCHANGE 4 TO 24 HOURS PER BANK CAN BE TARGETED AT CRITICAL AREAS ONLY	MIN 2 DAYS SUPPLY SINGLE VAPORISERS FOR 48 HRS MIN USE 1 or 2 OFF RESERVE SUPPLY TANK SYSTEMS NORMALLY EACH DEDICATED TO A PRIMARY T
EMERGENCY SUPPLY CRITICAL AREAS MGPS FAILURE	AUTO CHANGE or ERM TROLLEY or VIPR MIN 4 HOURS	AUTO CHANGE or ERM TROLLEY or VIPR MIN 4 HOURS	AUTO CHANGE or ERM TROLLEY or VIPR MIN 4 HOURS

5.154. Part of the current design approach is that each supply source must have duplicate pressure regulators as part of the requirements to maintain supplies to the MGPS under single fault conditions. Although BS EN ISO 7396-1 indicates that failure of the pipeline is not considered as a single fault condition, it is recommended to have duplicate supply lines from the primary and secondary supply sources to enable a supply of gas to be maintained at the terminal outlets under any single fault condition.

5.155. Figure 5.5 shows the basic layout for the liquid medical oxygen supply source VIE compound with duplicate supply lines.

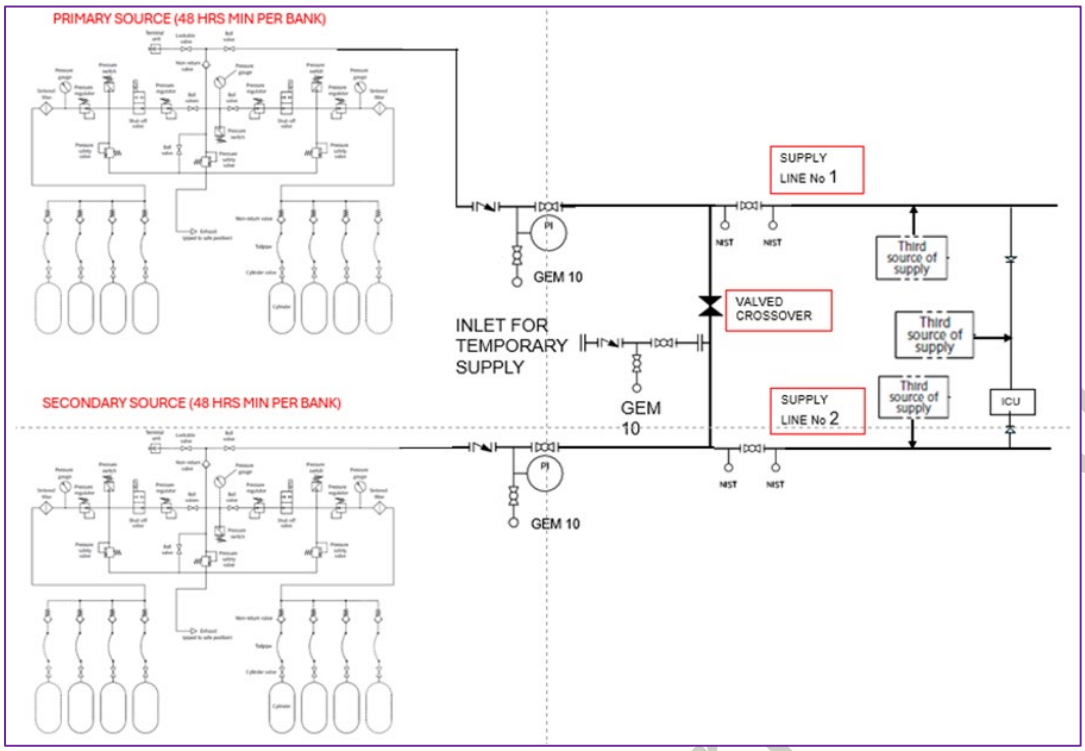
Figure 5.5 - Plan view of VIE compound, showing dual regulators and duplicate supply lines



5.156. Figure 5.6 shows two automatic cylinder manifolds supplying into two diverse supply lines. These either require switching valves on the MGPS pipework or a priority of operation setting for the manifold control panels. Reserve supply sources are shown feeding directly into the MGPS at a location nearer to the critical care areas, where the supply of medical oxygen is used to treat critically ill patients.

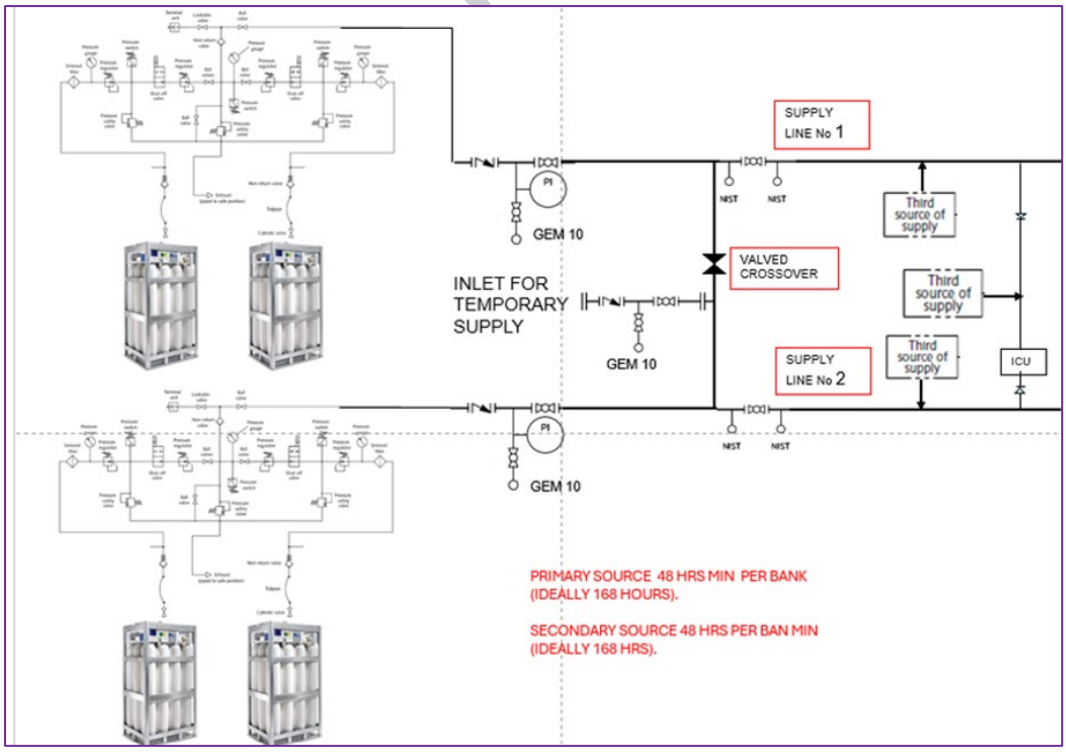
5.157. In this example, the automatic cylinder manifolds are considered as a single supply source for the MGPS.

Figure 5.6 - Supply system with compressed cylinder auto changeover manifold supply sources



5.158. Figure 5.7 shows the same configuration for a compressed medical oxygen supply system but using cylinder packs on a changeover manifold as the supply unit.

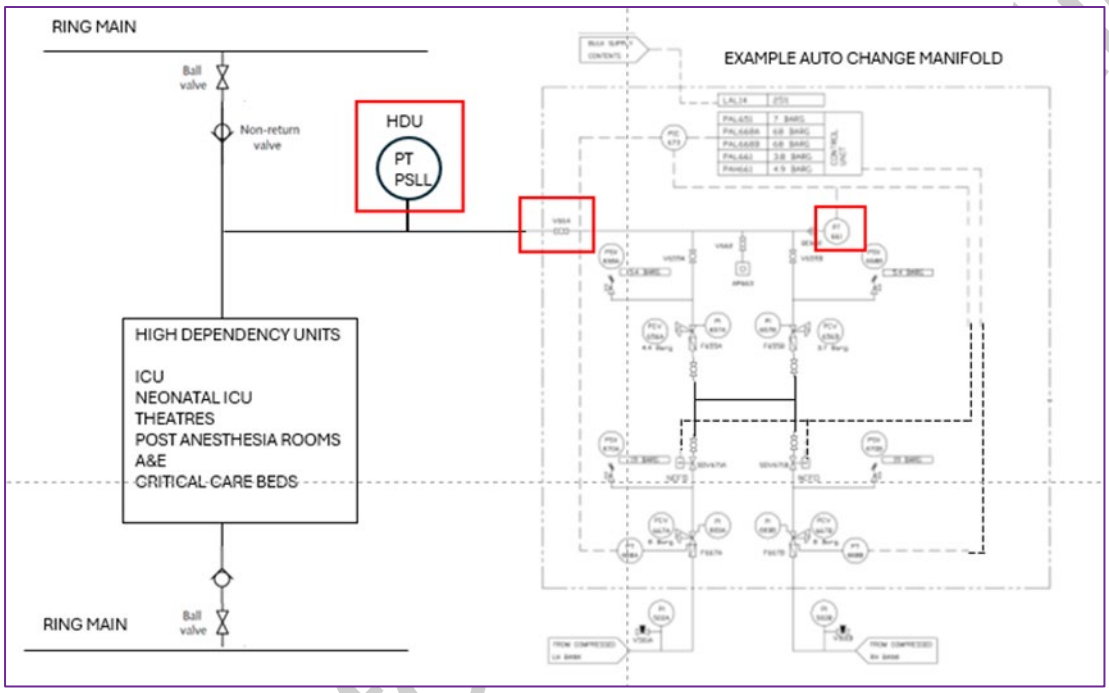
Figure 5.7 - Compressed cylinder pack with auto changeover manifolds for the primary and secondary supply sources



5.159. Figure 5.8 shows the configuration for a reserve supply system installed close to a critical care area for those critically ill patients who require medical oxygen continuously. The configuration shows the location of regulators to provide auto changeover and to automatically activate the high-pressure cylinder manifolds, located as close to the patients as possible.

5.160. These high-pressure cylinder manifolds should be capable of supplying medical oxygen immediately and allow sufficient time for manual valves to be operated on the MGPS to resolve the fault condition.

Figure 5.8 - Compressed cylinder reserve supply system for HDUs



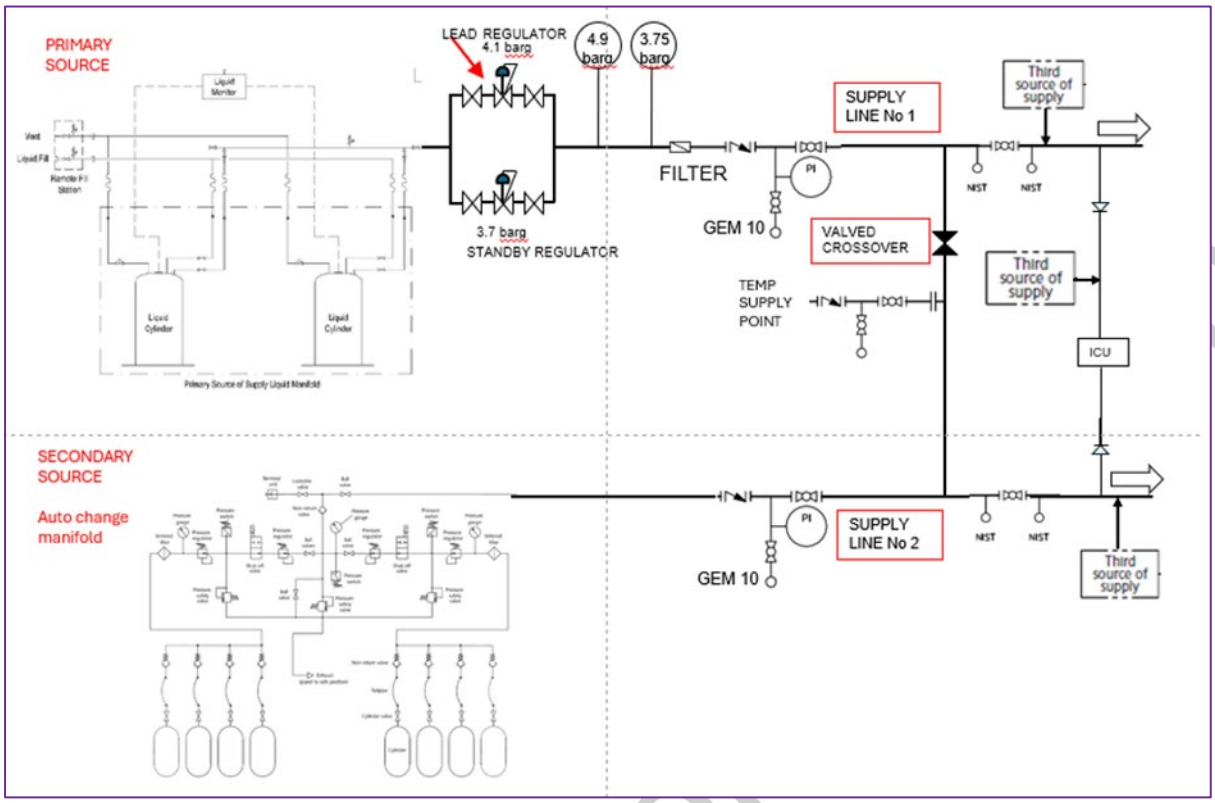
5.161. Figure 5.9 shows the configuration of the liquid cylinder supply system, where the liquid cylinders are manifolded together as the prime supply system, and a high-pressure changeover manifold as the secondary supply source.

5.162. The configuration includes two discrete, duplicate regulators on the primary and secondary supply sources feeding into duplicate pipelines. This changes how the secondary supply automatic manifold comes into operation.

5.163. The supply system also shows the potential locations for reserve supply sources located close to critical care areas.

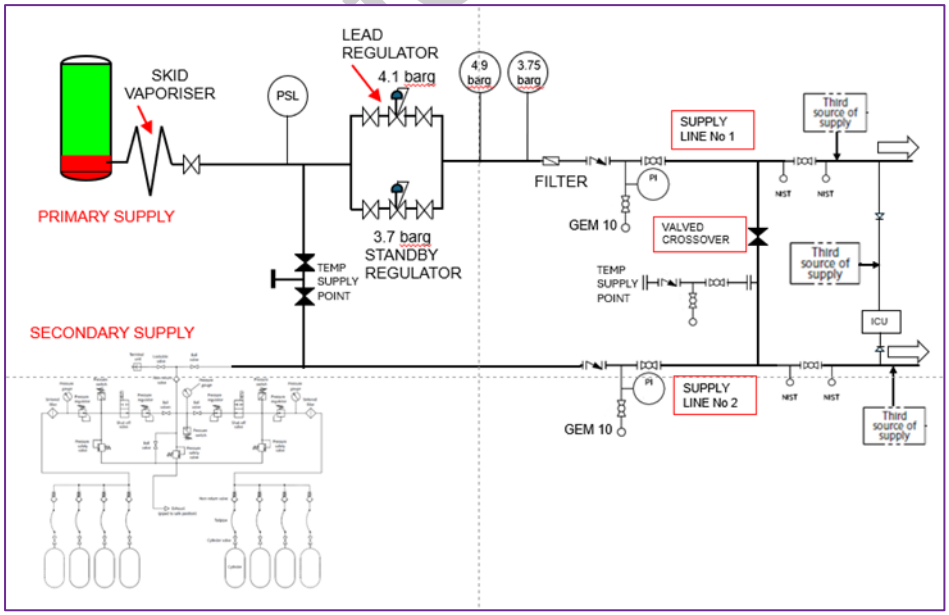
5.164. As multiple liquid cylinders are installed together, it allows exchanging a faulty liquid cylinder without causing any interruption to the flow of gas to the MGPS.

Figure 5.9 - Liquid cylinder primary supply source with auto changeover secondary supply source and remote reserve supply sources



5.165. Figure 5.10 shows the configuration for a single mini tank with the same valving as the liquid cylinder system, that will allow the onsite maintenance of the tank filling valves, pressure raising valve and level gauge without significant disruption to the MGPS.

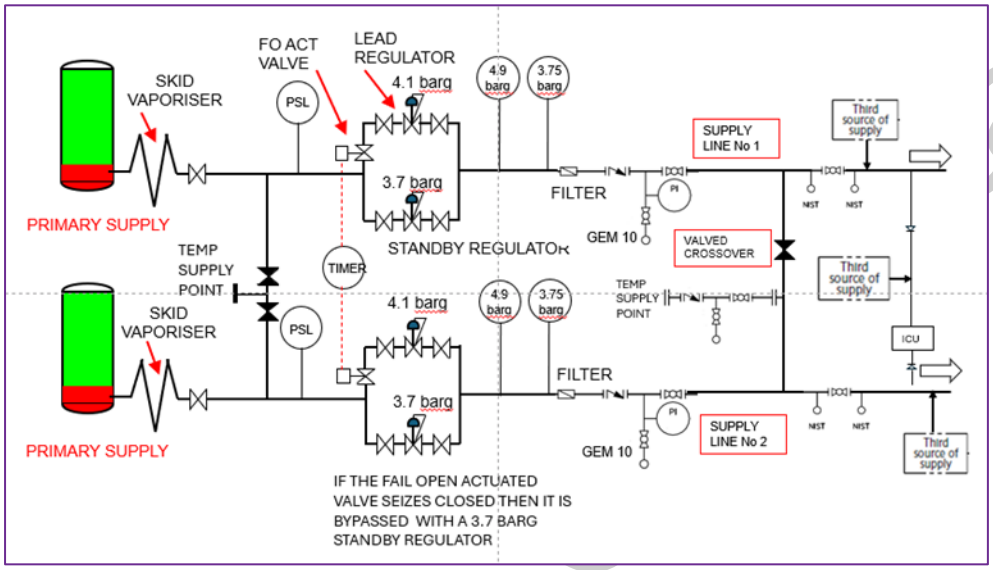
Figure 5.10 - Mini-tank primary supply system with high pressure cylinder auto changeover secondary supply source and remote reserve supply sources



5.166. Figure 5.11 shows the configuration for two mini-tank primary supply sources on a TCO. The duplicate primary supply source feed into duplicate supply lines. With duplicate mini-tanks alternated using a TCO system, it allows the skid mounted vaporisers to have a defrosting cycle. System controls and bypass arrangements provide for a failsafe design.

5.167. The mini-tanks require valving arrangements to facilitate the onsite maintenance of the tank filling valves, pressure raising valves and level gauges without significant disruption to the MGPS.

Figure 5.11 - Dual mini-tank primary and secondary supply systems with TCO arrangements between the two supply sources



5.168. Figure 5.12 shows the configuration for a VIE primary supply system used for a healthcare facility where the MGPS flow requirements are relatively low. It has a high pressure compressed cylinder auto changeover secondary supply source located adjacent to the VIE, feeding in to duplicate pipelines. The supply system also shows a high-pressure cylinder reserve supply source connected to the MGPS close to a critical care area. The supply cylinder manifold and its operating duration are very short, approximately one hour per bank in some instances has resulted in some systems being upgraded to a VIE + VIE system.

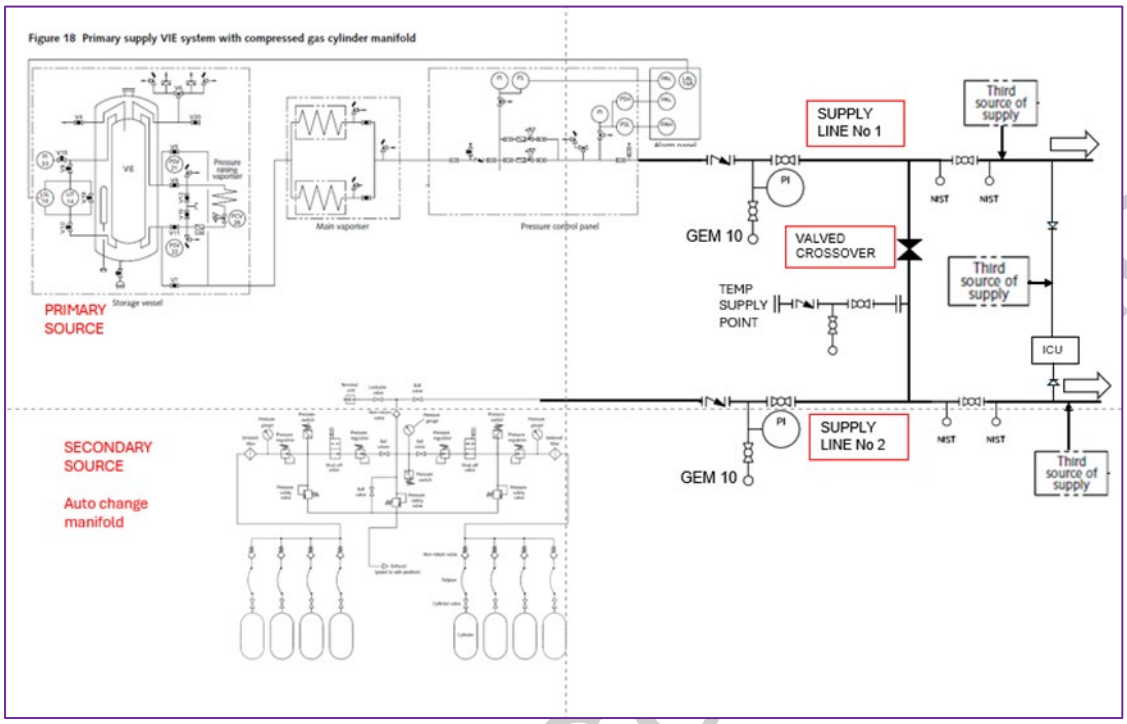
5.169. Should these systems be implemented on new healthcare facilities or when upgrading existing medical oxygen supply system, where the average flow exceeds 800 litres/min then a twin VIE system should be considered.

5.170. It is recommended that they use dual regulator panels on each supply source, with auto changeover manifolds and diverse supply lines.

5.171. This type of system is suitable for flows up to 400 litres/ min.

5.172. The VIE regulator control panel and vapouriser units should be designed for flowrates up to 3,000 litres/ min.

Figure 5.12 - VIE primary supply source with a high pressure cylinder automatic cylinder manifold as the secondary supply source



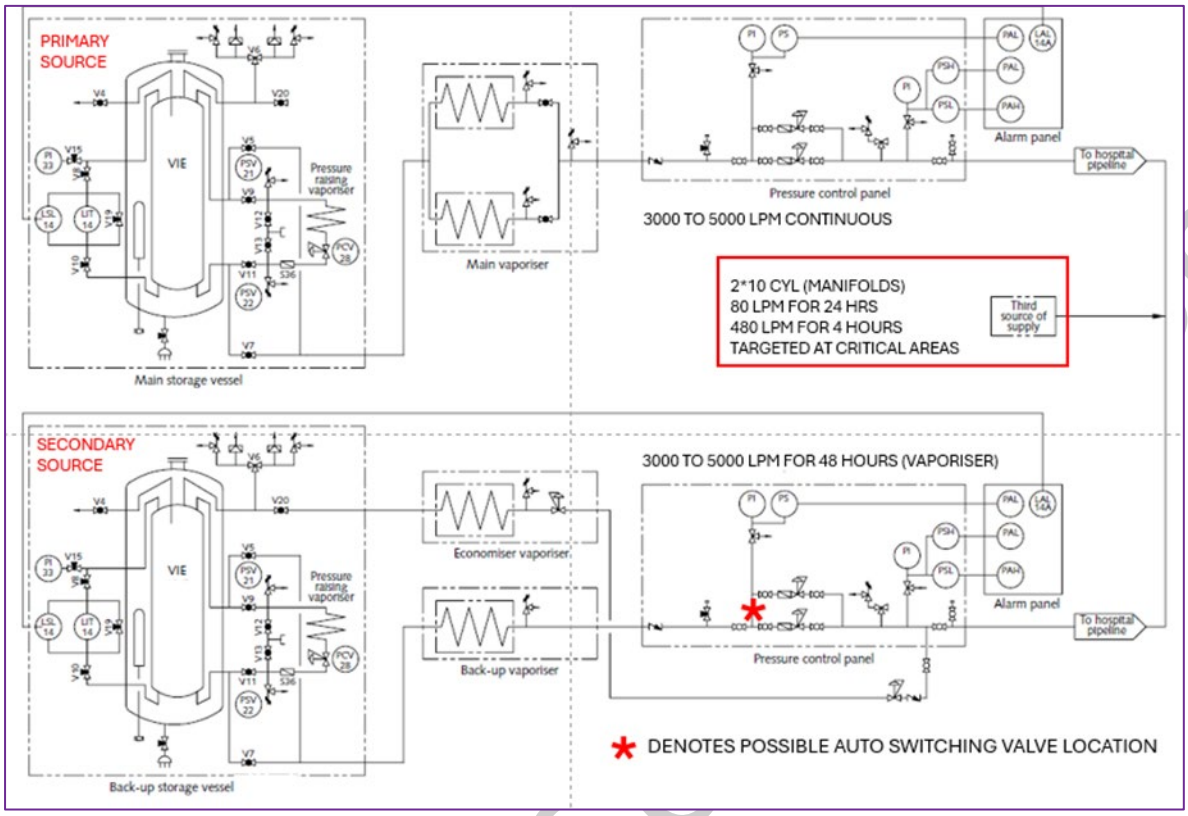
5.173. Figure 5.13 shows the configuration for a medical oxygen supply system where VIEs are used for both the primary and secondary supply sources for larger healthcare facility. Although a compressed cylinder supply source with an auto changeover control system could be used as the secondary system, the limited volume makes the two VIE system a more robust option and is being used for most healthcare facilities, when reviewing their medical oxygen supply systems.

5.174. With the changes in the requirements for three independent supply sources, this configuration requires a separate reserve supply source(s), located closer to the critical care areas that the MGPS supplies.

5.175. The configuration uses dedicated dual regulator panels for the two supply sources and diverse supply pipelines into the healthcare facility. The supply system has the ability to supply the healthcare facility over a wide range of annual usages, with flowrates up to 2,000 litres/min. The standard design control panel has a maximum flowrate capacity of 3,000 litres/min, which exceeds the requirements for most healthcare facilities.

5.176. Having dual VIEs for the supply system allows the two VIEs to be sited on different plinths remote from each other, providing a more robust layout.

Figure 5.13 - VIE primary and secondary supply sources, potentially located at separate locations with cylinder auto changeover reserve supply sources located within the healthcare facility



5.177. Figure 5.14 shows a medical oxygen supply system which utilises two primary supply sources but has no secondary supply source, normally only used for the largest healthcare facilities.

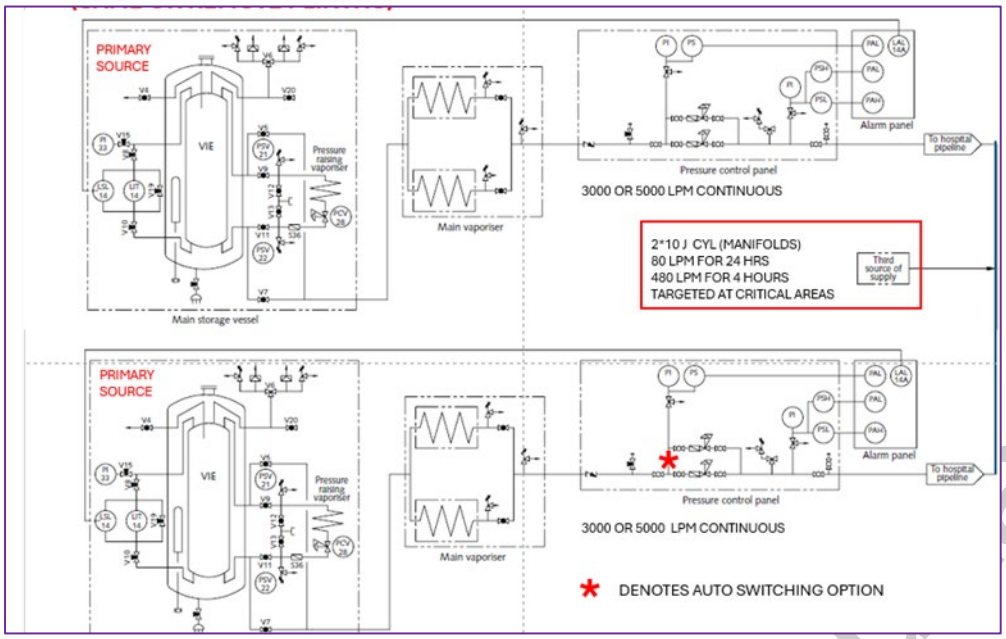
5.178. The two VIE primary supply sources can be located on separate sites to provide a more robust installation. Each VIE has twin auto changeover vapourisers to allow for continuous flow and a control panel with dual regulators to allow for single fault conditions.

5.179. The system also has the ability to switch between tanks on a TCO to allow the liquid supply line from the tanks to the vaporisers to defrost.

5.180. This configuration also allows the two VIEs to supply separate sections of the MGPS, with each section feeding only part of the healthcare facility. In the event of a single fault failure, using auto changeover valve arrangements, each VIE would be capable of supplying the total MGPS system, whilst the single fault condition is rectified.

5.181. Reserve supply sources should be provided to supply areas where critically ill patients are being treated, using automatic cylinder manifolds.

Figure 5.14 - Duplicate VIE primary sources feeding into separate sections of the MGPS with auto changeover valves between sections

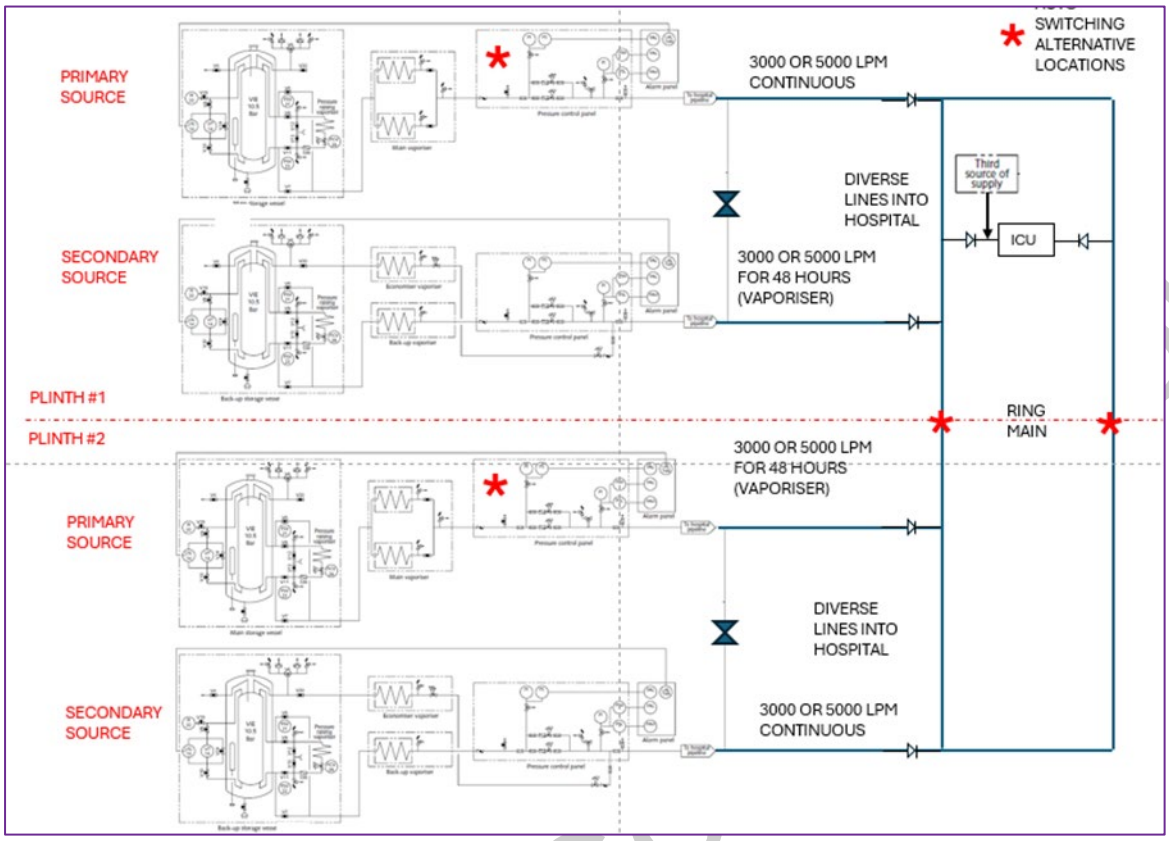


5.182. Figure 5.15 shows an alternative configuration for a medical oxygen supply system, utilising two separate supply system with a VIE primary and secondary supply source, for supplies to a large healthcare facility. Each primary and secondary supply source can be used to supply a separate section of the MGPS, with auto changeover valves, switching supply sources in the event of a failure of one of the systems.

5.183. Reserve supply sources should also be provided to supply areas where critically ill patients are being treated, using automatic cylinder manifolds, to allow for single fault conditions of the MGPS.

5.184. Having the two supply systems in separate VIE compounds also has the benefit if using smaller VIEs, which may be beneficial for planning permission.

Figure 5.15 - Dual VIE primary and secondary supply systems sited remotely feeding into separate sections of the MGPS



Supply system location/ siting

5.185. The siting of medical oxygen supply systems using high pressure cylinders and cryogenic storage tanks is covered in detail in the British Compressed Gas Association (BCGA) Codes of Practice (CP), available online to download.

5.186. BCGA Code of Practice CP 36; 'Cryogenic Liquid Storage at Users' Premises' provides best practice information about the siting of cryogenic storage tanks and the recommended safety distances for different sizes of storage tanks.

5.187. BCGA Code of Practice CP 40; 'Security Requirements for the Industrial, Medical and Food Gases Industry' provides best practice details the security and safety requirements for cylinder storage, covering the Healthcare Facilities. Secure storage arrangements and suitable separation distances are provided in the document.

5.188. For medical oxygen supply systems using liquid medical oxygen, the healthcare facility should involve the medical gas supplier in deciding the location of the cryogenic vessels on site to ensure that the chosen location meets the requirements specified in the BCGA Code of Practice CP 36.

5.189. Any relaxation of the specified safety distances should be risk assessed and the justification for reducing distances documented.

5.190. Typical distances for the different capacities of the storage tanks are given in Table 5.2 below:

Table 5.2 - Safety distances for cryogenic tanks on healthcare facility sites

Safety distances from exposure to Supply System storage tank/ 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 and the like	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
Medium voltage (MV) or high voltage (HV) electrical sub-stations	5	8

5.191. When considering the space requirements for the medical liquid oxygen compound(s), there may be operational advantages in having more than one compound in different areas on the healthcare facility 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 BCGA Code of Practice 36.

5.192. As the offloading process requires access to the offloading point (both day and night), and is very noisy, the cryogenic storage tank compound should not be located near any wards or departments that may be sensitive to noise.

5.193. The supply systems should be located in a secure fenced compound, which should be large enough to gain access to all of the control equipment and to inspect the integrity of the system. The compound should not be used for the storage of other equipment.

5.194. Ideally, the VIE or mini-tank should be installed on level ground, with only sufficient gradient to prevent the accumulation of water within the compound.

5.195. The area should provide adequate airflow for the air heated vaporisers to minimise the icing up of the tank and the associated pipework.

5.196. The layout of the compound should provide adequate access for the cryogenic delivery tanker to discharge its load into the cryogenic storage tanks.

5.197. The medical gas supplier should approve the area and confirm that it is suitable for the size and type of cryogenic tanker that will be used to deliver the product. For larger VIEs, the product may be delivered by 44 tonne articulated vehicles which will require adequate space to manoeuvre into position for offloading. For the deliveries to a liquid cylinder or mini-tank installation, normally a small rigid tank is used which requires significantly less space to make the delivery.

5.198. As the rear of the tanker is used for making the delivery, access to the compound should avoid any tight turning circles and permit the largest tanker to reverse in front of the tank.

5.199. The area directly in front of the storage tank should be kept clear to provide access for the delivery vehicle at all times. Under no circumstances should unauthorised vehicles be permitted to park in front of the compound.

5.200. The storage tank plinth should be of concrete construction and the area in front of the tank (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.

5.201. The medical liquid oxygen supply system control panel should preferably be housed in a clean dry area/ building, close to the supply system compound.

Alarm and monitoring systems

5.202. The alarm systems for medical oxygen supply systems need to comply with the requirements that are detailed in Section 10. The additional requirements that can be used

for medical oxygen supply system alarms and integrated information systems are given in the paragraphs 5.203 – 5.232.

5.203. Medical oxygen cylinder auto-change manifolds and liquid cylinder/ mini tank installation can be supplied with a human machine interface (HMI) visual display, which potentially can provide additional information including:

- the rate of supply and the time remaining in the manifold/ manifold bank
- pipeline pressure readings
- valve positions
- manifold system alarms (not covered by the standard alarm requirements)
- gas detection/ environment alarms for liquid cylinder and mini tank systems
- data logging of the information for preparation of reports

The integrated system is required to provide the outputs for connection to the healthcare facility alarm system.

5.204. Medical liquid oxygen supply systems usually have a fully mechanical operation design for both simplicity and reliability, with mechanical gauges for monitoring liquid levels and VIE and pipeline pressures. Switching between supply sources is achieved via pressure regulators and the alarms are provided using hardwired switches to give warnings and verification of the supply source in use and the pipeline pressure warnings.

5.205. The use of telemetry for liquid oxygen supply systems is highly recommended in order to ensure that both the liquid oxygen supplier and the healthcare facility are aware of the operation of the system and the need to refill the VIE. This allows the liquid oxygen levels to be monitored remotely by the gas supplier and provides software generated alarms for level and high flows at the supplier's delivery planning centre.

5.206. Although traditionally the information system for liquid oxygen have been less sophisticated, due mainly to the capacity of the system and the resilience of the delivery systems, the healthcare facility is still responsible for ensuring the status of the supply system.

5.207. It is possible for telemetry to be integrated with the standard alarm system to provide additional data that can be accessed by the healthcare facility either via the gas supplier web portals or directly for the supply into the healthcare facility's building management system. From the tank levels the average flows can be provided, with flowrate alarms, with estimates of time required for refilling/ VIEs becoming empty. Where telemetry systems provide the integrated information, the Healthcare Facility is still responsible for regularly monitor stock levels and VIE/ pipeline pressures. Mini bulk and liquid cylinders systems can also be supplied with telemetry systems.

5.208. Additional instrumentation can also be provided for VIE and pipeline pressures, gas temperatures exiting the vapourisers and flow meter readings to feed into the healthcare facility building management system. This would be intended for the healthcare facility staff to view and not for the gas supplier's delivery planners. This additional information is intended to provide more visibility of the medical oxygen supply systems to pre-empt alarms and be used for data logging and trending for input to the IDP.

5.209. Medical liquid oxygen supply systems can utilise more sophisticated systems to automate the operation of the plant, such as vaporiser timed changeover valves, supply source switching valves and pipeline switching valves which may require additional alarm functionality. In all instances these systems must be fail safe and/ or have bypass valves/ pressure regulators to give high integrity and prevent the loss of the oxygen supply for patient use.

5.210. All medical oxygen supply sources must be fitted with alarm systems to provide visual and audible warnings at the plant (each site) and in an area within the healthcare facility where there is continuous 24-hour occupation, with slave panels as required.

5.211. The alarm systems described in Section 10 have only four alarms indications and a 'Normal' condition green light. For VIE systems, it is usual for a single set of four alarms to cover both the primary and secondary sources of supply. It is necessary for the reserve source(s) of supply and items such as pipework switching valves to have their own individual sets of alarms. This is also the case if three or four VIE systems are used for large healthcare facilities or where no telemetry is provided.

5.212. It is imperative that if more than one bank of four alarms is provided for the oxygen supply sources and associated equipment that clear labelling is provided to avoid confusion if an alarm arises. The visibility of the alarms related to the different oxygen systems are clearly labelled when displayed on a building management type system. The variations of oxygen MGPS are shown in Figure 5.2, Figure 5.3 and Figure 5.4 the alarms for each type follow the same basic philosophy.

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

Table 5.3 - Oxygen plant alarm conditions

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

Compressed medical oxygen systems

5.214. If the medical oxygen supply source is compressed gas cylinders changeover manifold, the 'level' or stock condition is derived from pressure transmitters/ switches built into the manifold system. Depending on whether the changeover manifold is considered to be a single supply source or a double supply source, the alarm panel should provide an indication of the imminent need to change cylinders in the manifold. The cylinder content pressures in the secondary bank/ manifold should also be indicated to ensure that the person responsible for managing the system is aware of the timeframes available to ensure continuous supply.

Liquid medical oxygen systems

5.215. If the medical oxygen supply source is a VIE liquid oxygen system, the 'level' or stock condition is derived from the VIE level transmitters/ switches. When the primary source system operational stock has been dropped to the reorder level the first alarm condition will be indicated by a yellow alarm and the legend 'refill liquid' illuminated. The primary supply will still be in operation, but utilising the risk assessed stock derived from the delivery risk management process to take account of delays/ single fault conditions in the delivery system. Normally the gas supplier will have already arranged the delivery via telemetry monitoring, preventing the alarm situation. If the alarm activates then the healthcare facility should contact the gas supplier to arrange a delivery.

5.216. When the primary source system has used the risk assessed stock and the VIE pressure starts to decay, the secondary supply system should be designed to come into operation

automatically via means of a pressure regulator or switching valve. This second alarm condition will be indicated by a yellow alarm and the legend ‘refill liquid immediately’ illuminated. This alarm condition should continue until the primary supply system is refilled.

5.217. 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 should continue until the secondary supply system is refilled. The secondary source remaining product will supply the oxygen for at least a further 24 hours. The stock levels in the tank should be determined when completing the IDP as part of the risk management process.

5.218. Should the primary or secondary source of 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. The primary and secondary sources should be on diverse supply lines so that the oxygen supply to the healthcare facility is maintained.

5.219. Should both the primary and the secondary supply fail/ be unavailable, then the reserve supply source should be activated automatically.

5.220. If the pressure 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. The primary and secondary supply sources should be on diverse supply lines so that the oxygen supply to the healthcare facility is maintained, allowing the supply source causing the high pressure to be isolated.

5.221. If the primary and secondary sources are at the same location then the local alarm panel can cover both systems. If the supply sources are located on remote plinths, separate local panels will be required at each location. The labelling of the panels to identify them as primary and secondary supply sources is important to avoid confusion. This is especially important when they are located remote from each other.

5.222. In the event that the primary (or secondary) vessel becomes empty (or suffers from any other fault condition), the ‘normal’ display should be extinguished, indicating that the vessel is not available for use.

5.223. All alarm conditions should be transmitted to the central alarm system.

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

Table 5.4 - Liquid Oxygen central plant alarm conditions (3 VIE system)

Status/ fault condition	Indication	Legend
• Normal operation • System available for use	Green	Normal
• Primary supply source operation stock level alarm (reorder point) • Primary supply source risk assessed stock in use	Yellow	Refill liquid
• Primary supply source empty (and/ or low pressure) • Secondary supply source in use	Yellow	Refill liquid immediately
• Secondary supply source low level alarm, risk assessed stock in use	Yellow	• Secondary source low • Replenish secondary source stock
Pipeline pressure high or low	Red	Pressure fault
• Normal operation • System available for use	Green	Third supply source normal
• Third source of supply in use	Yellow	Check primary and secondary source faults
• Third source of supply low level, reorder point • Risk assessed stock in use	Yellow	Refill liquid
• Third source of supply empty (and/ or low pressure)	Yellow	Refill liquid immediately
• Pipeline pressure high or low	Red	Pressure fault

5.225. The primary and secondary VIE sources of supply are normally sited on the same plinth and the reserve VIE is on a remote plinth.

Table 5.5 – Liquid Oxygen central plant alarm conditions (4 VIE system)

Status/ fault condition	Indication	Legend
• Normal operation • System available for use	Green	Normal
• Primary supply source operational stock level alarm (reorder point) • Primary supply source risk assessed stock in use	Yellow	Refill liquid
• Primary supply source empty (and/ or low pressure) • Secondary supply source in use	Yellow	Refill liquid immediately
• Secondary supply source low level alarm, risk assessed stock in use	Yellow	• Secondary source low • Replenish secondary source stock
Pipeline pressure high or low	Red	Pressure fault

5.226. Where four VIEs are used to supply a major healthcare facility (where the medical oxygen pipeline system is split into two sections with a pair of VIEs supplying each section) the primary and secondary VIEs for each section will be installed on the same plinth with the plinths at separate locations. The two systems would normally operate independently, but with the ability for each system to supply the whole hospital under fault conditions, using manual or automatic valves on the MGPS. The identification of these systems is key to avoid operator confusion.

5.227. The following tables provide typical alarm panel configurations

5.228. Table 5.6 provides the typical alarm panel configuration for independent alarm control panels at each location where the third source is an automatic cylinder manifold(s)

Table 5.6 - Oxygen central plant alarm conditions (3rd source of supply via cylinders

Status/ fault condition	Indication	Legend
• Normal operation • System available for use	Green	Normal
Third source of supply in use	Yellow	Check primary and secondary supply source faults

Status/ fault condition	Indication	Legend
Left-hand or right-hand bank low	Yellow	Left-hand or right-hand reserve low
Left-hand or right-hand bank empty	Yellow	Replenish cylinders
Pipeline pressure high or low	Red	Pressure fault

5.229. Medical oxygen automatic cylinder manifolds typically have an HMI visual display. The alarm layout provides additional information to aid the operator, (see paragraphs 4.19 to 4.28).

5.230. If the reserve supply source comes into use then it is important to investigate what faults are present on the Primary and Secondary Supply Sources and to rectify faults as soon as possible. It is also important to organise cylinder stocks from the main store and have them available at the manifold.

5.231. If a manifold bank low level alarm activates, normally at 68 bar(g) then this gives an early warning to ensure additional cylinders are brought up from the central store to the manifold.

5.232. 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. Medical compressed air systems

General

Foreword from the National Patient Safety Alerting Committee (NaPSAC)

6.1. Prior to the end of 2021, it was usual to see air flowmeters on wall based medical gas pipeline system (MGPS) terminal units alongside oxygen flowmeters and suction apparatus. The use of an air flowmeter was primarily to drive the administration of nebulised medication; typically for short periods to manage respiratory conditions. Most other uses of piped medical air do not require an air flowmeter.

For over a decade, repeated patient safety incidents have reported misconnection of patients to the medical air flowmeter instead of an oxygen flowmeter. The proximity of the piped medical air and oxygen terminal units at the bedside, and the similarity in design of flowmeters, clearly presented a significant patient safety risk.

As a consequence of the reported incidents, the NHS England national patient safety team issued several patient safety communications in an attempt to mitigate this risk. This included:

- **Rapid Response Report** - Oxygen safety in hospitals (2009): highlighted the risk of misconnection and requested that organisations develop action plans to prevent these incidents
- **Patient Safety Alert** - Reducing the risk of oxygen tubing being connected to air flowmeters (2016): that mandated the implementation of three specific barriers

In 2018, 'Unintentional connection of a patient requiring oxygen to an air flowmeter' was added to the Never Event framework. Between 1 April 2018 and 31 March 2021, there were 108 reported Never Event incidents describing unintentional connection; over a third of incidents occurred in emergency departments. Consequences included respiratory arrest, cardiac arrest, collapse (requiring Intensive Therapy Unit (ITU) admission and ventilation), and nine incidents of incorrect connection when responding to cardiac arrest, which will have impacted on the chance of successful resuscitation; six patients subsequently died.

Review of incidents indicated that misconnection was often an 'unconscious error' (the person did not realise that they had made a wrong connection) and so incidents often went undetected even when other staff responded to deterioration or took over care. As a result, the NHS England national patient safety team adopted a more robust solution to eliminate the use of air flowmeters in their 2021 National Patient Safety Alert (NPSA) (Eliminating the risk of inadvertent connection to medical air via a flowmeter).

The resultant impact on the system is that the requirement for medical air outlets is now far less than when the previous edition of this Scottish Health Technical Memorandum (SHTM) was written.

6.2. Medical compressed air can be derived from compressor systems, from cylinders connected to an automatic manifold or by mixing gaseous oxygen and nitrogen from cryogenic liquid supply sources. Air produced by this latter method is referred to as synthetic air. All medical grade compressed air delivered in cylinders is also synthetic manufacture.

6.3. Current clinical practice has negated the extensive use of air for surgical purposes, therefore when designing healthcare facilities, consideration should be given for surgical air to be supplied from a portable source (that is compressed gas cylinders). The appropriate selection must be made based upon an informed design process (IDP) where an assessment of consumption has been undertaken.

6.4. With reference to the NPSA described in paragraph 6.1, the foreseeable use of medical air through a flowmeter for clinical use is negligible. Therefore, medical air consumption and hence supply source and distribution systems will be much smaller than systems designed based on earlier algorithms and tables. This may result in the most economical and sustainable supply source being from a compressed gas cylinder manifold system. For completeness, requirements for compressor and manifold systems will be described below.

Compressor systems

6.5. Other source of supply configurations are possible depending upon the specific design requirements, for example for larger hospitals:

- separate sources of supply could be justified each serving a particular area
- with synthetic air, however, careful planning is required to consider the emergency back-up required, the use of nitrogen for surgical use, safety and cost in comparison to the conventional means of supply

6.6. Conventional system configurations where medical air is derived from medical air plant may still be appropriate if it is determined that the requirement is of a level where other sources of supply would not be appropriate for example, an automatic manifold that may require regular cylinder changes resulting in increased cylinder storage as well as additional staff resources. Undertaking an assessment through the IDP (see Section 1), as well as using historical data from existing hospital sites should be considered for improved sustainability and cost effectiveness.

6.7. The following Table 6.1 sets out the various source of supply configuration which should be considered dependent on the healthcare facility, size, patient cohort and function.

Table 6.1 - Source of supply matrix

Source of Supply	Large acute teaching hospital (1)	District general hospital	Small specialist hospital (2)	Community hospital (3)
Compressor Plant (Primary)	Yes	Yes	No	No
Automatic Manifold (Emergency Reserve Manifold (ERM))	Yes	Yes	No	No
Automatic Manifold (Primary)	No	Yes	Yes	No
Manual manifold (ERM)	No	Yes	Yes	No

6.8. The above table may be considered as the basis of source of plant selection in conjunction with the IDP.

Quality

6.9. 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

6.10. The plant should have all-round access for maintenance purposes, and allowance should be made for replacing components. Other services should not obstruct access, for example electrical supplies for the plant should not be located on the plantroom floor.

6.11. The siting of the plant should allow for adequate natural ventilation for three different purposes:

- air intake to the compressors
- cooling of the compressed air by the aftercoolers
- cooling of the compressors

Compressor noise

6.12. 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.

Table 6.2 - Compressor noise levels

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

6.13. 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

6.14. 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, Anaesthetic gas scavenging system (AGSS) and ventilation systems or other sources of contaminants. 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.

6.15. Care is needed when considering air compressor locations.

6.16. 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 British Standard (BS) International Standard (ISO) 5011 and be either dry medium filters or grade CA paper element filters.

Compressor types

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

- reciprocating piston compressors
- rotary vane compressors
- rotary screw compressors

6.18. 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, for example consideration should be given to variable speed/ inverter drive motors. In medical compressed air applications, this would reduce the stop/ start frequency by maintaining a constant pressure within close limits. With this type of control, it is feasible to consider the eventual removal of the receiver.

6.19. Rotary screw compressors, particularly in the lower kW sizes, are commonly used 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

6.20. Compressors may be oil-lubricated, provided that suitable arrangements are made to ensure that the air quality specification given in Table K 2 is fulfilled (refer to Section 13).

6.21. The normal medical air compressor configuration is oil-sealed and 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, Polytetrafluoroethylene (PTFE) ring or diaphragm-sealed type. However, the pulsating frequency of the piston and noise generated would normally require an acoustic enclosure.

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

6.23. 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.

6.24. 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 6.70 to monitor compressor temperature and to close down the compressor on fault condition. BS EN ISO 15001 specifies the requirements for selecting materials used in medical supply equipment.

6.25. 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.

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

6.27. Once a compressor installation has been selected:

- the plant should include at least two compressors, but additional compressors may be included in accordance with requirements determined by the IDP
- the individual compressors should be arranged so that they will supply the system simultaneously if necessary
- the whole life capital and operating expenditure should be evaluated at the time of purchase. The operating costs should be calculated at realistic levels of usage and consider servicing and maintenance requirements
- 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

Aftercoolers

6.28. Aftercoolers (and intercoolers) usually form part of the compressor sub-assembly. Aftercoolers 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

6.29. Air receivers should comply with BS EN 286-1 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. Receivers should also be fitted with the facility to enable drainage to be undertaken manually.

6.30. 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.

6.31. 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

6.32. 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

6.33. Filtration for the purposes of removing solid contaminants in compressed medical air system generated by a compressor should conform to ISO 8573-1 and comply with the appropriate sections of the current edition of the Ph. Eur.

Water

6.34. 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/m3 to over 40 g/m^3 depending on the climatic conditions. The aftercooler and receiver remove some of this, but about 20 g/m^3 is likely to remain in the compressed air unless removed by dryers.

6.35. 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

6.36. 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.

6.37. 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 aftercooler properly designed, the amount of oil present as vapour should be small and is unlikely to exceed 0.5 mg/ m^3.

6.38. 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/ m^3, particle removal down to 1 micron and a dispersed oil particulate (DOP) penetration of less than 0.03%. The coalescing filter should further reduce the remaining oil content to 0.01 mg/ m^3, 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.

6.39. 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.

6.40. 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).

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

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

Dryer and filter assembly

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

Dryer controls

6.44. 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

6.45. 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.

Activated carbon filter

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

Bacteria filters

6.47. 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%.

Carbon monoxide

6.48. In areas where intermittent high levels of atmospheric carbon monoxide are present (for example, near a busy road), the healthcare facility should consider installing a treatment system to remove carbon monoxide from the compressed medical air supply.

Pressure control

6.49. The pressure control should maintain the nominal pipeline pressure within limits given in Section 2. Duplex line pressure regulators should be provided with suitable isolating valves. The regulators should be of the non-relieving type.

Safety valves

6.50. Safety valves should be provided in accordance with the requirements given below. All safety valves should conform to BS EN ISO 4126-1. 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

6.51. All safety valves should be of the closed-bonnet type and connected to suitably sized pipework to allow safe discharge.

Traps, valves and non-return valves

Automatic drainage traps

6.52. Electrically or mechanically operated automatic drainage traps should be provided on the aftercoolers, 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 aftercooler 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.

6.53. 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

6.54. 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

6.55. 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 and component items.

6.56. Manually operated ball isolation valves should be provided 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

6.57. Pressure indicators should comply with BS EN 837-1 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.

6.58. 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

6.59. Differential pressure indicators should be provided across each:

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

6.60. 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

6.61. 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/ transducers mounted internally or externally which may require adjustment when ‘live’ should be designed and operated at extra low voltage.

6.62. 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.

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

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

Plant control unit

6.65. 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 being supplied by a separate electrical distribution system/ distribution board.

6.66. 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

6.67. A warning notice that complies with BS EN ISO 7010 ‘should be affixed which indicates the presence of low voltage.

Plant control indication

6.68. There should be indicators for each compressor as follows:

- green ‘mains power supply on’
- green ‘compressor called for’, which indicates that the compressor motor is electrically energised
- an indicator of the pressure produced by the compressor

Motor control centre

6.69. 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 be constructed in accordance with BS 7671 'Requirements for Electrical Installations' and contain the following:

- an isolator interlocked with the covers
- an industrial grade ammeter to BS EN 60051-1 International Electrotechnical Commission (IEC) 60051-1 'Direct acting indicating analogue electrical measuring instruments and their accessories - Part 1: Definitions and general requirements common to all parts' (digital ammeters of similar accuracy to those compliant with BS EN 60051-1, IEC 60051-1 may be used)
- a 'total hours' counter if not included in the plant control unit including a facility to connect this to the healthcare facility building energy monitoring system
- a green 'mains power supply on' indicator if mounted separately from the plant control unit

Dryer control unit

6.70. 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.

6.71. The dryer control unit should contain the following:

- a duty dryer selector switch
- a service function - to enable selection of continuous/ normal running
- individually protected circuits, 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 dewpoint) 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

6.72. 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
  - medical air supplied from a compressor system, when carbon monoxide level exceeds 25 parts per million (ppm)
  - 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

6.73. 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 BS EN ISO 7010 to indicate the presence of low voltage.

6.74. 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’

6.75. 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

6.76. 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 6.74)
C. yellow ‘plant emergency’ (low reservoir pressure/ high moisture: that is, condition (b) in paragraph 6.74)

D. yellow ‘reserve low’ (emergency/ reserve banks low (<50%))

E. red ‘pipeline pressure fault’ (pressure fault)

6.77. Conditions (b) to (e) in paragraph 6.74 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 50V dc and 50mA.

6.78. Volt-free, normally closed contacts rated at 50V dc and 50mA should be provided for transmission of conditions (b) to (e) in paragraph 6.74 to the alarm system.

6.79. 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.

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

Plant management

6.81. Connections should be provided which allow monitoring of plant alarm conditions (b) to (e) in paragraph 6.74 and pump running for each ‘compressor’. These connections should be volt-free contacts normally closed for each condition having a minimum rating of 50V dc and 50mA. Building and energy management systems should not be used to control the plant.

Synthetic air

6.82. 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, BS EN ISO 7396-3 covers the technical description of these systems.

6.83. 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 Hazard and Operability (HAZOP) analysis and other safety analyses that may be necessary.

6.84. 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.

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

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

6.87. The vacuum insulated evaporator (VIE) system supplying the medical oxygen may be used to supply the synthetic air system, depending on the system demands.

6.88. 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.

6.89. 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

6.90. 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 5.

6.91. 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 and the like. 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.

6.92. 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.

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

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

6.95. 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

Storage vessels

Vessel summary

6.96. 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

6.97. The following operating pressures are required:

- main vessels: 12.5 bar
- back-up vessels: 12.5 - 14 bar

Main vessel capacity

6.98. 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 and the like, which need to be taken into account when sizing the main vessels.

Back-up vessel capacity

6.99. 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.

6.100. In addition to the normal instrumentation as set out in the 'Liquid oxygen systems' text within Section 5, the vessels should be fitted with a telemetry system to monitor continuously the vessel contents.

6.101. 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.

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

6.103. The safety relief valves and bursting discs should be sized in accordance with British Compressed Gases Association (BCGA) Code of Practice (CP) 36.

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

Vaporisation

6.105. 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.

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

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

6.108. The TCO will require a 110V or 240V power supply; this should be on a circuit connected to the safety power supply and a UPS should also be provided, with at least 4 hours' capacity.

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

Medical oxygen flow control

6.110. A control panel in accordance with the requirements of BS EN ISO 7396-3 and this SHTM should be provided - the only difference is that the secondary supply is taken from a low-pressure liquid source.

Surgical nitrogen flow control

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

6.112. The pipeline distribution system should be designed in exactly the same way as for surgical air 700 kPa systems, as described in Section 7.

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

6.113. 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).

6.114. 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.

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

6.116. 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

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

6.118. 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.

6.119. 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.

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

6.121. 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

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

6.123. 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.

6.124. 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

6.125. 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)

6.126. Conditions (b) to (e) of paragraph 6.125 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 50V dc and 50mA.

6.127. Volt-free, normally closed contacts rated at 50V dc and 50mA should be provided for transmission of conditions (b) to (e) of paragraph 6.125 to the alarm system.

6.128. 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

6.129. 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 5.

Additional use of medical air systems

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

6.131. 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 area valve service unit (AVSU) labelled to identify the equipment controlled.

6.132. Medical air systems must only be used for clinical applications, refer to paragraphs 2.3 and 2.4.

7. Surgical air systems

General

7.1. Current clinical practice has negated the extensive use of medical air for surgical purposes, utilising the informed design process (IDP) (see Section 1), should the need for surgical air be identified for occasional applications and specific items of equipment a portable supply source may need to be included within the departmental operational procedures. This would be dictated by a functional suitability assessment.

7.2. Should the IDP or functional safety assessment indicate a local medical gas pipeline system (MGPS) to be most suitable, consideration should be given to peak flows and duration of operation to identify the most suitable supply source (following IDP criteria detailed in Section 1).

7.3. If there is no compressed medical air requirement within the healthcare facility 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 non-interchangeable screw thread (NIST) connector is already specified for nitrogen and should be used.

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

7.5. 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 in accordance with British Standard (BS) EN International Standard (ISO) 7396.

7.6. The maximum pressure at the terminal unit under ‘no flow’ conditions should not exceed 980 kPa.

7.7. Cylinders of medical air or nitrogen stored locally should always be available for use in an emergency.

Extension of surgical air systems into dental departments

7.8. Current clinical practice and the utilisation of the IDP make it unlikely that the scenario of extending a surgical air system for a dental department would be an option. The preferred option for dental surgeries is a dedicated compressed air system. However, should this case present itself in a redevelopment the points detailed are worthy of consideration.

7.9. 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 make this practicable

8. Medical vacuum systems

General

8.1. Medical vacuum (MV) is widely used in clinical practice, some of the more common procedures are listed below:

- Pharyngeal Aspiration
- Tracheal Suctioning
- Gastrointestinal Suction
- Pleural Suctioning
- Surgical Suction

8.2. However, there are many more specialisms and applied purposes for the vacuum system in a healthcare facility. Each clinical situation presents physical problems that have to be solved by the clinician, in doing so care must be taken so that no harm occurs to the patient either due to trauma from the catheter probe end or from the sub-atmospheric pressure application.

8.3. Pharyngeal aspiration is a common and often lifesaving requirement (although usually of very short duration). As such bedhead provision of vacuum has been seen as a necessity and the most common method of supplying MV has been from large central plants with an extensive pipe work supply system.

8.4. Under turbulent flow conditions, pressure drop increases as the square of the volumetric flow rate. At double the flow rate, there is four times the pressure drop, hence supply system pipe diameters are much larger than for a similar flowrate in a positive pressure system due to this pressure drop characteristic, hence the larger the system, the larger the diameter to achieve a given flow rate.

8.5. These central systems require a significant capital expenditure and are very high in embodied carbon due to the large diameter copper pipe that is used extensively in central vacuum systems. There is also continued operational expenditure for routine planned preventative maintenance and energy.

8.6. With the current international climate emergency, hospitals should be designed efficiently and sustainably to meet the requirements of achieving ‘net- zero’. Solutions for providing MV should be reviewed and assessed by undertaking an informed design process (IDP) if climate emergency targets are to be met. Current research being undertaken by the NHS Scotland Centre for Sustainable Delivery and the National Green Theatre Programme has demonstrated that in some acute hospitals less than 1% of the generated MV is used for

clinical purposes, this statistic should be considered when selecting the most appropriate source of MV and may render a large-scale centrally distributed system unviable.

8.7. Applying a risk-assessed, evidence-based approach when calculating the design flow rate (through the IDP) rather than relying upon historically used algorithms and tables, will result in a system that is designed to meet clinical need with the resilience to accommodate increases in demand in line with business continuity plan and any foreseen expansion due to service development.

Vacuum Flow rates and pressure levels

8.8. The principles of MV were established in the 1960s by Rosen and Hillard and Mushin and Mapleson. They were established by research and experimentation and were based upon the industrial vacuum sources available during that period. The requirement of 40 litres per minute free airflow, taken as a current standard, was derived from the then surgical need to remove one pint of blood in 4 seconds equating to an 8 litres per minute flow rate. Using a standardised suction catheter configuration of 2.5 millimetres diameter and a 300 millimetres long probe, a free air flow of 25 to 30 litres a minute was needed at the origin of the suction retrieval system. This resulted in the 40 litres per minute value at the terminal unit that has largely gone unchanged from an accepted requirement although clinical practice and equipment has changed markedly in the intervening period.

8.9. In MV, the flow rate at which a fluid (air or liquid) is removed through the system and from the patient is determined by three key factors:

- the amount of vacuum pressure available from the supply source
- the resistance of the suction system primarily determined by the dimensions of the suction catheter and the resistance of connecting tubing and collection canister
- the viscosity of the fluid/ matter

8.10. Clinical use requires equipment consisting of collection canisters, suction tubing and catheters connected to a suction regulator. The suction regulator is supplied by the vacuum source. As the regulator is altered the vacuum transfers from the source through the equipment to the end of the suction catheter. Before suction is available at the tip of the catheter there must be a vacuum in the collection canister, if the depression in the collection canister is increased the flow rate of fluid through the tube will also increase. The maximum flow rate is limited by the total resistance within the system, therefore at a certain vacuum level no additional flow is gained by further increasing the level of vacuum. As the flow increases and there is a change from laminar to turbulent flow, the dynamic of vacuum flow conditions will mean that the collection canister depression must be increased nearly four times to double the flow rate through the equipment. Therefore, the clinician must be cautious when determining the amount of negative pressure applied to the patient and only

the minimum amount of negative pressure necessary to accomplish the suction procedure should be used. Should additional flow be necessary, changes in the other suction variables such as the tubing length and diameter of the catheter should be considered as increasing the negative pressure from the vacuum has diminishing returns and may ultimately not meet the requirements that the clinician requires. This increased depression may produce a free air flow through the system which is excessive and presents a risk to the patient.

8.11. Certain departments and clinical specialties will have a higher demand for medical suctioning systems therefore the IDP needs to be completed in collaboration with the clinical teams to establish the most appropriate vacuum system for the clinical services that are being delivered. Likewise, the critical flow requirements for the department will have to be calculated by an iterative process involving the clinical specialties taking into consideration the mode of delivery. Operating theatre suites or endoscopy departments would be better suited to utilising a surgical-fluid waste management system rather than traditional medical suction and collector canister arrangements from both an operational and health and safety and environmental perspective. Up to 40% of all clinical waste from these areas are vacuum containers containing 90% fluid that is incinerated. The incineration process uses large amounts of energy purely to boil-off water adding to the environmental impact from the collection and the disposal methods of hazardous clinical waste.

Vacuum sources

8.12. There are four supply methods in which MV can be provided in a healthcare facility, these are:

1. **Ejector or venturi units** - these devices work on the venturi effect using a pressure gas to entrain air and produce a flow that can be used as a negative source of supply. They are maintenance free as they rely upon a physical relationship to function and have no moving or serviceable parts. They are efficient as they are a point of use vacuum source and do not suffer from the pressure losses associated with distributed vacuum supply. They are ideally suited where there is a need for aspiration and there is a pressure gas available that is an oxygen terminal unit. Due to their method of operation, they utilise pressure gas as the driving force. If vacuum is required consistently for more than 5 to 10 minutes on a regular basis this would not be the most appropriate source of supply as the pressure gas is vented into the treatment area after going through the venturi.
2. **Portable vacuum pumps** - these devices are used commonly in most acute healthcare settings and will always be found on emergency resuscitation trolleys. They are more cumbersome than ejectors or traditional bed head systems but offer flexibility and are often the emergency supply source for vacuum should there be primary source vacuum failure. They are suited to most forms of vacuum usage and are flexible and adaptable. They may offer the most effective form for pharyngeal aspiration in an acute setting or treatment area where there is no pressure gas or central vacuum provision.

3. **Piped MV** - this is the 'traditional' current model of most clinical vacuum supply systems and for the reasons described in paragraph 2.60 requires very careful consideration as to its suitability for specific applications in order to maintain the maxim of the Hippocratic oath "First do no harm". Utilising a risk-assessed, evidence-based IDP will identify if piped MV is a viable supply source option.
4. **Coordinated waste management and disposal systems** - these systems are commercially designed to meet the ever-changing needs of complex clinical/ surgical procedures and approach the solution from an environmental and sustainability perspective. They mimic traditional system interfaces and operation but use modern technology to separate surgical/ clinical waste into specific waste-streams treating them accordingly. These systems can offer considerable financial and environmental savings and have a positive effect on the health and safety of users. Many of these systems combine medical suction and Local Exhaust Ventilation (LEV) functions (plume evacuation) in one unit.

Pipeline system configurations

8.13. The MV 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.

8.14. To ensure continuity of supply, the vacuum plant should be connected to the safety power supply.

8.15. The capacity of the vacuum supply system should be determined by undertaking the IDP as described in Section 1.

8.16. With the exception of the vacuum discharge to atmosphere, the pipeline distribution system for vacuum has traditionally been constructed of copper. Polyvinyl chloride (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.

8.17. The major components of a MV system and their layout are detailed in British Standard (BS) EN International Standard (ISO) 7396-1, 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.

8.18. The plant should consist of at least three pumps each with matching capabilities, 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.

Siting

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

8.20. 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.

Pump noise

8.21. 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.

Table 8.1 - Vacuum pump noise levels

Power (kilowatt (kW))	Noise level (dBA)
5	75
5.1 -15	82
15	89

8.22. 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

8.23. 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.

8.24. Noise from the exhaust should be considered and a silencer fitted if necessary.

8.25. 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

8.26. 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.

8.27. The capacity of the vacuum pump should be specified in terms of the free air aspirated 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

8.28. Any type of pump apart from water-sealed pumps can be used.

8.29. 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.

8.30. 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 start/ stop or continuous operation. The opportunity to maximise energy conservation should be taken into consideration including the use of variable speed/ frequency inverter drive motors that control energy consumption electronically, providing a rapid response to any output change and thus avoiding the start/ stop frequency within the present wider pressure change corridor. This application in MV systems, with larger capacity pipe sizing in many instances, may avoid the need for a reservoir.

Vacuum reservoirs

8.31. 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, 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.

8.32. 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).

8.33. 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.

8.34. If multiple reservoirs are provided, they should be arranged in parallel.

Bacteria filters

8.35. 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.

8.36. The bacteria filter should be marked with the legend ‘biohazard’, 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 Scottish Health Technical Memorandum (SHTM) - Appendix D.

8.37. The bacteria filters should have a filter efficiency, when tested by the sodium flame test in accordance with BS 3928, of greater than 99.995% at the system design flow.

8.38. 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).

8.39. 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.

Pressure control

8.40. 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).

8.41. 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

8.42. 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).

8.43. Manually operated valves should be arranged in positions to allow isolation of components.

Pressure regulation of vacuum system

8.44. 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 within operating theatres and endoscopy, and 25 litres/ min at all other locations whilst the system is operating at system design flow.

8.45. This performance is tested by the procedures carried out in accordance with Section 13.

8.46. 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

8.47. Vacuum indicators should comply with BS EN 837-1 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.

8.48. 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

8.49. 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

8.50. The electrical supply to the MV plant should be connected to the safety power supply. The control system should ensure that pumps restart in sequence to avoid overloading the power supply.

Pump operating and indicating system

General description

8.51. 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

8.52. 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.

8.53. 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

8.54. 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 the current edition of BS7671 'Requirements for Electrical Installations', including all current amendments, and the design should be such that no single component failure in the control unit will result in loss of plant output.

8.55. 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.

8.56. A warning notice which complies with BS EN ISO 7010 should be affixed which indicates the presence of low voltage.

8.57. 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

8.58. 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

Motor control centre

8.59. The motor control centre (MCC) should have individual starter units, each one operating a single designated pump. The MCC 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 MCC should allow automatic restart after an interruption to the power supply. Each MCC should be constructed in accordance with BS 7671 ‘Requirements for Electrical Installations’ and contain the following:

- an isolator interlocked with the covers
- an emergency stop
- starter
- an industrial grade ammeter to BS EN 60051-1 International Electrotechnical Commission (IEC) 60051-1 ‘Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts’ (digital ammeters of similar accuracy to those compliant with BS EN 60051-1, IEC 60051-1 may be used)
- 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

8.60. 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

8.61. 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 BS EN ISO 7010 to indicate the presence of low voltage.

8.62. 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

8.63. The following indication of plant conditions should be provided:

A. green ‘normal’ (indicator normal)

B. yellow ‘plant fault’ conditions (b) - (d); see paragraph 8.62

C. yellow ‘plant emergency’ condition (e); see paragraph 8.62

D. red ‘pipeline pressure fault’ (pressure fault).

8.64. Conditions (b) to (d) of paragraph 8.63 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 50V dc and 50mA.

8.65. Volt-free, normally closed contacts rated at 50V dc and 50mA should be provided for transmission of conditions (b) to (d) of paragraph 8.63 to the alarm system.

8.66. 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

8.67. Connections should be provided which allow monitoring (but not control) of plant alarm conditions (b) to (d) of paragraph 8.63 and pump running for each vacuum pump. These connections should be normally closed, volt-free contacts for each condition having a minimum rating of 50V dc and 50mA.

8.68. Plant should be operated in accordance with the manufacturer's instructions and be covered by an effective planned preventative maintenance (PPM) policy.

9. Anaesthetic gas scavenging disposal systems

General

9.1. Anaesthetic gases are considered to be substances hazardous to health for the purposes of the Control of Substances Hazardous to Health (COSHH) Regulations 2002, except where they are administered to a patient in the course of medical treatment.

9.2. Detailed guidance on compliance with COSHH and workplace exposure limits is provided by the Health and Safety Executive (HSE).

9.3. 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 healthcare facility management to implement the requirements of the COSHH regulations with respect to anaesthetic gases. This subject is covered in Part B.

9.4. Anaesthetic gas scavenging systems (AGSS) are a recognised control measure in the hierarchy of controls set out by the HSE for the management of occupational exposure to harmful substances under COSHH.

9.5. As such, AGSS would be classified as a local exhaust ventilation (LEV) system and be managed in accordance with HSE's Health and Safety Guidance (HSG) 258. These systems are the most common form of compliance control for Occupational Exposure Limits (OEL) where inhalational and gaseous anaesthetics are used.

9.6. The design considerations of AGSS are complex. Whilst AGSS must protect clinical staff from occupational exposure to waste anaesthetic gases, they must also not interfere with the patient breathing circuit being used in the anaesthesia.

9.7. The original specification for AGSS was British Standard (BS) 6834 and was withdrawn in 1999. Changes in anaesthetic clinical practice over the intervening years, the technological innovation of the administration of anaesthesia and the monitoring of patient vital signs has enabled closed circuit and low-flow anaesthesia procedures to be developed. In recent years this has enabled anaesthetics to be at the leading edge of net zero carbon reduction and environmental sustainability.

9.8. The current international standard for Anaesthetic gas scavenging (AGS) systems is BS EN International Standard (ISO) 7396-2. This standard recognises the great reduction in overall and fresh gas flows that have resulted from changes in clinical practice, and hence the reduction in the flowrates to control this. These low-flow anaesthetic procedures have continually developed and in some instances have reduced the Time-Weighted average (TWa) OEL below control levels without the requirement for an AGSS. The theme of this work is continuing and currently being evaluated by the National Green Theatre Programme

in Scotland. BS EN ISO 7396-2 is the system specification that should be utilised as the basis for an informed design process (IDP) (see Section 1) for the AGSS standard under current regulatory requirements.

Note 22: Low-flow anaesthesia are techniques that employ a fresh gas flow that is less than the alveolar ventilation. The complexities involved in the calculation of uptake of anaesthetic agents during the closed-circuit anaesthesia made this technique less popular. However, modern integrated digital technology and an increasing awareness of the dangers of theatre pollution with anaesthetic agents along with the ever-increasing cost of these agents have contributed to the revitalisation of low-flow techniques. Anaesthesiologists are more commonly adopting the practice of low-flow anaesthesia as standard to reduce environmental pollution and to make anaesthesia safer and more economical.

Terminology

9.9. An active system, as specified in BS EN ISO 7396-2 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.

9.10. The transfer and receiving system form part of the anaesthetic/ breathing system.

9.11. 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, (0.05 litres/min in accordance with BS EN ISO 7396-2).

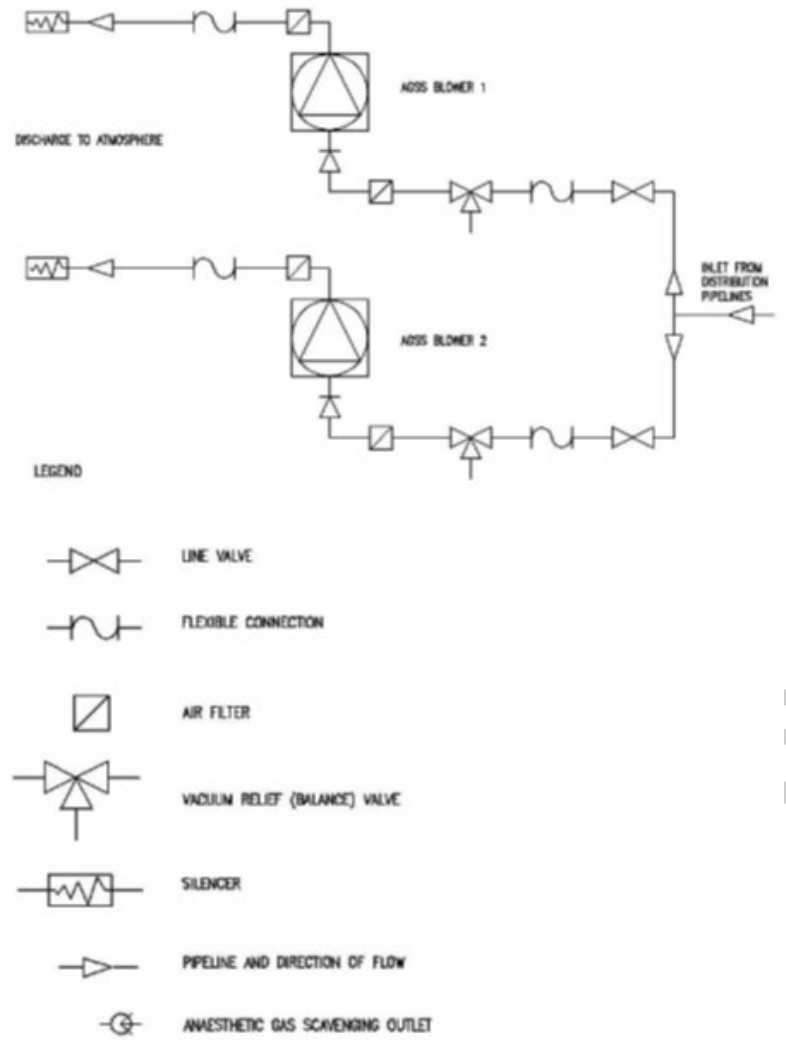
9.12. In the UK, only systems complying with BS EN ISO 7396-2 standard above are considered appropriate for scavenging waste anaesthetic gases from accommodation in which general anaesthesia is taking place.

9.13. 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, that is high level supply and low-level extract.

General

9.14. A typical system schematic is illustrated in Figure 9.1 and shows the terminology used.

Figure 9.1 - AGSS Plant schematic (duplex blowers shown)



9.15. 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.

9.16. The fixed pipework may be of copper or other suitable material such as Polyvinyl chloride (PVC). Where copper pipework is installed at the same time as the medical gas pipeline system (MGPS), it is desirable to use degreased pipework to the same specification as that used for the MGPS (see Section 12) in order to avoid confusion. Pipeline pressure testing and loss allowances should be in accordance with the requirements for AGSS pipeline pressure tests (see paragraph 9.23).

9.17. Where services (including pipes) penetrate compartment, sub-compartment, cavity barrier, or fire-resistant construction protecting escape routes (including corridors serving sleeping accommodation), they should be fire and smoke stopped to ensure they maintain at least the same level of fire resistance of the surrounding structure. (Scottish Health Technical

Memorandum (SHTM) 81 Part 1 'Fire safety in the design of healthcare premises' - section 21).

Selecting the number of disposal system pumps

9.18. The number of disposal system pumps selected for operating theatre suites should be determined through the IDP with an emphasis on the evaluation of the impact and level of disruption likely to be realised in the event of a single fault condition occurring which could result in the loss or partial loss of the system. The following selections could be considered:

- for a single stand-alone application, a duplex pump set will meet the requirements of BS EN ISO 7396-2 and 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 (OES) in compliance with the COSHH requirements being achieved
- when specifying an AGSS for multiple co-located applications such as a theatre department, an arrangement of simplex pumps connected to a manifold could be considered on an N+1 basis with manual changeover. The single pump arrangement 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. Due consideration should also be given to future maintenance requirements which will require all rooms with an AGS outlet on the system to be accessed within the same period for the purposes of carrying out a system performance test either as a planned preventative maintenance (PPM) activity or following modification of the system

Note 23: AGSS 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 BS EN 7396-2.

9.19. 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.

9.20. Protection of the system should include a safety relief valve set to suit system requirements.

9.21. The number of operating theatres and departments served by any one system should be estimated by plant location with respect to departments. 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

9.22. 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 theatre suite configuration and mode of operation should be considered in the IDP as anaesthetic rooms are not always specified or used with modern anaesthetic practices. However, should there be a requirement for simultaneous use, the plant should be sized for two AGS terminal units in dual operation for each theatre suite with that mode of operation. Otherwise, a flow rate for a single outlet should be the design criteria.

9.23. 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 Table 9.1.

Table 9.1 - Disposal system pressure and flow rates

Pressure limits	Pressure drop BS EN ISO 7396-2: 2007	Flow rate BS EN ISO 7396-2: 2007
Maximum	1 kPa	80 Litres/min
Minimum	2 kPa	50 Litres/min
Maximum static pressure	15 kPa(-ve)	N/A

Note 24: Notes applicable to Table 9.1:

a. Details of the test flows should be recorded in the commissioning documentation.

b. The pump inlet should include a vacuum indicator for commissioning and servicing purposes.

Discharge outlet

9.24. 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 E .

Plant control indication

9.25. 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)

9.26. Indicator panels should be installed in operating rooms and at other locations where gas scavenging is available.

9.27. 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.

10. System monitoring and alarms

General

10.1. The purpose of the integrated alarm and monitoring systems is to provide essential information in order to monitor the safe and efficient operation of a medical gas pipeline system (MGPS). The system shall be designed to provide the normal operating alarms, emergency operating alarms, emergency clinical alarms (as described in paragraphs 10.2 to 10.55), as well as providing information data. There are several reasons for the monitoring of these conditions which include:

- indication of the normal function of the MGPS by means of visual indicators
- to warn by visual and audible indication that one or more sources of supply within the supply source system are empty and the essential action should be taken. This includes routine replacement of cylinders, refilling of the vessel 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
- to inform clinical staff of high or low pipeline pressure, which could require an immediate response by both technical and clinical staff
- to provide real-time data, including information, for flowrates and timeframes for supply system availability, with exceptions of alarms and reminders

10.2. The basic requirements for ‘dedicated’ monitoring and alarms for medical gas systems are described in chapter 6 of British Standard (BS) EN International Standard (ISO) 7396-1. The detail below describes points that should be taken cognisance of in the informed design process (IDP) to meet this standard. However, as identified during the COVID-19 pandemic, local alarms and flow monitoring can assist in the operational delivery of safe patient services and inform clinical escalation points. Further information on this is included in paragraphs 10.52- 10.54.

Dedicated systems

10.3. The requirements of ‘dedicated’ warning and alarm systems are covered in paragraphs 10.4 to 10.55 and a schematic diagram of a typical central system layout is shown in Figure 10.1. Warning and alarm systems are required for all medical gas and vacuum systems. A simplified system is required for anaesthetic gas scavenging system (AGSS), with the warning/ indication panel located in the operating room or other area where AGSS is used.

10.4. Monitoring systems can comprise of pressure sensors, pressure transducers, flow-metering integrated into 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 area valve service units (AVSU) (see Section 3).

10.5. Pressure sensors should be fitted using a minimum leak connection. Whenever possible, pressure sensors should be installed in the AVSU (for single or multi-gas wall-mounted panels) or in a dedicated panel or box. Where this cannot be achieved, ventilation of the space will be required. They should not be installed in the ceiling space.

Panel location

Central indicator panel

10.6. Warning and alarm conditions for all medical gas supply systems should be displayed on a central panel located in a position within the healthcare facility where there is continuous 24-hour occupation.

Repeater indicator panel

10.7. 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. The inclusion of a repeater alarm panel within critical care areas (Intensive Therapy Unit (ITU), Coronary Care Unit (CCU), High Dependency Unit (HDU), Special Care Baby Unit (SCBU) and the like.) should be determined during the IDP dependant on the department escalation procedure and emergency supply source location.

Area warning and alarm panel

10.8. 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 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

10.9. Warning and alarm systems should include the following functional elements:

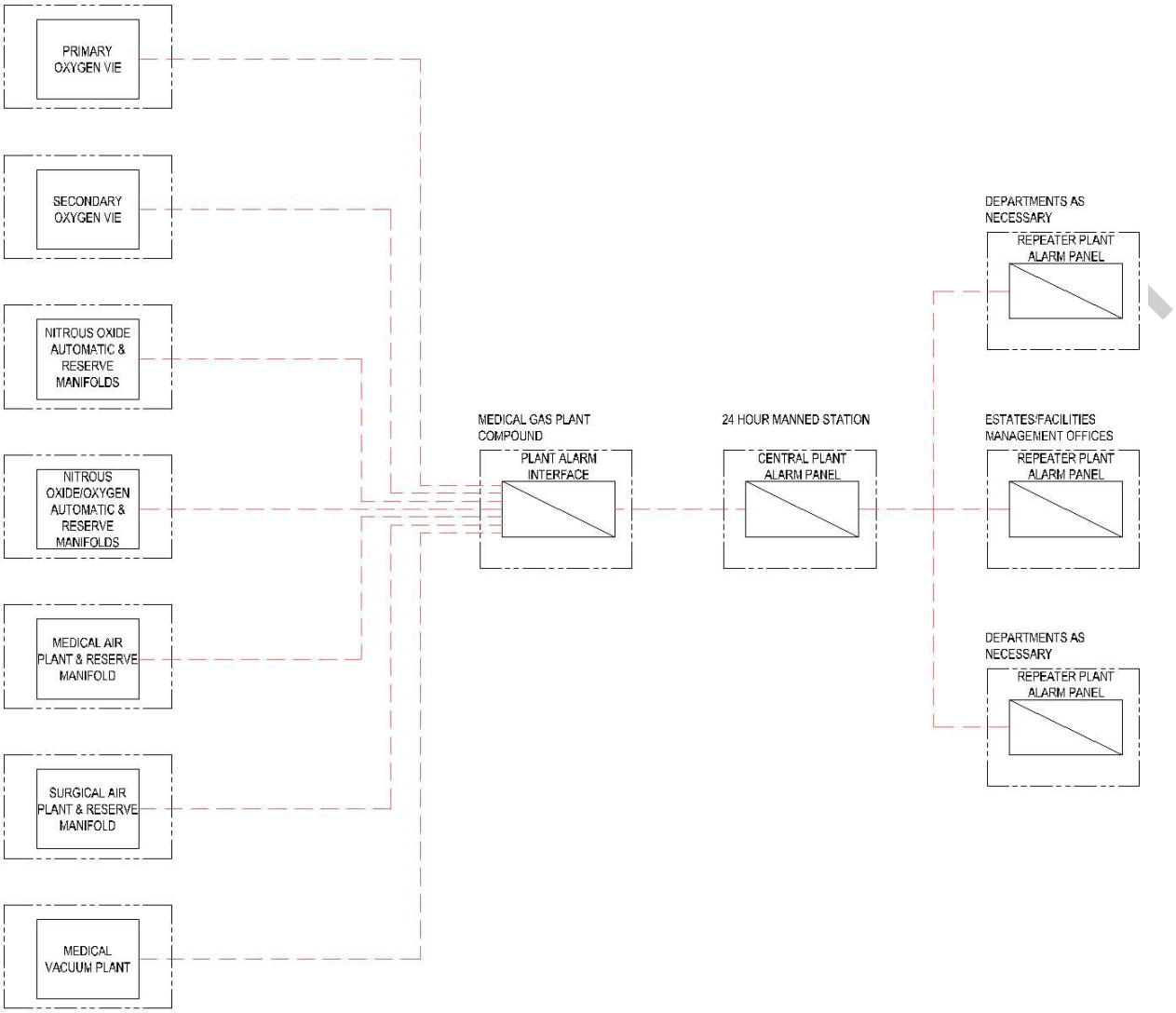
- interfaces/ transmitters that convert the signal from the plant or manifold volt-free alarm contacts into a form which can be transmitted via multiplexed cable (for example using pulse-width modulation). The transmitter may be a separate unit or may be incorporated in:
    - a plant or in a supply system control panel
    - 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

10.10. A typical system layout is shown in Figure 10.1, which shows initiating devices at remote locations such as the vacuum insulated evaporator (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 Estates Department to provide information requiring action by Estates and other support staff.

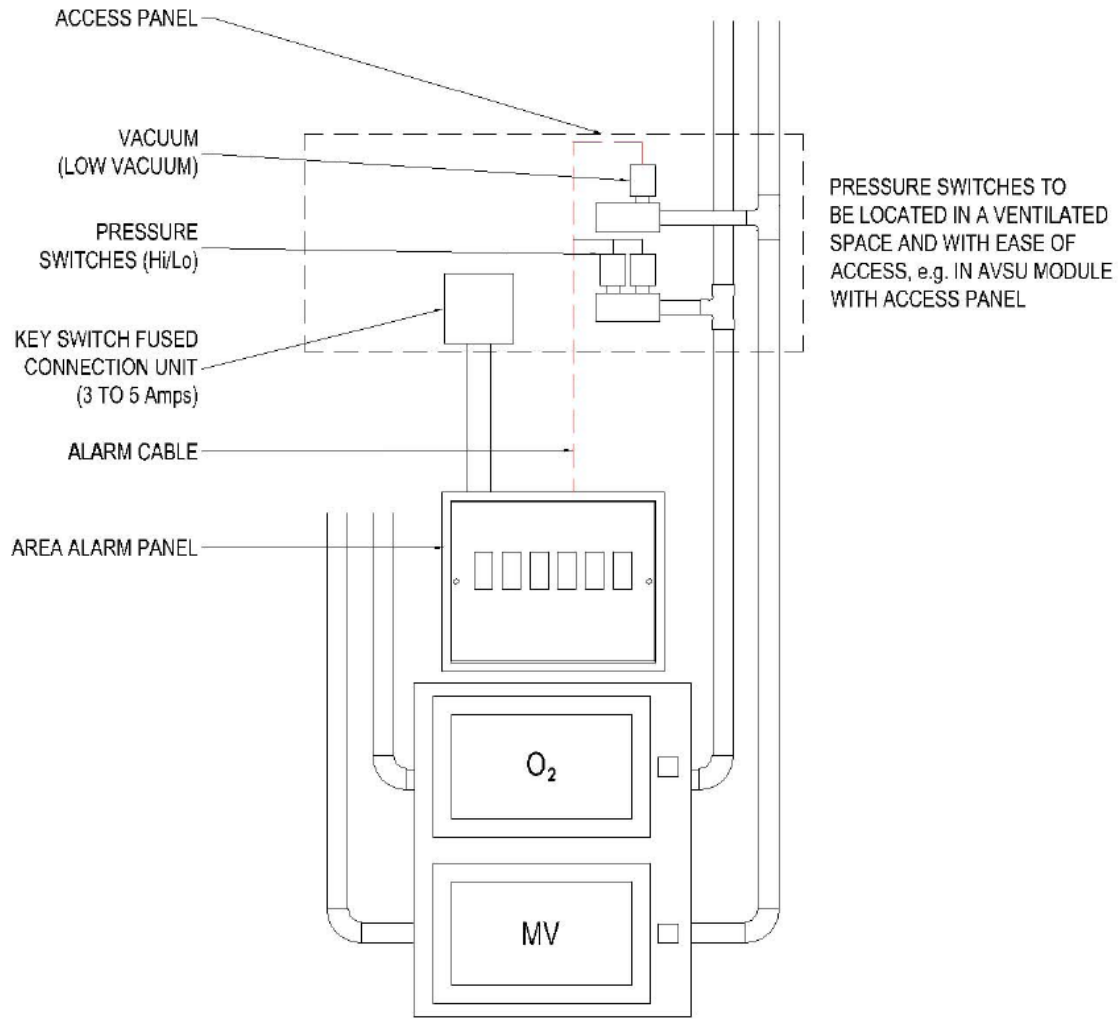
Figure 10.1 - Central plant alarm



Area alarm systems

10.11. A typical layout of an area alarm system is shown in Figure 10.2 for illustration purposes. For each gas service there should be local pressure transducers for low pressure; high pressure transducers are also required where 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 10.2 - Area alarm panel arrangement (2-gas service shown)



General requirements

Labelling

10.12. Alarm panels should be labelled as a ‘Medical Gas Alarm’ system, and all visual signal panels should be permanently labelled according to their function, including:

- identification of the medical gas/ services indicated, and the areas and departments served
- areas and departments served, with clear identification of the areas, rooms or departments

Visual signals

10.13. Flashing visual signals should have alternate ‘on’ and ‘off’ periods, each of equal duration between 0.25 and 0.50 seconds.

10.14. There should be two separately energised light sources for each signal, arranged so that the failure of one source does not affect the other.

10.15. The light sources should have a design life of at least five years of continuous operation.

Audible signals

10.16. 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

10.17. 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

10.18. 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

10.19. 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

10.20. All electrical wiring should be in accordance with the current edition of BS 7671 ‘Requirements for Electrical Installations’ including all current amendments.

System integrity

10.21. 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.

10.22. 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.

10.23. The system should be designed to reject spurious radio frequency or mains noise typically arising in hospitals, examples being diathermy equipment and current spikes caused by plant start-up and the like.

Relay conditions

10.24. If relays are used to transmit alarm signals, the relays should be energised in their normally closed condition.

Mains power supply

10.25. The mains electricity supply should be from a circuit that is connected to the safety power supply.

Safety extra low voltage/ functional extra low voltage power supply

10.26. 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 the current edition of BS 7671 ‘Requirements for Electrical Installations’.

10.27. The ELV power supply may be housed either in the alarm panels or in a separate metal enclosure.

10.28. 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

10.29. 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.

Indicators

10.30. Panels should be provided with indicators for all of the gas services in local use.

10.31. 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 (MV) plant

10.32. 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

Construction

10.33. The fascia panel should be removable to allow access to the rear of the fascia or to the panel for maintenance purposes.

10.34. Access to the interior of the panel should be tamper-proof.

10.35. It should be possible to replace the source of illumination without removing the legend.

10.36. Panels should have electrical sections with protection at least equal to IP4X as defined by BS EN 60529.

10.37. Panels and their housings should be of adequate strength for their purposes and be manufactured from corrosion-resistant materials.

Remote audible sounder

10.38. All panels should have provision for connection to a remote audible sounder.

Central indicator panel requirements

Displays

10.39. The central panel should display all signals for all MGPS which are generated by the warning and alarm system, as described in paragraphs 10.40 - 10.42, below.

Normal

10.40. 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

10.41. 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 10.1).

Emergency alarms

10.42. Emergency alarms should be indicated by loss of pipeline pressure or vacuum and are with a flashing red visual signal, accompanied by a mutable audible signal.

Panel legend and display

10.43. Panel legend and display should be as shown in Table 10.1.

Repeater indicator panel requirements

Displays

10.44. 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 reflected in the IDP.

Panel legend and display

10.45. The panel legend and display should be as shown in Table 10.1.

Area alarm panel

Panel displays and legend

10.46. Area alarm panels should display the conditions listed in Table 10.2.

Warning and alarm system faults

General

10.47. 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

10.48. 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

10.49. The system should indicate an alarm system fault in the event of loss of data transmission between panels and transmitters.

Mains power failure

10.50. 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 10.18), but the visual indicator should continue to flash until either the fault has been rectified, or the battery has discharged.

Stand-by battery

10.51. 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

10.52. The legend on this indicator should be 'alarm system fault'.

Integrated systems

10.53. Integrated technology-based information systems can provide a range of functions, such as patient information, nurse call requirements and other alarm conditions. These can be utilised to further include certain provisions of medical gas pipeline warning and alarm conditions. Where these additional functions are provided, it does not change the basic requirements for the alarm panel and the functions that are described within this Section.

10.54. The advantage of a computer-based system is that the information/ data provided can be stored and reports can be provided to assist in the performance of the MGPS to update/ confirm the design requirements of the system. The advice given can be in the form of text messages that 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 to in-patient ward accommodation; it may not be appropriate for central warning and alarm conditions to be displayed in individual operating rooms and other accommodation in which anaesthetic procedures are taking place.

10.55. When utilising integrated systems, the supplier will be required to provide the necessary instructions to operate the integrated system and to produce reports. Where the decision is taken to not display the alarm outputs described in paragraphs 10.1 to 10.52, then a separate panel shall be installed to meet the basic requirements. Audible alarms 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 made available to the end-user before the system is formally accepted.

Table 10.1 - Signals and displays for central alarm panels and repeater panels

Supply system (see note 25)	Alarm conditions	Legend	Colour	Audible system	Location (see note 25)
Automatic cylinder manifold as primary source of supply operating with secondary source of supply full	No alarm conditions	Normal operation	Green	No	A B
Automatic manifold as primary and/ or secondary source of supply	1. Duty bank empty: stand-by bank running	Change cylinders	Yellow	Yes	A B
Automatic manifold as primary and/ or secondary source of supply	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 paragraph 4.20	Reserve low	Yellow	Yes	A B
Compressed cylinders on reserve manifold serving an automatic manifold	Reserve pressure below 68 bar (<14 bar for Nitrous Oxide (N_2O))	Reserve low	Yellow	Optional	A B
Medical air compressor and surgical air compressor	1. Plant fault 2. Plant emergency	Plant fault Plant emergency	Yellow Yellow	Yes Yes	A B A B

Supply system (see note 25)	Alarm conditions	Legend	Colour	Audible system	Location (see note 25)
MV plant	1. Plant fault 2. Plant emergency	Plant fault Plant emergency	Yellow Yellow	Yes Yes	A B A B
Oxygen concentrator	1. Plant fault 2. Plant emergency	Plant fault Plant emergency	Yellow Yellow	Yes Yes	A B 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 2 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 2	Pressure fault	Red	Yes	A B

Note 25: notes applicable to Table 10.1:

1. For liquid supply systems, see Section 5
2. A = Central alarm panel - at a location within the healthcare facility that has 24-hour occupancy and B = Facilities Management (FM) office reception
3. Locations should include critical care areas, (ITU, CCU, HDU, SCBU, Accident and Emergency (A&E), Resuscitation, and the like) can be considered as appropriate

Table 10.2 - Area alarm panel legend and display

Alarm function	Legend	Colour	Auditory signal
For oxygen, nitrous oxide and medical air to indicate that the pressure in the pipeline serving the department has risen above the normal value given in Section 2.	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 2.	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 2.	Vacuum fault	Red	Yes

11. Pipeline installation

General

11.1. Generally, medical gas pipeline systems (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 and the like

11.2. Service ducts, ceiling spaces or voids containing pipelines that include valves and the like. 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 Scottish Health Technical Memorandum (SHTM). Service ducts, ceiling spaces or voids containing mechanically connected valves or pressure switches will require ventilation in line with the requirements of British Standards (BS) 8313.

11.3. 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 fire-hazard room or fire-hazard department. Additionally, medical gas pipelines should not be installed in protected escape routes such as stair enclosures, protected corridors or protected lobbies. Where pipelines in hazardous areas are unavoidable, they should be installed in accordance with BS EN International Standard (ISO) 7396-1, paragraph 12.1.7. 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.

11.4. 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 and the like**: similar protection as detailed previously should be provided to withstand 'stepping' damage using profiled section

11.5. 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.

11.6. Internal pipelines should be suitably protected where there is a possibility of physical damage, for example damage which might be caused by the movement of portable equipment such as trolleys, stretchers and trucks, in corridors and in other locations.

11.7. 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 equipotentially bonded and wrap-insulated, in accordance with BS7671 'Requirements for Electrical Installations'. The pipeline should have main equipotential bonds where they enter and exit buildings. 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).

11.8. Underground pipelines should be installed in accordance with BS EN ISO 7396-1 paragraph, 12.1.8 and risk assessed in accordance with BS EN ISO 14971. The valves should comprise line valve assemblies (LVAs) with non-interchangeable screw thread (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 11.1). 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 11.2) or double-end supply should also be considered for both air and oxygen within the curtilage of the building.

Figure 11.1 - Miscellaneous pipe routing and protection arrangements

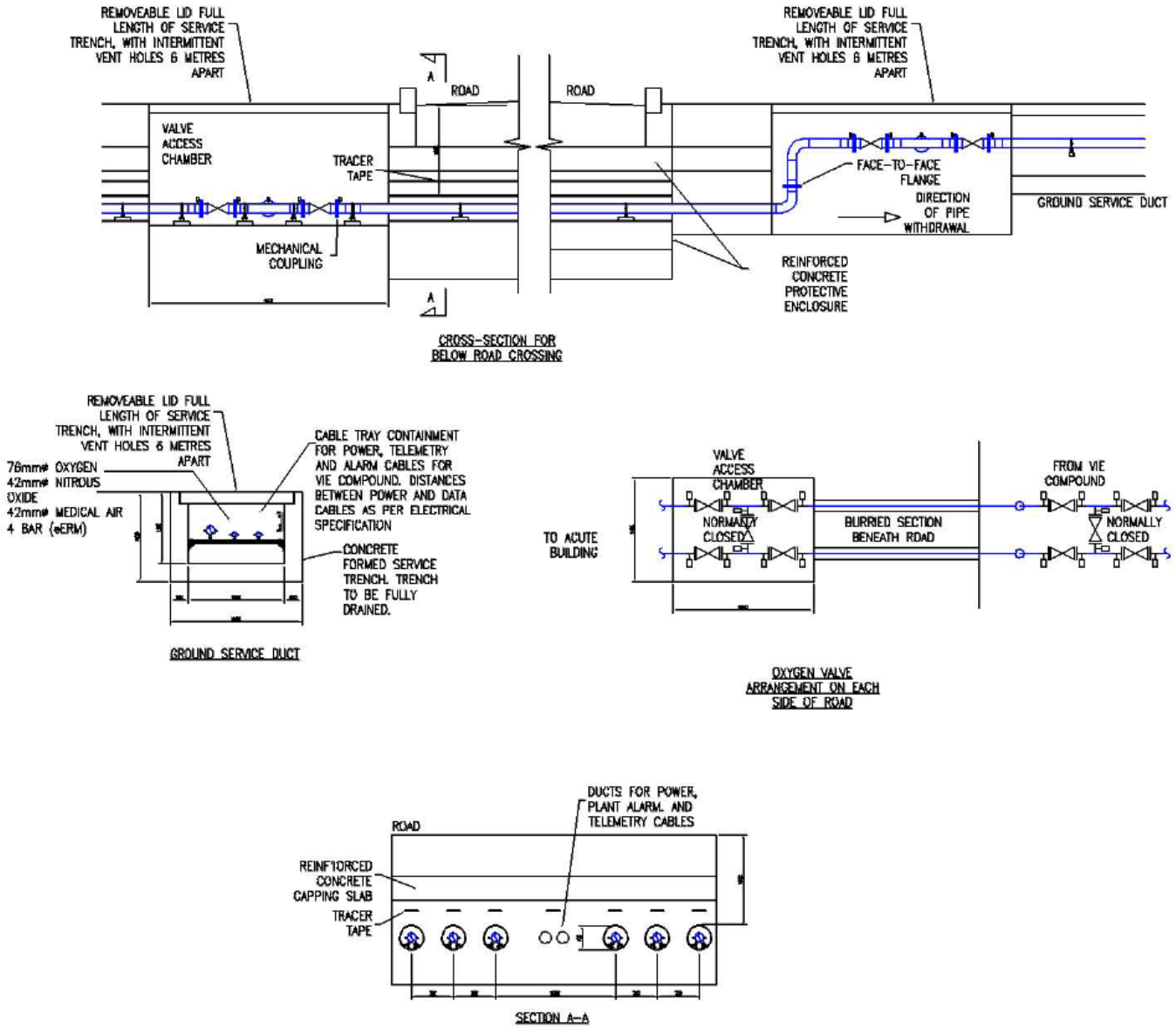
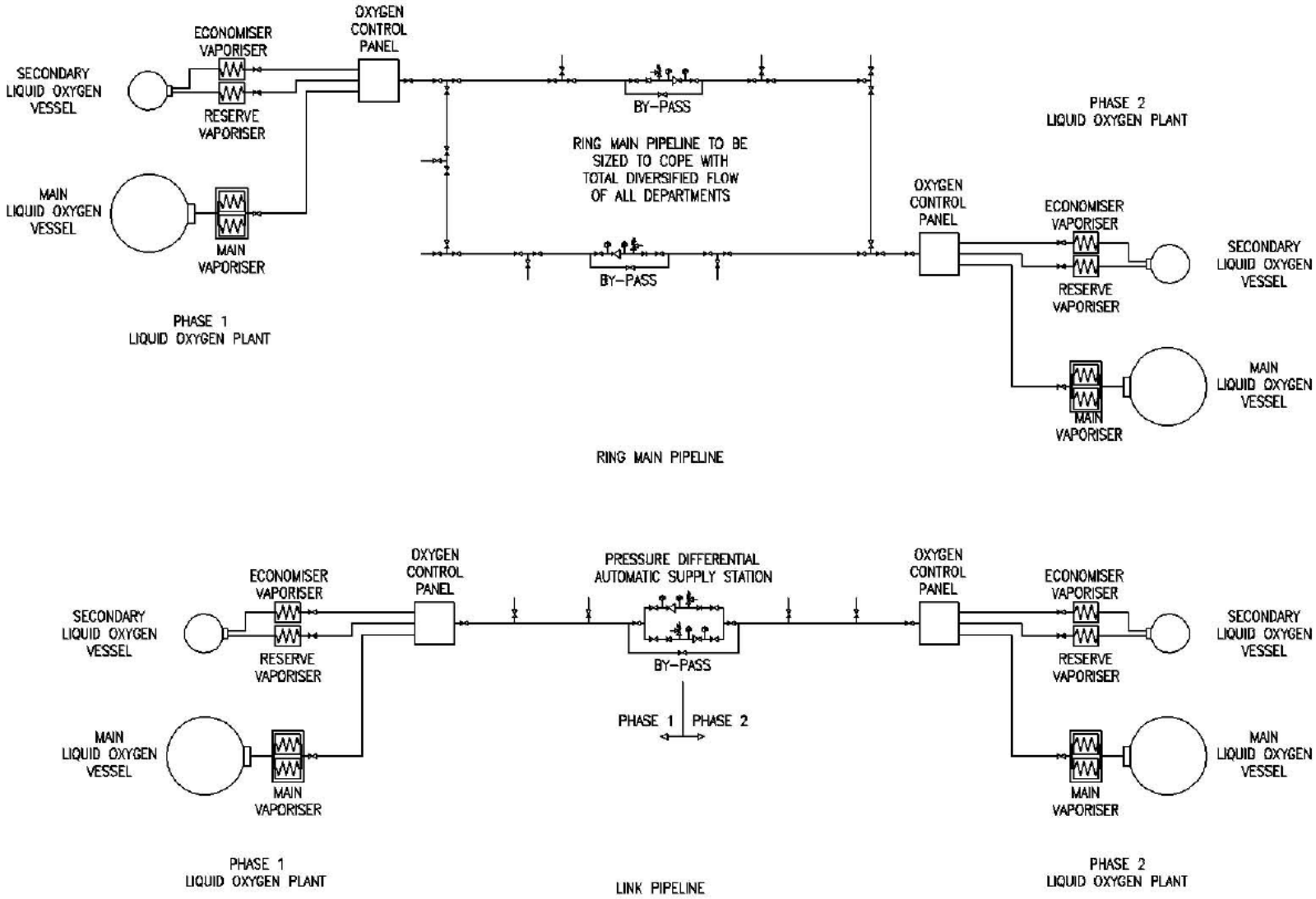


Figure 11.2 - Typical ring main and link pipeline arrangement



11.9. 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 and the risk of damage by penetration. If the enclosure of pipelines within plaster wall finishes is unavoidable, they should be wrapped in protective grease-free tape.

11.10. Pipelines need further protection in certain circumstances as follows:

- where copper 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, for example by adhesive tape
- where penetrations are exposed to general view, be provided with appropriate wall or ceiling plates
- in radio-diagnostic procedure rooms and the like, radio frequency screening wave guides may be required (the advice of the equipment manufacturer should be sought)
- corrosion of copper 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. Where treated timber is used this should be effectively sealed with paint or varnish before the pipes are fixed to it. Such precautions are not required where untreated timber is used

Pipeline materials

Quality

11.11. The manufacturer should comply with BS EN ISO 9001 for pipes and for all materials including fittings, terminal units and the like.

11.12. Where materials are obtained from suppliers from other countries, the suppliers should be registered in accordance with BS EN ISO 9001.

Pipes

11.13. Material for pipes should be manufactured from phosphorus deoxidised, non-arsenical copper to BS EN 1412 grade CW024A (Cu-DHP) in metric outside diameters and to:

- BS EN 13348: – R250 (half hard) for sizes up to 54mm; or
- BS EN 13348: – R290 (hard) for larger sizes.

Pipe jointing fittings

11.14. In addition to the above, pipe jointing fittings should be end-feed capillary fittings to BS EN 1254-1.

Other fittings

11.15. 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

11.16. 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. They must be individually capped at both ends and delivered to site identified as medical gas pipes.

Pipe jointing fittings

11.17. 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.

11.18. Although it is not essential to use degreased pipelines and components for vacuum and Anaesthetic gas scavenging system (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. Polyvinyl chloride (PVC) pipework may also be used for vacuum and AGSS but is unlikely to be of benefit other than for exhaust discharges.

Note 26: Pipes should only be cut with wheel pipe cutters, not hacksaws, to prevent the ingress of copper particles.

Pipeline jointing

General

11.19. 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 27: 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.

11.20. 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.

11.21. 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 28: 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.

11.22. 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.

11.23. The brazing technique should be used on all medical gas pipeline services.

Pipe preparation

11.24. 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. Expanded joints should be made using the appropriate tools and dies. Only where the cut pipe has either deformation

or a burr which significantly restricts the flow of gas will de-burring be necessary. Only oil- and grease-free tools and dies should be used. When brazing copper-to-copper joints:

- the brazed joints should be made using a silver-copper-phosphorus brazing alloy Code of Practice (CP) 104 to BS EN ISO 17672. No flux should be used
- ensure adequate protection of adjacent pipe runs and other services

Note 29: 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 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 N2 internal inert gas shield

11.25. 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.

11.26. 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

11.27. OFN should be used as an internal inert gas shield for all positive pressure gases, vacuum and AGSS pipelines.

Note 30: 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, and the like. 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.

11.28. 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.

11.29. It is recommended that the pipeline to be brazed should first be subject to a high flow of OFN to remove air, followed by a period of 'pickling' at a low flow prior to brazing whilst maintaining the flow.

11.30. 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, for example 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.

11.31. 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.

11.32. 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.

11.33. 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

11.34. 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.

Note 31: Work with asphyxiating gases in a restricted area may create a confined space. The healthcare organisation's confined space procedures should be adhered to when working with asphyxiating gases in a restricted area.

Control of cylinders

11.35. The contractor and the Authorised Person (AP (MGPS)) or Contract Supervising Officer (CSO) 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

11.36. Ultrasonic straight-beam testing can be used to test brazed joints and filler material penetration that are oriented parallel to the surface of a pipe. Typically, a good joint returns an echo since the braze metal or bonding material differs from the material being joined. Comparative testing however will normally show that a lack of bonding returns an even larger echo, so the bond line echo amplitude is used as an indicator of the bond condition and will indicate actual braze penetration. It is a simple technique with many commercially available devices to perform the procedure it provides a digital record of the quality of the penetration and joint condition efficiently and with no physical interference to the pipework.

11.37. Inspection of joints should be carried out by a recognised non-destructive testing (NDT) method as a 'rolling' procedure on a monthly basis as work progresses for each team performing the installation in accordance with the following procedure:

- the CSO or AP (MGPS), whoever is responsible for the inspections and validation, should identify a number of fittings for inspection in order to establish the quality of the finished joint. The exact number to be inspected will vary with the size of the installation: as a guide, a ratio of one fitting per 200 should be inspected; a minimum of ten for all systems should be inspected (it is preferable to perform these checks before pressure-testing sections of pipeline). The actual NDT inspection of the joints should be witnessed by the CSO or AP (MGPS). If the NDT identifies persistent defects with joints, then an invasive method of inspection would be required. It is generally not necessary to request joint inspections from vacuum and AGSS pipelines
- in order to maintain a record of the inspected joints, consideration should be given to photographing the joint or annotating the location on any digital records (NDT), recording the pipeline section the joint is located, the comments by the CSO or AP on their findings, for example 'Pass' or 'Fail' and reasons for failure

Internal cleanliness

11.38. 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

11.39. 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)

11.40. It is not envisaged that mechanical joints, with the exception of NIST connections, will be required for new works unless Corrugated Metal Tubing (CMT) is being used where the manufacturers prescribed installation method and training must be adhered to. 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 individually inspected with an acoustic camera to provide a digital record of the integrity of the joint.

11.41. Mechanical joints in keeping with paragraph 11.43 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 11.29 - 11.35. 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.

11.42. Polytetrafluoroethylene (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.

11.43. 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.

Capping

11.44. Sections of pipeline should be capped with brazed copper end caps to BS EN 1254-1 and pressurised with medical air as soon as they are completed to prevent the ingress of debris.

Pipeline supports

11.45. The pipeline should be adequately supported at sufficient intervals in accordance with Table 11.1, 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.

Table 11.1 - Intervals between copper pipe supports (horizontal and vertical)

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

Note 34: Consideration should be given to additional supports near LVAs, elbows, and the like. where the potential effects of inadvertently applied torque can result in severe pipeline distortion or fracture.

11.46. In situations where medical gas pipelines are required to span building movement joints or are vulnerable to extremes of temperature creating expansion or contraction, consideration shall be given to the method by which pipelines are supported to prevent mechanical damage. CMT or seismic qualified jointing assemblies shall be considered.

11.47. 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.

11.48. 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 and the like, vacuum pipes should connect into the underside of terminal units.

11.49. 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

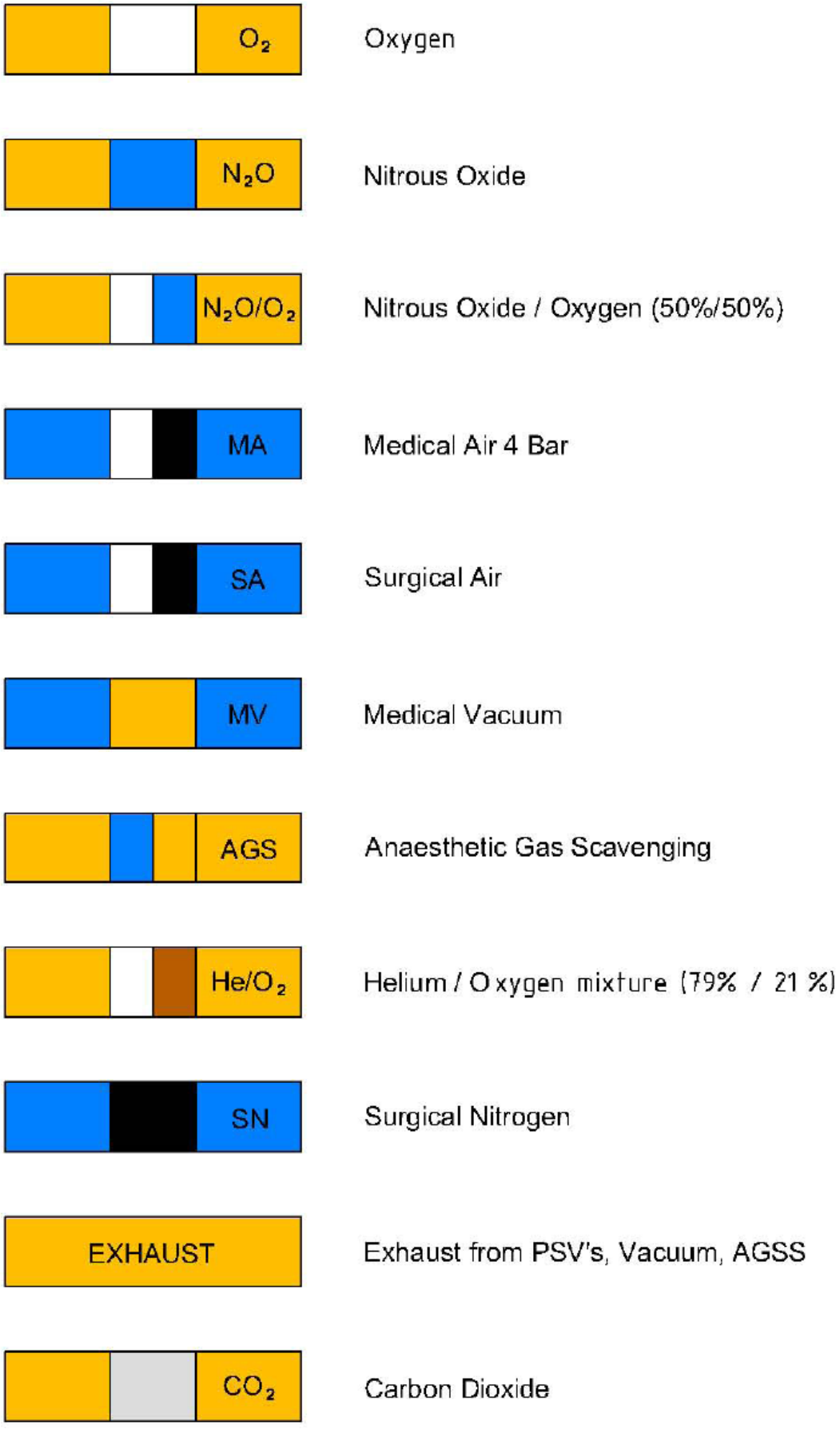
extension should have a clear sight glass throughout its length or alternatively be fully transparent. Robust flexible hosing, providing it is of sufficient clarity and capable of withstanding 150 kPa positive pressure and 100 kPa negative pressure is a further alternative and has the advantage of being 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.

11.50. 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

11.51. Pipelines should be identified in accordance with BS 1710, table C.1, and colour banding for the pipelines should be used. Colour band identification (see Figure 11.2) 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 11.3 - Pipeline identification colour



11.52. 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, for example Ring Main or Link Pipeline.

Pipeline components

11.53. Pipeline components, which may be attached to an MGPS, include various types of terminal unit, area valve service units (AVSUs) and other components such as emergency inlet ports and pressure control equipment.

Medical supply units

11.54. These should comply with BS EN ISO 11197. The construction should provide segregation of functional extra low voltage (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.

11.55. 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.

11.56. The flexible hoses should be free from volatile or organic compounds and certificated to that effect by the pendant manufacturers or suppliers by Quality Controller (QC) tests conducted at manufacturers' premises prior to pendant assembly.

11.57. 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.

11.58. Excess hose length is a contributory factor in system pressure drops across the pendant which may exceed the limits in SHTM 02-01 and BS EN ISO 9170-1.

11.59. 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.

11.60. The recommended height for rigid pendants is 2,000mm above finished floor level (FFL). The maximum height for pendants capable of vertical movement should be 2,000 mm above FFL in the fully retracted position.

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, that is the pressure required.

Flexible pendant fittings

11.61. These should comply with the requirements of BS EN ISO 9170-1 and BS EN 5359. In particular, all loose assemblies should be provided with appropriate NIST connectors.

Bed-head trunking/ walling systems

11.62. These fittings should generally be in accordance with BS EN ISO 11197. Separate compartments should be provided for medical gas pipelines, electrical services, communication diagnostic systems and the like.

11.63. The medical gas compartment should be provided with ventilation by means of louvres, slots, and the like to prevent the accumulation of any gas in the event of leakage from the medical gas pipeline services. Unit construction should prevent the accumulation of gas in the 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.

11.64. 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 and the like). 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.

11.65. There are two 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 MGPS is retained, brazed copper endcaps 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

LVAs and AVSUs

11.66. 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.

Line Valve Assemblies

11.67. 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.

11.68. In the event of leakage of the 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.

11.69. 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 36: A single NIST connector will suffice in ring-main branch connections between the three closely spaced valves.

11.70. LVAs should be provided as follows:

- source shut-off valve
- main shut-off valve
- riser shut-off valve
- branch shut-off valve
- area shut-off valve
- ring shut-off valve
- maintenance shut-off valve
- inlet shut-off valve

11.71. If not specified, the location of all shut-off valves and the extent of the area served by each area shut-off valve shall be determined by the informed design process (IDP).

11.72. The IDP risk assessment shall also take into account the hazards arising from the possible rupture of low-pressure hose assemblies fitted within any medical supply units.

11.73. Consideration should be given to providing a shut-off valve at the point where the pipeline enters a building unless the main, riser or branch shut-off valve is accessible within the building.

Note 37: Considerations for the installation of AVSUs and LVAs:

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 shut down without delay 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 are 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, and the like. in risers can be considered if there is adequate movement of air within riser compartments

AVSUs

11.74. 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 38: 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, for example Estates Department or Facilities Management (FM) 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.

11.75. 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.

11.76. 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 controlled under functional safety documentation and kept under appropriate review.

11.77. 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.

11.78. Provision and location of AVSUs is covered in Section 3.

Note 39: 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

11.79. All AVSUs should be labelled to identify the individual rooms, sets of terminal units and the like controlled. The upstream and downstream NIST connectors should be clearly identified by a permanent label, securely fixed.

11.80. In critical care areas, where dual circuits and/ or subdivisions of circuits occur, terminal units need to be correspondingly identified with the specific AVSUs.

11.81. 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

11.82. 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.

11.83. 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 incorporating a non-return valve and test point. 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

11.84. 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.

11.85. Pressure sensors can be installed within:

- AVSUs valve boxes

- AVSU modular wall panels
- individual wall box
- pressure sensors need not be installed close to an alarm panel but appropriately located pressure sensors can aid setting alarm conditions visually

Pressure gauges

11.86. 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 and the like. They should be installed with isolation cocks.

Digital pressure and flow monitoring

11.87. Modern digital technology enables monitoring of whole or discrete systems for pressure and flow rate. This is measured in real-time and has the capability to store data for future analysis (trending). This data can be used to predict escalation of medical gas consumption and inform clinical protocols/ resources in both business as usual and major incident scenarios. Local digital displays can be colour coordinated (for example Red, Amber, Green (RAG)) to provide immediate visual indication of the MGPS status for the area served. These can be used to indicate flow rate and/ or pressure.

11.88. These systems have the facility to enable the digital information to be viewed centrally and can be utilised to inform business continuity planning.

Test points

11.89. Each supply plant, that is, liquid facility, manifold (main and Emergency Reserve Manifold (ERM)), compressor plant, pressure swing adsorber (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

11.90. Medical oxygen 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 54mm diameter 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.

Line pressure alarms and safety valves

11.91. 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.

11.92. 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.

11.93. 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.

11.94. 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.

12. Design and construction of plant and manifold rooms

Location of manifold rooms

12.1. Cylinder gas/ liquid supply systems should not be located in the same room as medical air compressors, pressure swing adsorber (PSA) systems or vacuum plants.

12.2. Manifold rooms, emergency/ reserve manifold rooms for PSA systems, vacuum insulated evaporator (VIE) installations and medical compressed air systems locations should be confirmed as part of the informed design process (IDP) (see Section 1) and take cognisance of any significant findings from the risk assessment and their geographical location on the site for cylinder replenishment.

12.3. All manifolds, including the emergency reserve manifolds, may be located within the same room. Where practicable, cylinder 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 and cylinder stores should be risk assessed in accordance with British Compressed Gases Association (BCGA) Code of Practice (CP) 44 and Guidance Note 11 for their ventilation requirements.

12.4. Where the emergency/ reserve manifold for liquid oxygen systems is a compressed gas manifold, this should be located separately from the VIE compound.

12.5. If the IDP has identified a piped source for surgical air as the volume of gas used is relatively small even though the instantaneous flow rates are high, it may be more practical to include the manifold within the operating department.

12.6. 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 40: It is permissible to accommodate medical compressed air plant, vacuum plant and Anaesthetic gas scavenging (AGS) disposal system pumps within general plant areas accommodating such equipment as air handling units, water service systems and the like. They should not, however, be located with heating or hot water service equipment or equipment likely to produce any fumes or odour.

Access

12.7. Suitable access should be provided for the delivery and collection of medical gas cylinders, refer to BCGA CP 44 chapter 6.4 for further information.

12.8. A functional suitability assessment, in accordance with Appendix 1 of BCGA CP 44, should be undertaken for the configuration of access and egress to cylinder manifold rooms, taking cognisance of any foreseeable emergency situation that may arise and cylinder handling and replenishment. 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).

12.9. Internal walls and ceilings, including any internal doors of the manifold room, should be of a suitable non-combustible two-hour fire-resistant material. Fire detection should be provided. The provision of automatic fire suppression/ gas leak detection should be considered as part of the functional suitability assessment.

Construction and layout of manifold rooms

12.10. 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. Further replacement cylinders should be supplied from the medical gas cylinder store. The size of the manifold room should be determined by the IDP. Adequate space should also be allowed for cylinder handling.

12.11. 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 similar to those used on the manifolds; the stored cylinders may be closer together. Racks should conform to International Standard (ISO) 32. With the exception of small cylinders of Nitrous Oxide (N_2O)/O2 mixtures, under no circumstances should rooms contain gas cylinders other than those appropriate to their manifolds.

Heating and ventilation

12.12. Ventilation 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 44 and Guidance Note 11 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.

12.13. All ventilation louvres should be vermin/ bird-proof.

12.14. PSA and medical air compressors liberate considerable heat. Where practicable, natural ventilation should be provided. Where this is not possible suitable 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.

12.15. 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 and the like.

12.16. 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.

12.17. Cylinder recognition charts, supplied by the medical gas supplier, should be prominently displayed as appropriate.

Lighting

12.18. Manifold rooms and medical gas plantrooms should be provided with lighting to an illumination level of 200 lux by means of suitable luminaires with an appropriate degree of protection in accordance with British Standard (BS) EN 60529.

Noise control

12.19. 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.

12.20. Acoustic enclosure and/ or plantroom design must not inhibit normal cooling functions or maintenance activities.

12.21. Free-field noise levels should be given to the architect to assist in acoustic design of the plantrooms.

12.22. The discharge from some vacuum pumps may require silencing.

12.23. 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.

12.24. 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 in accordance with the current edition of BS7671 'Requirements for Electrical Installations' will be required.

Labelling/ signage

12.25. Labelling for medical gas systems, equipment and accommodation should be in accordance with Appendix 3 of BCGA CP 44.

13. Validation and verification

General

13.1. Validation and verification is required to determine that the designer(s), Medical Gas Pipeline System (MGPS) manufacturers and MGPS contractor have fulfilled all the necessary conditions identified during the informed design process (IDP) by confirming and verifying the initial design data and substantiating that the contractor has installed the MGPS in accordance with the IDP and in accordance with the guidance set out in this document and other relevant standards. Pharmaceutical and Quality Control testing and requirements are now included in Appendix K of this Scottish Health Technical Memorandum (SHTM).

13.2. This section describes the tests required and the test methods. The contractor should provide instrumentation for the engineering tests. The Quality Controller (MGPS) (QC(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.

13.3. 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 13.12 - 13.14.

13.4. 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 ‘blank spades’ in area valve service units (AVSUs) and line value assemblies (LVAs), or by cutting and capping the pipe. Prohibition or ‘danger - do not use’ labels or tamperproof terminal unit blank plugs are typically applied to all terminal units of the system affected in occupied areas.

13.5. 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.

Note 41: A system leakage test can be undertaken using a suitable leak detection spray or by use of an acoustic camera. Acoustic cameras are advantageous in that they record the test being undertaken and identify any remedials that are required.

13.6. 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: Systems that are not to be taken immediately into use should be filled with medical air at a suitable Eu. Ph grade and maintained at operating pressure. 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).

13.7. The personnel and test equipment needed for these tests are listed together with the test requirements in Table 13.1. The particulate contamination test for all pipeline systems, excluding medical vacuum (MV) and Anaesthetic gas scavenging system (AGSS), may be checked using medical air to establish that the pipeline has been constructed correctly and is not contaminated. Successful completion of the engineering commissioning tests normally indicates the end of the MGPS installation contract and the system is ready for pharmaceutical testing by the Quality Controller (MGPS).

13.8. The systems may then be left under pressure, filled with medical air until such times that the QC testing is to be undertaken using the working gas. A regime for ensuring that the system remains under pressure should be set up with the person responsible for the pipeline (this may be the Contract Supervising Officer (CSO) or Authorised Person (MGPS) (AP(MGPS)) dependant on the location of the installation) checking the pressure utilising pressure gauges connected to the system. System pressure checks should be undertaken weekly as a minimum and recorded. Responsibility for the system during this period needs to be clearly defined in the contract; the AP(MGPS) who is 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 ‘Non-profit distributing’/

'Private Finance Initiative'/ 'Public Private Partnership' (NPD/ PFI/ PPP) projects, to ensure there cannot be a conflict of interest, the CSO preferably from an independent organisation, can be appointed in accordance with SHTM 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 13.95- 13.101).

Table 13.1 - Personnel and test equipment requirements

Paragraph	Test	Personnel	Equipment
13.1	Validation of design prior to installation	CSO or AP	N/A
13.11	Labelling and marking	AE, CSO or AP and Contractors Representative (CR)	Visual
13.11	Sleeving and supports	AE, CSO or AP and CR	Visual and measuring tape
13.11	Leakage	AE, CSO or AP and CR	Pressure-measuring device
13.11	Cross-connection	AE, CSO or AP and CR	Pressure-measuring device
13.12	Functional tests of all supply systems	AE, CSO or AP and CR	Flow meter/ Dew-point meter/ electrical test equipment
13.12	Leakage	AE, CSO or AP and CR	Pressure-measuring device
13.12	Closure of AVSUs and LVAs	AE, CSO or AP and CR	Pressure-measuring device
13.12	Zoning of AVSUs and terminal unit identification	AE, CSO or AP and CR	Open probes or special test device
13.12	Cross-connection	AE, CSO or AP and CR	Open probes or special test device

Paragraph	Test	Personnel	Equipment
13.12	Flow and pressure drop at individual terminal units, mechanical function and correct installation	AE, CSO or AP and CR	Special test device, certified probes
13.12	Non-interchangeable screw thread (NIST) connectors	AE, CSO or AP and CR	Full bore NIST probes and nut
13.12	System performance	AE, CSO or AP and CR	Metered leaks and special test device
13.12	Supply systems	AE, CSO or AP and CR	Visual
13.12	Pressure safety valves	AE, CSO or AP and CR	Visual, safety valve test certificate
13.12	Warning and alarm systems	AE, CSO or AP and CR	Visual, Pressure-measuring device
13.12	As-fitted drawings	AE, CSO or AP and CR	Visual
13.12	Purging and filling	AE, CSO or AP and CR	Gas source and delivery equipment
13.12	a) Other supply system functional tests b) Particulate contamination	AE, CSO or AP and CR	Particulate matter test device (PMTD)
13.12	Anaesthetic gas scavenging (AGS) disposal systems	AE, CSO or AP and CR	Metered leaks and AGS test device
13.13	Gas quality	AE, CSO or AP, CR and QC (MGPS)	PMTD, oil, moisture, CO, CO_2, SO_2 and N_2 oxides measuring devices, O_2 and Nitrous Oxide (N_2O) analysers
13.13	Gas identification	AE, CSO or AP, CR and QC (MGPS)	O_2 analyser and N_2O meter

Note 44: Refer to SHTM 02-01 Part B for description of the duties and responsibilities of the various parties included in Table 13.1.

13.9. All supply systems and their major components should have certificates (as specified in the IDP and included in the contract specification documents) which show that they meet the design requirements of the MGPS.

13.10. Only contractors who are registered to British Standard (BS) EN International Standard (ISO) 9001/ BS EN ISO 13485 with their scope of registration defined to include commissioning should undertake engineering validation and verification.

Note 45: BS EN ISO 9001 registration is also recommended for independent medical gas testing agencies but is not necessary for appropriately trained and registered hospital-based QCs (MGPS).

13.11. All relevant tests should be carried out by the persons listed in Table 13.1 and witnessed by the appropriate persons, who must record the results of the tests in writing for the healthcare facility.

Summary of tests

Tests and checks on the pipeline carcass

13.12. 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 if accepted by the AE or CSO or AP but may choose to carry out a zoning check.)

Tests on the pipeline system

13.13. 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 engineering tests. Where it is shown that a high degree of oxide particles are 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, consideration should be given to invite the QC (MGPS) to carry out particulate contamination, odour and taste tests. 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 and potential environmental damage. The CSO particulate test does not negate in any way the role and responsibility of the QC to repeat the test with the working gas
- tests for anaesthetic gas scavenging disposal systems

Note 46: Nitrous oxide and nitrous oxide/oxygen mixture are not tested for odour.

Tests before use

13.14. The following tests must be carried out after purging and filling with the working gas:

- tests for particulate contamination (see Appendix K)
- tests for gas identity
- tests for gas quality

General requirements for testing

13.15. 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. Paragraphs 13.33 to 13.45 give details of the tests required for modifications/ extensions to existing systems.

13.16. The medical air and vacuum plant should be tested during or immediately following carcass tests.

13.17. Where medical air plant is used as a test gas for other medical gas pipelines (including MV for first-fix pressure tests only), the medical air plant must be tested by the QC(MGPS) certifying that the medical air is of the correct quality. Certification to be included within the appropriate test documentation.

13.18. 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.

13.19. Testing for leakage is normally carried out in two stages: the first to the pipeline carcass where second fix items such as terminal units, pendant hoses, pressure switches and pressure transducers should not be connected. The second to the completed distribution system, which will include all second fix components connected as appropriate.

13.20. 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 Appendix K. The shield gas may be used for the tests on the pipeline carcass described in paragraphs 13.50- 13.57. Cylinders of medical air will normally be used as the source of test gas for oxygen, nitrous oxide and nitrous oxide/oxygen mixture systems in order to prevent the possibility of contamination with oil.

13.21. 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 Appendix K have been met and that the air supply plant is continuously monitored for moisture during the test.

13.22. The medical compressed air plant can also be used for the single point performance tests and the like 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 (QC) (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.

13.23. 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.

13.24. It is also important not to introduce such a compressor after identity checks have taken place.

13.25. Special care will be required when carrying out QC checks, as some synthetic oils cannot be detected using portable equipment.

13.26. 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.

13.27. New terminal units are supplied with 'Do not use' labels or tamperproof blanking plugs. These should remain in place until the final identity and quality tests have been completed. They are then removed by the Authorised Person (MGPS). A schedule should be created for the removal of labels and a record of handover to the Designated Clinical Officer (DCO), for example familiarisation and instruction of the system and equipment. This is not in lieu of using an appropriate permit-to-work document.

13.28. In the case of existing systems, ‘Do not use’ labels or tamperproof blanking plugs should be affixed to all terminal units within the section being modified.

13.29. 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.

13.30. For second-fix system pressure tests on all medical gases and vacuum leakage tests, the system under test must be physically isolated from the source of supply (for example by the use of blanking spades at the side of the valve not under test).

13.31. All errors found during testing must be rectified, and the relevant systems must be retested as appropriate before the records are signed.

13.32. The contractor (MGPS) must provide all engineering forms, labour, materials, instruments and equipment required to carry out the tests described in this section. 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, acoustic camera and AGS disposal system test equipment. The Quality Controller (MGPS) will be responsible for supplying all QC forms, unless otherwise requested by the healthcare facility, calibrated test equipment, connections and the like.

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.

13.33. The Quality Controller (MGPS) should provide the test equipment specified in Appendix D , Appendix E and Appendix 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).

13.34. In a completely new installation, flow meters, anaesthetic trolleys and the like 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 or tamperproof terminal unit blanking plugs. The permit-to-work system should be followed.

Modifications, extensions or repairs to existing systems

13.35. Where modifications, extensions or repairs to existing systems are carried out, the tests and the sequence of tests summarised in paragraphs 13.12- 13.14 should be followed as far as possible.

13.36. 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 healthcare facility and therefore would not normally be a member of the installation contractor's staff.

13.37. Whenever modifications or extensions are carried out, it is advisable to test both the existing system and the new system separately before the break-in is made. Existing systems should be tested to determine their performance and to identify any potential limitations that may arise as a result of modifications. Any potential limitations should be reviewed in the IDP risk assessment and either noted and accepted by the Medical Gas Safety Group or an alternative installation plan proposed.

13.38. 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 healthcare facility to ensure that these tests are carried out prior to the design phase of any modifications or extensions.

13.39. It is the responsibility of the healthcare facility management to ensure that any required remedial work is carried out on an existing system before extensions are added.

13.40. It is important that any modifications during the testing and commissioning period are documented and that any additional testing required, as a consequence of those modifications, is performed.

13.41. 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.

13.42. 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.

13.43. The Quality Controller (MGPS) will normally carry out all checks, including a repeat of the particulate matter test, using the working gas.

13.44. 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 13.2.

13.45. 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 13.78). To ensure a valid result from such a test, it should be performed when flows in the system are representative of typical maximum demands.

13.46. 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.

13.47. 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).

Table 13.2 - Validation and verification: pressure during pipeline system tests

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	100	380
N_2O	440	420	400	100	380
O_2/ N_2O mixtures	440	420	400	275 (Labour, Delivery, Recovery and Post-partum (LDRP)) 100(others)	310(2) 380
Medical air (400 kPa)	440	420	400	100	380
Surgical air (700 kPa) Wall outlet	860	825	784	350	700
Surgical air (700 kPa) Pendant	940	900	854	350	700
Vacuum	67 – 88 (500-660 mmHg)	60 kPa (450 mmHg)	55.3 kPa (400 mmHg)	40	40 kPa (300 mmHg)

Requirements for pipeline carcass tests

13.48. 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 51: 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

13.49. 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. The results of the checks are recorded on Form A2.

Sleeving and supports

13.50. 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 11.1. The results of the checks are recorded on Form A2.

Leakage

13.51. 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 52: 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.

13.52. 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

13.53. This test should be carried out with AVSUs, LVAs and other service valves open; any pipeline components that could be adversely affected by the higher pipeline carcass test pressure such as pressure sensors and pendant hoses should be removed and the connections blanked off. The results of the test may be recorded on Form A2.

Cross-connection

13.54. Before performing these tests, any links between systems should be removed and all pipelines should be at atmospheric pressure with all AVSUs and the like open.

13.55. 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.

13.56. 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.

13.57. The test is repeated for other systems, one at a time.

13.58. The results may be recorded on Form A2.

Requirements for pipeline system tests

13.59. 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.

13.60. 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 the risk assessment created during Stage 3 of the IDP.

Leakage from total compressed medical gas systems

13.61. 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.

13.62. 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 Figure A.3

Leakage into total vacuum systems

13.63. 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.

13.64. The test results may be recorded on Figure A.3.

Closure of area valve service units and line valve assemblies

13.65. 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.

13.66. 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.

13.67. For LVAs, a similar test procedure is adopted. There is no change in the time for vacuum.

Note 53: 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.

13.68. The test results may be recorded on Figure A.4 and Figure A.5.

Zoning of AVSUs and terminal unit identification

13.69. 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; 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.

13.70. 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 54: Notes on the testing of zoning of AVSUs and terminal unit identification:

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.

c. These tests can be performed at the same time as the cross-connection/ terminal unit pressure drop tests

d. 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

13.71. The test results may be recorded on Figure A.4 and Figure A.5.

Cross-connection

13.72. 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 55: 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.

13.73. 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.

13.74. 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,

13.75. 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.

13.76. The process is then repeated for nitrous oxide/oxygen mixture. If other medical gases are encountered, 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 56: 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.

13.77. This test must be repeated in full if any subsequent modifications are made to the pipeline system.

13.78. The test results may be recorded on Figure A.7.

Flow and pressure drop at individual terminal units, mechanical function and correct installation

13.79. 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 13.2 at the specified flows.

Note 57: 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.)

13.80. 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 58: Further considerations when undertaking terminal unit checks:

a. terminal units to BS EN ISO 9170-1 need not be challenged with the full complement of BS 5682 test probes

b. the terminal unit should be fitted complete with bezel plates and the like. 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

13.81. The results of the tests may be recorded on Figure A.4, Figure A.5 and Figure A.6.

13.82. 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 59: In certain circumstances factory-assembled units are dismantled for installation purposes and can be subsequently incorrectly re-assembled. In the case of LVAs, 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, all personnel making connections to NIST fittings should be appropriately qualified and authorised to do so.

All NIST connectors should have the manufacturer's certificate of test provided for fitted terminal units within pendants.

13.83. 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 60: Personnel should take care not to stand in front of the NIST connector when performing this test.

13.84. The results may be recorded on Figure A.9

Performance tests on the pipeline system

13.85. 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 2.10) to represent the IDP peak 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.

Note 61: Further considerations for the undertaking of performance tests on pipeline systems:

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 IDP designed flowrates. 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 calculated flow demand concentration rather than distance from source. Any escalation flowrates calculated for major incident purposes need to be validated in the configuration in which they would be operated during these events, taking cognisance that this may differ from the normal in use supply 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

13.86. 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 62: 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

13.87. All supply systems must be tested for normal and emergency operation, according to the manufacturers' manuals and contract specifications. The results of these tests should be recorded on Figure A.10 - Figure A.14 and Figure A.18.

Pressure safety devices

13.88. 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 Figure A.10 to Figure A.13 inclusive.

13.89. Check that the specified pressure safety valves have been fitted and that their flow pathways are correct.

13.90. Verify that the pressure safety valves are certified to operate in accordance with the contract specification and conform to BS EN ISO 4126-1.

Warning and alarm systems

13.91. 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 Table 10.1 and Table 10.2
- 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 safety power supply source
- that all indicator panels are labelled to show the areas they serve, or as detailed in the contract specifications

13.92. 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 alarm pressure switches and transducers function correctly at their requisite setting
- 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

13.93. The results of the tests are recorded on Figure A.15.

Verification of as-fitted drawings

13.94. The as-fitted drawings and Building Information Modelling (BIM) files should be reviewed by 'Delivery Group B' (see Section 1) to ensure that all variations from the contract drawings have been recorded and any observations noted on Figure A.19.

Filling with medical air

13.95. 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 Appendix K 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.

13.96. 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.

13.97. 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 MV pipeline need not be maintained under vacuum.

13.98. Provision should be made for regular running and maintenance of all supply plant during such an interim period.

13.99. 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).

13.100. The ‘Danger - do not use’ label or tamperproof terminal unit blank plugs should remain affixed to each terminal unit until all testing is completed.

13.101. When the construction contract has finished, the contractor should record the removal of all special connectors and cylinders from site.

Purging and filling with specific gases

13.102. 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 and nitrous oxide/ oxygen mixtures discharged during the process must be released to a safe place

Note 63: For installations of nitrous oxide and nitrous oxide/ oxygen mixtures that may have flexible low-pressure hoses in their final construction (such as pendants or some medical supply units), consideration needs to be given to purging with medical air until the required dryness is achieved and then the working gas admitted. This process may require the use of test gases and special connectors and would need to be discussed with ‘Delivery Group B’ (see Section 1).

13.103. The results of the purging process may be recorded on Figure A.20.

13.104. Purging is not necessary for vacuum systems.

Operational policy

13.105. 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

13.106. There should be recorded visual checks for correct labelling, including batch numbers (see SHTM 02-01 Part B).

Removal of construction labels

13.107. When all tests have been completed satisfactorily, the Prohibition or ‘danger do not use’ labels or tamperproof terminal unit blank plugs should be removed from terminal units on the authority of, or by, the Authorised Person (MGPS). This should be recorded on the permit-to-work.

Appendix A Testing, commissioning and filling for use

A.1 Appendix A contains the forms that are to be completed during testing and commissioning of piped medical gases systems (MGPS).

Table A.1 - MGPS carcass tests

Test	Form
Labelling and Marking	A2
Sleeving and Supports	A2
Leakage Test	A2

Table A.2 - Systems tests

Test	Form
Pipeline Pressure Test	A3
Vacuum Leakage Test	A3
Area Valve Service Unit - Zoning, Closure and Non-interchangeable screw thread (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, Cross-Connection and Gas Specificity Tests	A7/1 and 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 (MV) Plant	A13
Area Alarm Panel Test	A14
Central Alarm Panel Test	A15
Particulate Matter Tests	A16
Anaesthetic Gas Scavenging System (AGSS) Tests	A17
As Installed Drawings	A18
Purging and Filling	A19
Medical Gas Identification Tests	A20
Medical Gas Quality Tests	A21
Medical Gas Pipeline System (MGPS) - Completion Certificate	A22

Figure A.1 - MGPS test summary sheet - A1

Medical Gas Pipeline System Test Summary Sheet – A1

System location:		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 : .....

Figure A.2 - Carcass test sheet – 1st fix pressure, labelling/ marking, sleeving/ supports and cross-connection – A2

Carcass Test Sheet – 1st Fix Pressure, Labelling/ Marking, Sleeving/ Supports and Cross-connection – A2

System location:				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.

Figure A.3 - Second-fix pressure test - A3

2nd Fix Pressure Test - A3

System location:		Date:		Test by:	
Project No:				Witnessed by:	

Service	Gauge No.	Temp (°C)	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

Figure A.4 - Area valve service unit - zoning, closure and NIST tests - A4

Area Valve Service Unit – Zoning, Closure and NIST Tests - A4

System location:		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				

Note 64: Notes applicable to area valve service unit – zoning, closure and NIST tests:

a. pressure differential between upstream (working pressure) and downstream (approximately 300 kPa)

b. vacuum systems to be on vacuum system plant side at distribution pressure and on terminal unit side at approximately 15 kPa (112 mmHg)

c. test should be conducted over a period of 15 minutes with no change in pressure

Figure A.5 - Line valve assembly and line valve - zoning, closure and NIST tests - A5

Line Valve Assembly and Line Valve – Zoning, Closure and NIST Tests – A5

System location:		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				

Note 65: Notes applicable to line valve assembly and line valve – zoning, closure and NIST tests

a. Pressure differential between upstream (working pressure) and downstream (approximately 300 kPa)

b. Vacuum systems to be on vacuum system plant side at distribution pressure and on terminal unit side at approximately 15 kPa (112 mmHg)

c. Test should be conducted over a period of 15 minutes with no change in pressure

Figure A.6 - Pendant/ miscellaneous NIST connectors - specificity and function tests - A6

Pendant/ Miscellaneous NIST Connectors - Specificity and Function Tests – A6

System location:		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	

Figure A.7 - Terminal unit schedule and cross-connection tests - A7/1

Terminal Unit Schedule and Cross-Connection Tests – A7/1

System location:				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

Figure A.8 - Terminal unit schedule and cross-connection tests - A7/2

Terminal Unit Schedule and Gas Specificity Tests – A7/2

System location:				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

Figure A.9 - Terminal unit functional tests exemplar - A8

Terminal Unit Functional Tests exemplar – A8

System location:		Date:		Test by:	
Project No:				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 66: Mechanical function test to include, probe insertion, capture and release. The anti-swivel pin is present or absent dependent of orientation.

Figure A.10 - Plant performance, operation and siting – liquid oxygen systems - A9

Plant Performance, Operation and Siting – Liquid Oxygen Systems – A9

System location:		Date:		Test by:	
Project No:				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 5.2 and BCGA CP19		
8	Compound/ room provided with hazard/ warning signs in accordance with Appendix E		
9	Access to and within compound acceptable		
10	Lighting provided		
11	Plant provided with all necessary valves and ancillaries.		
12	Plant schematic provided		

Figure A.11 - Plant performance, operation and siting - medical gas manifold systems - A10

Plant Performance, Operation and Siting – Medical Gas Manifold Systems – A10

System location:		Date:		Test by:	
Project No:				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 E		
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		

Figure A.12 - Plant performance, operation and siting - medical air/ surgical air plant - A11

Plant Performance, Operation and Siting – Medical Air/ Surgical Air Plant – A11

System location:		Date:		Test by:	
Project No:				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 E		
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		

Figure A.13 - Plant performance, operation and siting - synthetic air systems - A12

Plant Performance, Operation and Siting – Synthetic Air Systems – A12

System location:		Date:		Test by:	
Project No:				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 5.2 and BCGA CP19 and BCGA 21		
8	Compound and blending station room provided with hazard/ warning signs in accordance with Appendix E		
9	Access to and within compound and blending station room acceptable		
10	Lighting provided		
11	Plant schematic provided		

Figure A.14 - Plant performance, operation and siting - medical vacuum plant - A13

Plant Performance, Operation and Siting – Medical Vacuum Plant – A13

System location:				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 E		
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		

Figure A.15 - Area alarm panel test - A14

Area Alarm Panel Test – A14

System location:		Date:		Test by:	
Project No:				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		

Figure A.16 - Central alarm panel test - A15

Central Alarm Panel Test – A15

System location:		Date:		Test by:	
Project No:				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

Figure A.17 - Particulate matter tests - A16

Particulate Matter Tests – A16

System location:		Date:		Test by:	
Project No:				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		

Figure A.18 - Anaesthetic gas scavenging system tests - A17

Anaesthetic Gas Scavenging System Tests – A17

System location:				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 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

Figure A.19 - Design review and as installed drawings - A18

Design Review and As Installed Drawings – A18

System location:				Test by:	
Project No:		Date:		Witnessed by:	

A18 is superseded by the requirements of the Informed Design Process as set out in Section 1 of this SHTM, this form may be a relevant means for recording this information for minor projects.

Comments

The following 'As Installed' drawings schedule records all variations from the contract drawings:

Drawing Number	Revision	Description	CSO/ AP	Date

Figure A.20 - Purging and filling - A19

Purging and Filling – A19

System location:				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 13.95 - 13.101 and/ or 13.102 - 13.103 as follows-

Action	O_2	N_2O	N_2O/O_2	MA4	SA	MV
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						

Figure A.21 - Medical gas identification tests - A20

Medical Gas Identification Tests – A20

System location:		Date:		Project No:	

This is to certify that medical gas systems have been tested in accordance with paragraphs K.67 – K.77 as follows (insert values for gases and tick for vacuum)

Gas and Source	Paramagnetic oxygen analyser reading	Thermal conductivity/ infra-red instrument reading	Liquid n 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			-	-

Contract Supervising Officer (CSO)/ Authorised Person (AP)

Name:	Signed:.....
Status:	Date: .....

Quality Controller (QC)

Name:	Signed:.....
Status:	Date: .....

Figure A.22 – Medical gas quality tests - A21

Medical Gas Quality Tests– A21

System location:		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 Appendix K as 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: .....

Figure A.23 - Medical gas pipeline system - completion certificate - A22

Medical Gas Pipeline System – Completion Certificate – A22

System location:		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 13 and Appendix K, 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

B.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.

B.2 Pressure changes due to temperature difference may be calculated according to the Gas Laws (see the 'Glossary' in Scottish Health Technical Memorandum (SHTM) 02-01 Part B).

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

B.4 The change in gas pressure with temperature is as follows:

P1/T1 = P2/T2

where:

P1 = the initial absolute pressure of a fixed volume of gas

P2 = the final absolute pressure of a fixed volume of gas

T1 = the initial absolute temperature

T2 = the final absolute temperature

therefore:

P2 = (P1 x T2)/T1. (1)

B.5 Care must be taken to express pressure and temperature in absolute values.

B.6 Pressure is normally expressed in 'gauge' pressure: Absolute pressure = gauge pressure + atmospheric pressure.

B.7 Temperature is normally expressed in K.

Examples

B.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.

therefore, using Equation (1):

P2 = (14.5 x 290)/286

= 14.7 bar (absolute pressure)

= 13.7 bar (gauge pressure)

B.9 That is, gauge pressure should read 13.7 bar at the end of the test, assuming that no leakage has occurred.

Appendix C Pressure conversion chart

C.1 Conversion factors for units of pressure:

Figure C.1 - Pressure conversion chart

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 (pound per square inch (lb/ in^2))	6.895	1	144	0.0682	0.0703	51.713	2.0359	2.307
1 pound/ft^2 (pound per square foot (lb/ft^2))	0.048	0.00694	1	0.0005	0.00052	0.3591	0.01414	0.01602
1 int atmosphere (standard atmospheric pressure)	101.3	14.696	2116.2	1	1.0333	760	29.92	33.9
1 kilogram/cm^2 (kilogram per square centimetre (kg/cm^2))	98.07	14.223	2048.1	0.9678	1	735.56	28.958	32.81
1 mmHg (millimetre of mercury (1 torr))	0.133	0.0193	2.785	0.0013	0.00136	1	0.0394	0.0446
1 in Hg (inch of mercury (In Hg))	3.387	0.4912	70.73	0.0334	0.0345	25.400	1	1.133
1 ft water (foot of water (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

Appendix D Annual audit aide memoir and associated risk assessments for cryogenic liquid oxygen supply system

General

D.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.

D.2 Some factors that should be considered are outlined below.

Delivery frequency

D.3 Does current frequency cause logistical problems for the supplier/ your site? Review original risk assessment (assessment considerations as per paragraph D.27 of this Appendix).

Calculating consumption

D.4 Use pharmacy records for cylinder/ liquid consumption. Look for peaks in demand, for example winter influenza epidemics. Review original risk assessment (assessment considerations as per paragraph D.27 of this Appendix).

D.5 When average and peak flow rates are known, calculate the required size of the emergency supply. Review original risk assessment (assessment considerations as per paragraph D.29 of this Appendix).

Age of current system

D.6 The secondary supply of older vacuum insulated evaporator (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

D.7 Considerations for the siting of the system and the site survey:

- what planning restrictions apply (vessel size, noise and the like)?
- 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 routes for the emergency supply manifold (Emergency Reserve Manifold (ERM))
- availability and presentation of alarms for ERM
- power and lighting during work
- drainage - catch pits, diversions, pad resizing

Costs

D.8 Make sure **all** costs are allowed for, for example:

- site inspection
- cost of continuing delivery using rigid and non-articulated vehicles
- gas charge/ 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 and the like may need to be negotiated
- check defects liability (usually 12 months)

Emergency provision

D.9 Considerations for emergency provisions:

- 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

D.10 Considerations for 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 non-interchangeable screw thread (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

D.11 The following paperwork should be included and provided during and on completion of the installation:

- 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

- electrical installation certificate in accordance with the current edition of British Standard (BS) 7671 'Requirements for Electrical Installations'
- 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)
- Medical gas pipeline system (MGPS) operational policy protocols

Health and safety

D.12 Health and safety considerations:

- 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

D.13 Considerations for the preparation of the site and the installation of the system:

- 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 Quality Controller (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

D.14 Installation requirements:

- 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 and the like but a three-phase 60A supply will be needed for delivery vehicle pump if appropriate
- earth bonding/ lightning protection for fences
- alarm interface/ telemetry boxes at an appropriate 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, and the like), welding and cutting flames/ sparks
- power and lighting supplies during work
- water supply (washing and concrete) during work

Follow-up

D.15 Points to be considered to review on completion of the installation:

- 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 Appendix G of SHTM 02-01 Part B)
- update MGPS operational policy and any relevant insurance policies

Determining system size through risk assessment

Introduction

D.16 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.

D.17 The risk assessment should take cognisance of 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.

D.18 Additional local factors and requirements identified during the informed design process (IDP) (see Section 1) 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.

D.19 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).

D.20 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 1SO 7396-1 that is, the medical oxygen supply system should normally consist of:

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

D.21 The capacity of the primary and secondary supply system will consist of:

- operational stock
- reserve stock

D.22 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.

D.23 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.

D.24 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.

D.25 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. This would need careful consideration and option evaluation within the IDP in respect of BS EN International Standard (ISO) 7396-1 as this would not meet the supply criteria for single fault condition and may be better answered with a split or alternative supply source/ system. If unavoidable however, 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

D.26 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 impact the safety of the system or the security of supply.

Sizing plant - general

VIE installations

D.27 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.

D.28 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

D.29 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.

D.30 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.

D.31 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

D.32 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.

D.33 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.

D.34 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

D.35 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

D.36 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.

D.37 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 (HDUs).

Initial risk assessment for siting of plant

D.38 The initial risk assessment should consider the requirements to ensure a continuous supply of medical gas to the patient.

D.39 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 and the like], 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 British Compressed Gases Association (BCGA) Code of Practice (CP) 19
- 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 (SHTM) 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

D.40 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

D.41 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

D.42 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

D.43 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

D.44 The current average daily demand can be calculated by dividing the current annual consumption by 365 days.

D.45 The operational stock should be based on an average daily demand predicted for the end of the contract period calculated by:

D.46 Average daily demand = Current daily demand + Planned growth + Natural growth.

D.47 The operational stock is calculated as:

D.48 Operational stock = Average daily demand x Agreed delivery period.

D.49 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.

D.50 The delivery period for the primary supply will be based on the gas supplier's normal delivery frequency.

D.51 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.

D.52 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

D.53 Table D.1 provides a matrix for the calculation of primary reserve stock based upon distance from gas supplier and fitting of telemetry.

Table D.1 - Requirement for remote indication for stock levels

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

Calculation of secondary reserve stock

D.54 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.

D.55 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)

D.56 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 D.1, 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.

D.57 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

D.58 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.

Appendix E Signage requirements

E.1 The signage requirements for medical gas pipeline systems (MGPS) and plant rooms are described in this appendix.

Figure E.1 - General plant room signage

Location	Wording	Notes
Plantroom	Medical Gas Plant Room – No unauthorised 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 and the like
	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

Note 67: Other MGPS signage considerations:

- 'Bacteria filter change procedure' sign is not available commercially and will have to be made locally.
- No 'Danger medical gas/ vac/ Anaesthetic gas scavenging system (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.

Figure E.2 - Manifold room signage

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

Note 68: also required:

a. Cylinder ID charts, manifold cylinder change procedure, emergency manifold operating procedure

b. check with fire officer for any local fire brigade requirements for fitting 'HAZCHEM' signs for example, 'HAZCHEM 2SE Cylinders'

Figure E 3 - Main cylinder stores signage requirements

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)

Note 69:

a. 'Danger liquid nitrogen' sign is available for a separate liquid nitrogen store (see British Compressed Gases Association (BCGA) Code of Practice (CP) 30).

b. Cylinder ID chart(s) to be posted

c. Check with fire officer for any local fire brigade requirements for fitting 'HAZCHEM' signs for example, 'HAZCHEM 2SE Cylinders'.

Figure E.4 - Ready-to-use cylinder stores signage requirements

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

Note 70: Post cylinder ID chart(s) and cylinder change procedure.

Check with fire officer for any local fire brigade requirements for fitting 'HAZCHEM' signs, for example, 'HAZCHEM 2SE Cylinders'

Figure E.5 - Ward cylinder parking bay signage requirements

Location	Wording	Notes
Ward (Cylinder parking bay)	Medical gas cylinder parking area	Defines cylinder parking as per Scottish Health Technical Memorandum
	Emergency Tel No Gas suppliers Estates Pharmacy Porters	External wall
	Gas leak action	On nurses' station

Note 71: Post cylinder chart(s) and cylinder change procedure.

Operational policy may dictate posting of area valve service unit (AVSU) emergency operation and medical gas pipeline system (MGPS) alarm responses.

Figure E.6 - Medical equipment workshop (electronic and biomedical equipment (EBME))

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	

Note 72: These signs should be posted during installation/ modification/ maintenance of an MGPS. Multiple signs may be required.

Figure E.7 - Pipeline identification

Location	Wording	Notes
Pipework	Gas identity	
	Flow direction	

Figure E.8 - Line valve and line valve assembly identification

Location	Wording	Note
Line Valves& Lockable Valve Assembly	Gas identity	On pipeline label
	Flow direction	
	Valve No	Sequential number system
	Key No	

Figure E 9 - AVSU 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

Figure E.10 - Alarm system 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	

Figure E.11 - Bulk liquid oxygen/ liquid oxygen cylinder/ pressure swing adsorber (PSA)/ Synthetic air plant

Location	Signage will be determined by the equipment supplier but will usually include plant schematic, safety warnings and emergency actions
VIE/ Liquid cylinders/ PSA/ synthetic air	

Appendix F Oxygen supply source data

Table F.1 - Oxygen supply source data

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
Cylinders • Pressures 137 to 230 bar(g). • 300 bar(g) cylinders requires special considerations. • Typical contents 6 to 10 m^3 per cylinder	0	• 300 m^3 up to 7300 m^3. • (impacted by cylinder pressure, see calc sheets).	• 0.5 m^3/ hour	• Regulator dependent • Typically 5m^3/hour	• Regulator dependent and changing cylinders • typically 60m^3/hour	• The flowrate from cylinders is limited by the 5mm orifice in the cylinder valve BUT more importantly by the pressure regulator(s). • The pressure regulator has to perform from full cylinder pressure down to 'empty' condition of ideally 20 bar(g). • Normally the pressure is reduced in 2 stages to provide the accurate 4.1 bar(g) outlet pressure. • Liquid cylinder supply can be considered at usages from 1500m^3 upwards.

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
Cylinder Packs • Pressures 137 to 230 bar(g). • 300 bar(g) packs require special considerations. • 90 to 150 m^3 per pack	0	• 4500 m^3 up to 20,000 m^3	• 2.5 m^3/hour	• Regulator dependent • Typically 25m^3/hour up to 50 m^3/hour	• Regulator dependent and changing packs • typically, 60m^3/hour up to 200 m^3/hour	Notes as per above + • cylinder packs vary from 12 to 16 cylinders. • BOC have 15 cylinder packs • AP/ AL have 16 cylinder packs • Packs are not widely used in the UK because liquid cylinder supplies are deemed more sensible/ practical/ cost effective. • However, to back up a pressure swing adsorber (PSA) plant in remote locations packs could be a possibility. • Mechanical handling required to manoeuvre packs.

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
Liquid cylinders • size range 160 to 240 litres • 200 liquid litres of Liquid oxygen (LOX) = 168 m^3 of gas	• 2% of contents per day to avoid boil off • minimum usage 4m^3 per day per 200 litres LOX	• 1500 m^3 up to 20,000 m^3	• 0.5m^3/hour per liquid cylinder • delivery dependent	• 10m^3/hour per liquid cylinder • Design flow • 30 to 80 m^3/hour	• Vaporiser dependent and regulator dependent and LOX delivery dependent	• The flowrate from liquid cylinders is limited by its internal vaporiser coil and the supporting pressure raising coil. • They are manifolded together to provide more storage and more flow capacity. • Mini-bulk tanks should be considered at usages from 3000m^3. • Mini-bulk timed changeover (TCO) system can be considered at 6000m^3

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
Mini-bulk tanks • Size range 800 to 3000 liquid litres • 1000 liquid litres of LOX =840 m^3 of gas	• 0.5% to 1% of contents per day to avoid boil off • minimum usage 8m^3 per day per • 1000 litres LOX	• 3000 m^3 up to 100,000 m3 • Mini Bulk TCO system can be used at 6000m^3	• 2.5 to 20 m^3/ hour	• Design flow 100m^3/ hour	• Vaporiser dependent and regulator dependent and LOX delivery dependent	• Mini-bulk tanks are now preferred to liquid cylinders when the LOX volume stored on site is 900 litres or above. • LOX deliveries can be limited by the mini tanker and geographical coverage. • If mini-bulk tanks can accommodate bulk tanker deliveries, then it's an advantage. • However normally their small filling valves do not allow that. • Moving to bulk deliveries/ bulk tanks is recommended at annual usages of 10,000 m^3

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
• Bulk Tanks • Size range 1000 up to 100,000 liquid litres. • Modern bulk tanks tend to start at 3000 litres capacity. • Old small bulk tanks are still available @ • 1000/ 1600/ 1800 litre sizes.	• 0.25% to 0.5% for tanks >3000 litres of contents per day to avoid boil off. • For older small tanks its typically 0.5% to 1% of contents per day. • minimum usage is 4m^3 per day per 1000 litres of LOX for Primary tank. • Note back up tanks have	• 5,000 m^3 min • 10,000 m^3 • up to 5,000,000 m^3 • The biggest UK hospital uses circa 1,000,000 m^3 each year, which is an average of 1900 lpm.	To be determined by site	Ensure vaporiser were updated in COVID-19 pandemic to ensure design flow is achieved. • Design flow • 180m^3/ hour • (3000 lpm) Or • 300m^3/ hour • (5000 lpm) Or • By special arrangement duplicate panels and large vaporisers 300m^3/ hour (10,000lpm)	• Vaporiser dependent and regulator dependent • Typically 240 m^3/ hour (4000 lpm) Or • 390m^3/hour • (6500 lpm) Or • By special arrangement duplicate panels and large vaporisers 780m^3/ hour • (13000 lpm)	• Bulk tanker deliveries offer the widest geographical coverage of the UK • Mini-bulk systems/ deliveries overlap with bulk systems/ deliveries by a considerable margin. • Where a bulk delivery can be made to outlying areas of the UK, mini-bulk is usually limited to the large cities and industrial areas of the country and has a much smaller geographical coverage. • Sometimes mini-bulk is implemented where bulk would normally be employed in inner cities, especially London due

Supply Method	Minimum Flow	Annual Usage Supported	Average Typical Flow	Maximum Flow	Short Term Peak Flow	Notes
	economisers to feed into the pipeline automatically					to delivery access restrictions. • Mini-bulk LOX is more expensive the bulk LOX.

Appendix G Pipeline pressure-drop calculations

Pipeline pressure-drop calculations

G.1 Example: Calculate the pressure drop in a 15mm diameter pipe, 11m in length, with two 90° elbows, carrying medical air at a design flow rate of 800 litres/min.

Solution

G.2 The pressure drop Δp across the pipe can be calculated from the formula:

$$\Delta p = \frac{TL_{ACTUAL}}{L_{TABLE\,G\,1}} \times \left[\frac{Q_{ACTUAL}}{Q_{TABLE\,G\,1}}\right]^2 \times \Delta p_{TABLE\,G\,1} \qquad (2)$$

where:

Δp = Pressure drop across pipe section (kPa)

ΔpTABLE C1 = Pressure drop from the table in Figure G.1 (kPa)

TL ACTUAL = Measured length of pipe, plus total equivalent length for fittings, valve, and the like. (m)

L TABLE C1 = Nearest length of pipe from the table in Figure G.1 (m)

QACTUAL = Design flow (litres/min)

QTABLE C1 = Nearest flow from the table in Figure G.1 (litres/min)

G.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 the table in Figure G.2

TL = Total length

therefore:

TL = 11 + (0.47 x 2)

TL = 11 + 0.94 = 11.94m

G.4 From the table in Figure G.1, 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.

G.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

G.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.

G.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

Figure G.1- Section of pressure drop table for medical air

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

Figure G.2 - Equivalent lengths (in metres) for copper fittings

	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

G.8 It is possible to insert the above formula into a spreadsheet and use mathematical functions to calculate required pressure drops (see the tables in Figure G.2, Figure G.3, Figure G.4 and-Figure G.5).

G.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.

G.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.

G.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.

G.12 Each valve, fitting and the like 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.

G.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 the fittings and the like. in that run are added.

G.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.

G.15 Equivalent lengths of some fittings are given in the tables in Figure G 6 and Figure G.7.

Figure G.3 - Pipeline pressure loss: 400 kPa (4 bar) pipelines

BS 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

BS 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)																
	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

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). for example: $122/122 \times (706/706)^2 \times 7$
2. A flow of 1200 litres/min in 122m of 28mm pipe would result in a pressure loss of 18.26 kPa. for example: $122/122 \times (1200/1287)^2 \times 21$
3. 140m of 28mm pipe would carry 800 litres/min with a pressure loss of 9.92 kPa. for example: $140/152 \times (800/912)^2 \times 14$

Figure G.4 - Pipeline pressure loss: 700 kPa (7 bar) pipelines

BS 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

BS 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)																
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

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 1800 litres/min in 122m of 28mm pipe would result in a pressure loss of 22.11 kPa. for example: $122/122 \times (1800/2232)^2 \times 34$
3. 140m of 28mm pipe would carry 1100 litres/min with a pressure loss of 10.78 kPa. for example: $140/152 \times (1100/1203)^2 \times 14$

Figure G.5 - Pipeline pressure loss: 1,100 kPa (11 bar) pipelines

BS 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

BS 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)																
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

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). for example: $122/122 \times (1145/1145)^2 \times 7$
2. A flow of 2200 litres/min in 122m of 28mm pipe would result in a pressure loss of 25.43 kPa. for example: $122/122 \times (2200/2544)^2 \times 34$
3. 140m of 28mm pipe would carry 1300 litres/min with a pressure loss of 10.39 kPa. for example: $140/152 \times (1300/1448)^2 \times 14$

Figure G.6 - Pipeline pressure loss (vacuum)

BS 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

BS 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																
	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

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). for example: $122/122 \times (71/71)^2 \times 1.3$
2. A flow of 120 litres/min in 122m of 28mm pipe would result in pressure loss of 2.99 kPa. for example: $122/122 \times (120/137)^2 \times 3$.
3. 140m of 28mm pipe would carry 90 litres/min with a pressure loss of 2.20 kPa. for example: $140/152 \times (90/94)^2 \times 2.6$

Figure G.7 - Equivalent lengths (in metres) for ABS (acrylonitrile butadiene styrene) vacuum 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

Appendix H Pressure testing procedure

H.1 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 (HSE) guidance note GS4.

Note 73: 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

H.2 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, such as safety valves, pressure switches.

H.3 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 paragraph 13.51 and 13.52
4. the test pressure(s) and temperature(s) should be witnessed by the Authorised Person Medical Gas Pipeline Systems (MGPS) or Contract Supervising Officer (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

Table H.1 - Second fix pressure test

Service	Test Pressure	Pressure drop (max)	Timescales
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

Service	Test Pressure	Pressure drop (max)	Timescales
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 (MV)	450 - 700 mmHg	1 kPa/ 7.5 mmHg	1 hour

Appendix I Design question sets

I.1 The design question sets to assist the completion of the informed design process (IDP) as described in Section 1 are contained within this appendix.

Table I.1 - Medical oxygen design question set

Is medical oxygen required? (Yes/ No)
• if no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final informed design process (IDP) risk assessment. • if yes, answer the following what equipment is used?
Will a medical oxygen flowmeter be used? • how many flowmeters are required? • what is the maximum flowrate envisaged? • what is the diversity of flowmeters in use (insert %) • what is the duration of use **Will medical vacuum (MV) be supplied locally by ejector units?** • If yes, please refer additionally to the vacuum section (see Section 8) and make an allowance for 25 litres/ minute for device activation in ejector mode • discuss configuration for ejectors, twin terminal unit, splitters or combined oxygen supply and vacuum device • rail assembly or direct probe attached configuration?
A. Flow rate for flow meter application: ○ Peak flow rate ○ Average continuous demand ○ Escalation requirement (if any)
Will medical devices be used, such as ventilators, anaesthetic machines, and the like? • **Level of acuity** - is this a critical care area? Consider alternative supply requirements ○ dual circuits ○ HP integral valve cylinders ○ transit requirements and emergency procedure ○ hybrid configuration (discuss cylinder configuration on bed) • How many ventilators are required?

Is medical oxygen required? (Yes/ No)

- Diversity of ventilators in use (insert %)
- Ventilator manufacturer:
- Model (insert model reference):
- Clinical assessment of flowrates used and duration (look at clinical notes and clinical audit data sources)

B. Flow rate ventilators/ equipment

- peak flow rate
- average continuous demand
- escalation requirement (if any)

C. Will anaesthetic machines be used?

- How many anaesthetic machines are required?
- Diversity of anaesthetic machines in use, if any (insert %)
- Manufacturer
- Model (insert model reference)

- **Maximum flow rate for connected equipment (to be discussed) -** clinical assessment of flowrates used and duration (look at clinical notes and clinical audit data sources)
  - expected techniques that may be used giving Peak flow rate and duration
  - induction flowrate and duration (if different from above)
  - maintenance flowrate and duration
  - average considered flow and duration
  - number of episodes for clinical list

Summation of A, B and C

Total Flowrates

- Peak flow rate
- Average continuous demand
- For delivery unit
- Source or sources for Delivery Unit (DU) flow requirement

Table I.2 - Medical vacuum design question set

Is medical vacuum required? (Yes/ No)
• if no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final IDP risk assessment. • If yes, answer the following what clinical applications is used? 1. Pharyngeal aspiration 2. Tracheal suctioning 3. Pleural suctioning 4. Gastrointestinal suction 5. Surgical suction 6. Endoscopy, lower gastrointestinal suction 7. Other application
Application 1 and 2 • number of positions that will require this? • how often are they used/ needed? (Look at clinical notes and clinical audit data sources • discuss duration of operation • review delivery unit layout and configuration (that is single rooms, bays, open ward treatment rooms areas)
Application 3 and 4 • number of positions that will require this • how often are they used/ needed (look at clinical notes and clinical audit data sources • discuss duration of operation • review delivery unit layout and configuration (that is single rooms, bays, open ward treatment rooms areas)
Application 5 and 6 • number of positions that will require this • how often are they used/ needed (look at clinical notes and clinical audit data sources • discuss duration of operation • review delivery unit layout and configuration (that is operating suite/endoscopy scoping room, bays, treatment room areas)

Is medical vacuum required? (Yes/ No)
Application 7 • number of positions that will require this? • how often are they used/ needed? (Look at clinical notes and clinical audit data sources) • discuss duration of operation • review delivery unit layout and configuration (that is single rooms, bays, open ward treatment rooms areas)
Total Vacuum requirement Summation of 1,2,3,4
Design requirements from Section 8
Total Flow • For delivery unit • Source or sources for DU flow requirement

Table I.3 - Medical air (4 bar) design question set

Is medical air 4 bar required? (Yes/ No)
• If no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final IDP risk assessment. • If yes, answer the following what equipment is used? In line with current National Patient Safety Alert (NPSA) guidelines there should be no requirement for equipment connected by a flow meter.
Will Medical Air flow meter (15 l/min) be used? • how many flow meters are required? And how will their administration be controlled (see NPSA guidance) • what is the diversity of flow meters in use (insert %) • what is the duration of use

A. Flow rate (medical air 4 bar) flow meter application
• will medical devices be used, such as ventilators, anaesthetic machines and the like?
  ○ how many ventilators are required?
  ○ diversity of ventilators in use (insert %)
  ○ ventilator manufacturer:
  ○ model (insert model reference):
  ○ clinical assessment of flowrates used and duration (look at clinical notes and clinical audit data sources)

B. Flow rate ventilators/ equipment (medical air 4 bar)
Summation of A and B
Total Flow • For delivery unit • Source or sources for DU flow requirement

Table I.4 - Nitrous oxide (anaesthesia applications) design question set

Is nitrous oxide for anaesthesia required? (Yes/ No)
• If no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final IDP risk assessment. • If yes, answer the following what equipment is used?
Will anaesthetic machines be used? • how many anaesthetic machines are required? • diversity of anaesthetic machines in use, if any (insert %): • manufacturer: • model (insert model reference):
Maximum flow rate for connected equipment (to be discussed) Clinical assessment of flowrates used and duration (look at clinical notes and clinical audit data sources): • expected techniques that may be used giving peak flowrate and duration • induction flowrate and duration (if different from above) • maintenance flowrate and duration • average considered flow and duration • number of episodes for clinical list
Control of Substances Hazardous to Health (COSHH) considerations • has discussion taken place as whether a local exhaust ventilation (LEV) system be required? (see Section 9) • has anaesthetic gas capture technology been considered? • has alternative means of nitrous destruction been considered?
Summary • design decision factors and mitigation actions (with conscience to the Royal College of Anaesthetists (ROCA)/ Association of Anaesthetists of Great Britain and Ireland (AAGBI) guidance on pipeline reduction) • source or sources for DU flow requirement
Total Flow • For delivery unit:

Table I.5 - Nitrous Oxide (Sedation/ Analgesia Applications) Design Question Set

Is Nitrous oxide for sedation/ analgesia required? (Yes/ No)
If no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final IDP risk assessment. If yes, answer the following what equipment is used? • inhalation sedation (IS) gas mixers for dentistry or pain management applications • anaesthetic machines • other forms of pre-set or fixed blender/ mixers • other: (describe)
How many anaesthetic machines/ blenders are required? • Diversity of devices in use, if any (insert %): • Manufacturer: • Model (insert model reference): • Any specific system requirements:
Maximum flow rate for connected equipment (to be discussed) Clinical assessment of flowrates used and duration (look at clinical notes and clinical audit data sources) • expected techniques that may be used giving peak flowrate and duration • induction flowrate and duration (if different from above) • maintenance flowrate and duration • average considered flow and duration • number of episodes for clinical list
COSHH considerations • has discussion taken place as whether an LEV system be required? (see Section 9) and Society for the Advancement of Anaesthesia in Dentistry (SAAD) guidance (or is possible with a mobile application?) • has alternative means of nitrous oxide removal/ destruction been considered? • has an environmental ventilation assessment been completed In line with Health and Safety Executive (HSE) guidance? And its significant findings form part of the IDP solution?
Summary • design decision factors and mitigation actions

Is Nitrous oxide for sedation/ analgesia required? (Yes/ No)
• source or sources for DU flow requirement (see paragraph 2.41)
Total Flow • for delivery unit:

Table I.6 - Nitrous oxide/oxygen (pre-mixed) design question set

Is Nitrous oxide/oxygen (pre-mixed) going to be used? (Yes/ No)
• If no, questionnaire complete, no further action - annotate design note to indicate and make sure reviewed during final IDP risk assessment. • If yes, answer the following?

Is this application for?
• Maternity/ Birthing
  ○ how many points of supply will there be?
  ○ will use be supervised or patient controlled?
• Endoscopy
  ○ what is the department configuration for use of gas? How many supply points for the medical gas pipeline system (MGPS)?
  ○ does it need to be available during and post procedure? And if so, is it supervised, or patient controlled
• other pain management
Will the gas be used from
• a MGPS
• cylinder application
• or both

Maximum flow rate for connected equipment (to be discussed) Clinical assessment of flowrates used and duration (look at clinical notes, birthing plans and clinical audit data sources) • expected techniques that may be used • possible flowrate and duration (if different from above) • average flow and duration • number of episodes for clinical session, procedure, birthing plan
COSHH considerations • has discussion taken place as whether an LEV system be required? (see Section 9)? • has an environmental ventilation review been carried out? • has alternative means of nitrous oxide destruction been considered? • has a suitable COSHH assessment been carried out? Is it up to date and does it reflect current or proposed operational procedures?
Summary

Is Nitrous oxide/oxygen (pre-mixed) going to be used? (Yes/ No)
• design decision factors and mitigation actions (with conscience to the ROCA/ AAGBI guidance on pipeline reduction) and significant findings from environmental ventilation and COSSH assessment • inhalational gasp requirement (instantaneous 275 litres/ minute) • source or sources for DU flow requirement

Total Flow
• For delivery unit:
  ○ MGPS
  ○ Cylinders

Appendix J Informed design process master control sheet

J.1 The master control sheet for the informed design process (IDP) (see Section 1) is provided to assist in the completion of the IDP.

Table J.1 – Informed design process madter control sheet

Objective	Category	Design Requirements	Design Criteria	IDP Stage Checked					
				Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Quantity	**Pipeline system**	**Determine use in each Delivery Unit**	Complete gas design question-set (O2, N2O, O2/N2O, MA4, SA7, Vac)						
			Area/ Department type (Theatre/ ITU/ Respiratory)						
			Number of beds/ theatres/ cots						
			Clinical/ Treatment Procedures						
			Point of use flow and pressure requirements						
			Equipment and equipment flows: Ventilators/ CPAP/ oxygen high-flow therapies						
			Does flow rate require MGPS						
			Changes in use to area – decant and the like						
			Patient cohort type						
			Pendants/ Bedhead Units						

Objective	Category	Design Requirements	Design Criteria	IDP Stage Checked					
				Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
	Sources of supply	Size and capacity of supply source	Supply system flow capacity to be established						
			Confirm expected design flow – Average continuous demand and peak demand flow rates						
			Determine type of supply system to meet the average continuous peak demand flow						
			Does flow rate require MGPS?						
			Are there any extensions/ expansions planned						
		Supply system types	To meet the total system peak flow design capacity						
		Additional supply – examples include pandemic preparedness, major incident	Strategically located Inlet ports						

Objective	Category	Design Requirements	Design Criteria	IDP Stage Checked					
				Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Continuity and Identity	**Sources of supply**	**Configuration**	Three sources of supply						
			Primary and secondary supply located separately (VIE)						
		Location	To prevent mechanical damage to the installation						
			Appropriate vehicle delivery access						
			Meet the required safety distances						
			Meet ventilation requirements						
			Allow safe unhindered access						
			Safe storage						
		Additional emergency supply provisions – tertiary manifolds (ERM's)	Continuous supply to critical care areas in the event of a supply or pipeline failure						

Objective	Category	Design Requirements	Design Criteria	IDP Stage Checked					
				Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
	Pipeline system	Emergency inlet ports	Strategically located Inlet ports						
			Ring main system						
			Future extensions/ expansions						
			Impact on existing services						
Quality	Sources of supply and pipeline system	Engineering commissioning and testing and Pharmaceutical QC checks	Refer to Section 13 and Appendix K						
Signature:				Date:					

Appendix K Pharmaceutical

Introduction

K.1 All medical gas systems should be designed, installed, tested and used in line with this Scottish Health Technical Memorandum (SHTM). This section describes quality control testing protocols and acceptance criteria used to assure medical gas quality and patient safety.

K.2 Quality control (QC) testing is the final independent test for new medical gas installations or following repairs and modifications and is essential for verifying the correct quality and identity of the medical gas for patient use.

K.3 Medical gases are medicines and as such must comply with the Human Medicines Regulations 2012 (as amended) and the relevant current British/ European Pharmacopoeia monograph. In addition, the medical gas pipeline system (MGPS) must comply with the relevant standards listed within this SHTM.

K.4 Medical gas quality control testing is carried out by the Quality Controller (MGPS) (QC (MGPS)).

Quality Controller (MGPS)

K.5 The QC (MGPS) should be independent of those carrying out engineering work on the pipeline system.

K.6 The QC (MGPS) should be listed on the UK Quality Controller (MGPS) register.

K.7 Only individuals who have been appointed to the Quality Controller (MGPS) register may act as a QC (MGPS). The UK register is maintained by the UK Medical Gas Group under the auspices of the NHS Pharmaceutical Quality Assurance Committee.

K.8 Inclusion on the Quality Controller (MGPS) register will normally be sufficient to qualify an individual to act as QC (MGPS) for any healthcare organisation. However, the healthcare organisation's Chief Pharmacist may choose to specify or restrict which registered QC (MGPS) are permitted to operate within their organisation.

K.9 The QC(s) (MGPS) appointed by the Chief Pharmacist within the healthcare organisation should retain a signed authorisation. The appointment should describe arrangements for testing new/ modified installations and routine tests (for example, medical/ dental air compressor plants). A list of sites to which the authorisation applies should be included. A statement confirming ongoing evidence of maintained competence should be provided.

K.10 The QC (MGPS) should demonstrate a thorough understanding of the guidance set out in this chapter to provide assurance that testing is undertaken in accordance with appropriate procedures and should familiarise themselves with the content of Parts A and B of this SHTM.

K.11 In addition, the QC (MGPS) should complete relevant education and training as detailed in Section 7 of SHTM 02-01, Part B.

K.12 To be appointed to the register and be allowed to act as a QC (MGPS), candidates should meet the following competency requirements:

- be a graduate who is eligible for membership of the Royal Pharmaceutical Society of Great Britain (RPSGB now Royal Pharmaceutical Society (RPS)), Royal Society of Chemistry (RSC) or Royal Society of Biology (formerly Institute of Biology)
- have a degree in a relevant science subject

Note 74: Master of Science (MSc) in Pharmaceutical Technology and Quality Assurance (PTQA) is an approved course.

- be registered with the relevant regulator organisation, for example General Pharmaceutical Council (GPhC)
- have successfully completed an accredited training course for QC testing of medical gases and MGPS
- have practical experience of QC testing of medical gases and MGPS and can demonstrate competency
- be familiar with the requirements of SHTM 02-01
- undertake regular Continuing Professional Development (CPD) in medical gases and MGPS to maintain competency
- attend an approved refresher course at least every five years to re-validate QC (MGPS) registration

K.13 The QC (MGPS) should be an active member of the Medical Gas Safety Group (MGSG) and be involved in all MGPS designs, installation and validation and in the development of policies and procedures to ensure the safety of medical gas supplies.

K.14 The QC (MGPS) should have an understanding of the:

- MGPS within the relevant healthcare organisation
- location of primary, secondary and tertiary supplies
- operation of oxygen vacuum insulated evaporator (VIEs), medical/ surgical/ dental compressor plants, pressure swing absorber (PSA), synthetic air plants and cylinder manifolds as appropriate and where testing is required.

K.15 If the QC (MGPS) is testing at a site, where they are not a member of the MGSG, they should also have access to local medical gas policies and procedures to aid site

familiarisation. Information included in paragraph K.13 should be made available as required.

Quality control testing/ verification process

K.16 Different scenarios are identified within the quality control, testing and verification process and will include:

- new installations
- extension/ upgrade/ modification to existing installations
- repair (emergency)
- regular planned QC testing
- ad hoc testing of the MGPS/ source supplies in response to adverse QC test results or concerns raised by the Authorised Person (MGPS) (AP(MGPS))

New installations

K.17 New installations should be formally approved by the QC (MGPS), through QC testing and reporting.

K.18 For new installations and extensions (for example, a new ward, a new department or a complete hospital), the QC (MGPS) should be involved from project concept. They should have access to pipeline construction drawings and should prepare a test protocol for the required works with the information supplied from the Authorising Engineer (MGPS) (AE (MGPS))/ AP (MGPS). A pre-site meeting may be required to clarify these works.

K.19 The appointed QC (MGPS) should be granted access to any site where works are in progress, to carry out any preliminary testing and maintain familiarity of the installation.

K.20 In new installations, QC testing should be carried out to demonstrate compliance with monograph acceptance criteria at supply source for example, oxygen VIE or medical air compressor plant prior to opening line valves to the MGPS. This will ensure that contamination is not introduced into the pipeline system.

K.21 Final QC testing should not be undertaken on any site until post-construction cleaning has been completed and the site is in its final stages of preparation for handover. This is to minimise the risk of system damage to, or contamination of, the MGPS. Where patient use of the MGPS is not planned immediately following completion and approval of QC results, a programme of purging and re-testing should be considered.

K.22 A permit to work is not required for a new installation (except where the new installation connects with an existing system). The relevant form contained within Appendix A of this SHTM should be used.

K.23 On completion of testing, the QC (MGPS) should supply a detailed and approved report within an agreed reasonable timescale for inclusion with the project file. A copy of this report should be submitted to the MGSG and the Chief Pharmacist.

K.24 No medical equipment intended for connection to the pipeline system (flowmeters, anaesthetic trolleys, and the like) should be brought into any department until all validation and verification testing has been satisfactorily completed.

Modification of existing systems

K.25 Prior to any QC testing, the AP (MGPS) should provide the QC (MGPS) with a description of the engineering work to be carried out, the methodology (as appropriate), details of the medical gases involved, the location and reference of the AVSU, number of terminal units and relevant as-fitted drawings. Site familiarisation should be provided as required.

K.26 All work involving modifications to an existing pipeline system and QC testing is controlled under a high hazard permit to work. This also includes the connection of a new installation to an existing system (see paragraph K.21).

K.27 In existing installations, particular care should be taken to ensure that clinical medical gas equipment (for example, anaesthetic gas equipment) left in areas where work or testing is taking place is, and remains, disconnected from the system and removed from the terminal unit location to avoid inadvertent connection and use. The removal of this equipment may require to be undertaken by the Medical Physics/ Electro Bio-Medical Engineering (EBME) team.

K.28 Medical gas flowmeters and suction equipment will also require to be removed from terminal units. Clinical staff should be made aware of this status by the display of appropriate exclusion notices and labels affixed to, or the insertion of ‘Terminal out of use’ plugs into the affected terminal units.

K.29 Maintaining the supply of medical gases to patients during this time requires careful consideration. A number of medical gas cylinders may be required. Safe storage and handling should be reviewed and risk assessments prepared by the AP (MGPS)/ Designated Clinical Officer (MGPS) (DCO (MGPS)) as appropriate.

K.30 During all QC tests, the Competent Person (MGPS) (CP (MGPS)) and the AP (MGPS) should be in attendance to assist the QC (MGPS) when required.

K.31 Although a structured approach to testing should be adopted, access and time limitations to parts of the MGPS may lead to some disruption of the proposed test regimes. This should be risk-assessed and recorded on the test report.

K.32 The system will only be taken back into use once the medical gases have been tested and verified as being fit for patient use. At each stage of the project, the relevant section of the

permit to work should be signed off by the AP (MGPS), CP (MGPS), QC (MGPS) and the DCO.

K.33 No unplanned modifications should be undertaken to any system once the testing has commenced. If changes are required to the system, testing should be stopped. The test protocol should be reviewed and may need to be revised to accommodate the new work. An impact assessment should be carried out prior to re-commencing the QC test programme.

Repair (emergency)

K.34 See paragraphs K.29 to K.37

Regular planned QC testing

K.35 Medical gases are medicines. Where medical gases are manufactured on site, QC testing should be carried out at defined frequency to provide assurance of quality. QC testing of medical gases produced by medical/ surgical/ dental air compressor plants, synthetic air plants and oxygen generators should be carried out in accordance with Table K.1.

K.36 As with MGPS, when carrying out QC testing on medical/ surgical/ dental air plant, oxygen generators and other supply sources, test protocols should be in place and confirmed with the AP (MGPS).

Table K.1 - Routine QC testing scenarios and frequencies

Reference	Testing	Frequency
(a)	Medical/ surgical air compressor plants	Quarterly
(b)	Dental air compressor plants	At least annually (see K.38 to K.42)
(c)	Synthetic air plants	Quarterly
(d)	Endoscopy	Quarterly
(e)	Oxygen generator	Quarterly

K.37 For dental surgeries with up to five chairs, annual testing is acceptable. However, the test requirements and frequency should be based on system performance and agreed between the users, the AP (MGPS) and the QC (MGPS), with reference made in the operational policy.

K.38 Dental surgeries with over five chairs or those located on NHS sites should comply with the medical air testing requirements for frequency and quality, with the exception of the dew point: this is accepted at –20ºC so long as this can be maintained under all conditions.

K.39 All plant suppliers should provide guidance on plant siting and the associated filtration and drying equipment necessary to achieve the air quality standards recommended in this SHTM. Users should engage with suppliers to ensure that the selected plant configuration meets the required performance specifications. The QC (MGPS) may be contacted to verify medical gas quality and compliance with acceptance criteria, when considering plant location.

K.40 The cost of instrument repair or replacement can be significant. These costs, along with the increased risk of infection and the potential for system, equipment and dental composite failure, should be carefully considered against the cost of installing the recommended air treatment measures.

K.41 Regardless of system structure, poor or absent maintenance is still a significant factor in the degradation of air quality and consequent premature failure of air-driven equipment. A properly planned and administered maintenance scheme - carried out by a competent organisation and fully in accordance with the plant manufacturer's requirements - will rapidly offset its cost through the avoidance of equipment, plant and instrument repair or replacement. QC testing forms part of this verification process. A suitable test point should be provided.

Ad hoc testing of the MGPS/ source supplies

K.42 Ad hoc testing of the wider MGPS may be required as part of an investigation following the recording of adverse results during regular quarterly/ annual testing or following pipeline installation/ modification, or in response to concerns raised by the AP (MGPS) for example, reports of discoloured flowmeters.

K.43 QC testing from the supply systems may also be required as part of the investigation process.

K.44 Ad hoc testing may also be needed in low usage/ dormant systems to ensure maintenance of medical gas quality.

K.45 Test regimes may include sampling at terminal units (end-of-line points), randomly selected locations, and areas where hoses are used within architectural systems.

K.46 The need for this testing should be supported by evidence of system failures in recent years, including the accumulation of oil, particulates and other contaminants within the pipeline systems.

K.47 A full system test should not be needed; however, a risk-based approach should be taken and individual point testing carried out on each of the medical gas systems installed on site as appropriate and as described in paragraph K.45.

K.48 Records of these tests, where required, should include date, location and results. Reports may be requested by the MGSG.

Pharmaceutical quality of medical gases and medical gas pipeline systems

General principles

K.49 The objective of these tests is to ensure compliance with pharmacopoeia for medical gas quality and to establish whether the medical gas pipeline has been contaminated during construction or modification. The tests indicate whether work has affected gas quality, and report compliance with pharmaceutical specifications for medical gases.

K.50 The European/ British Pharmacopoeia monographs should be regarded as the baseline minimum standard for assessing the quality of medical gases, as the principal application is to the manufacture and distribution of medicines according to well-established manufacturing processes.

K.51 This SHTM supplements the pharmacopoeia tests by focusing on the pipeline systems, the potential for contamination and the types of failure that might occur with the on-site generation of gases.

K.52 Refer to Table K.2, Table K 3, Table K.4 and Table K.5 for acceptance criteria

K.53 Electronic equipment should be used for QC testing purposes. Such equipment should provide a level of repeatability, resolution and accuracy and should be calibrated to the appropriate European/ British Standards.

K.54 Calibration prior to testing should be carried out on site. If a drift in concentration is recorded when using medical gas analysers, the analyser calibration should be checked and re-calibrated as required. Consideration should be given to repeating previous tests. Calibration should also be checked at the end of the test.

K.55 The QC (MGPS) should ensure that all equipment used for medical gas testing is maintained and serviced according to manufacturer's recommendations and local protocols. Records of servicing should be retained.

K.56 Oil, 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.

K.57 Detector tubes give a quantitative response and are not intended for reuse. They should be agent-specific, since non-agent-specific (polytest) tubes can respond to various agents such as volatile inorganic compounds, giving misleading results.

K.58 However, it is recommended that the use of polytest tubes be considered as an optional general test for contamination of pipelines on a representative sample of terminal units.

K.59 Users should be aware of the limitations of this type of detection equipment, including the ambient operating conditions for example, high humidity or low temperature, and cross-sensitivities specified for each type of detector tube.

K.60 In particular, water vapour should be measured with a dew point meter due to the environmental impact on detector tubes described in paragraph K.57.

K.61 The QC (MGPS) should define the programme of pharmaceutical testing, depending on such factors as the extent and nature of the work and the age and condition of the existing systems.

K.62 QC tests should be carried out on terminal units/ non-interchangeable screw threads (NISTs) in each system in line with the test protocol supplied by the QC (MGPS).

K.63 Where a new extension is to be connected to old pipework, it is important to ensure that the old system is 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 new pipelines.

K.64 For a new installation, all sources of supply should be tested for quality before the pipeline distribution system is filled with the working gas. These tests are to ensure that supply source equipment (manifolds, compressors, VIEs, and the like) reach and maintain the quality of the gases when delivering them to the pipeline systems.

K.65 When extending existing systems, supply sources will not typically be retested before being used to fill the extension with the working gases unless an issue is reported during QC testing requiring further investigation.

K.66 The Control of Substances Hazardous to Health (COSHH) Regulations requires oxygen, carbon dioxide, nitrous oxide and nitrous oxide/oxygen mixtures discharged during the QC test process be released to a safe place.

Medical gas identification, purity/ quality

K.67 The identity of the gas should be confirmed at all terminal units on MGPS and confirmed that this matches the source gas. This would include all new and existing terminal units, whether on a new installation or a modification or extension, which may have been affected by the work. The nominal gas concentration at specific terminal units is given in Table K.4

K.68 The identity of the gas should also be confirmed when testing source supplies - oxygen VIE plants, oxygen generators, cylinder manifolds and medical/ surgical/ dental plant.

Note 75: When testing medical gas quality at medical/ surgical/ dental compressor plants, transient increases in O2 levels will be seen during dryer changeover. This is not a fail.

K.69 The composition of the specific medical gas should be positively identified and not inferred.

K.70 It should be demonstrated that the system under test is free from shield gas.

K.71 For oxygen and nitrous oxide/ oxygen systems, medical/ surgical/ dental systems, an oxygen analyser should be used to ensure that the oxygen concentration complies with acceptance criteria in Table K.2.

K.72 For nitrous oxide systems, an instrument based on thermal conductivity, or an infrared meter, should be used to check nitrous oxide concentration and compliance with acceptance criteria.

Note 76: it may be useful to check absence of nitrous oxide in oxygen systems to provide additional assurance of no pipeline crossover.

K.73 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 K.4.

K.74 Medical carbon dioxide (MCD) is generally used for insufflation during laparoscopic surgery and as such can form part of a MGPS. The primary source of MCD will generally be provided through a cylinder manifold, which connects to the pipework system, and acts as a delivery method for the gas. The pharmaceutical quality tests for MCD can be found in Table K.3. Testing of MCD systems is less common than most other medical gases (O_2, MA, SA, N_2O and the like) and due to the inhalation danger associated with the gas, the system terminates with a NIST connection unit rather than a gas specific terminal unit to prevent accidental connection. There are portable analysers' available, using infrared technology, which can provide an accurate identification of MCD but these are not commonplace in most QC's (MGPS) armoury. In the absence of a portable CO_2 analyser, inferred identification can be performed using a paramagnetic analyser.

Note 77: the supply of other gases (N_2O for example) as part of the installation/ modification, which would also produce a similar inferred result, should be isolated to provide assurance of no cross connections.

K.75 Equipment should not be left attached to the gas flow for sustained periods as parts of the system can freeze over.

K.76 Multi gas analysers that measure CO_2 in parts per million (ppm) may not be suitable attached to the system as these can overload the sensors affecting their reading and sensitivity, so please check with the manufacturer prior to use. Other suitable (portable) analysers or, in absence of these, suitable gas detection tubes can be employed.

K.77 The British Pharmacopeia (BP) also recommends MCD be tested for Hydrogen Sulphide of ≤1 ppm V/V, there are suitable gas detection tubes available to allow for this test to be carried out.

Particulate matter

K.78 All terminal units should be tested for particulate content.

K.79 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 shield gas.

K.80 However, on-site contamination can occur from the ingress of building materials, dust, poor purging techniques, poor welding techniques and the like. The presence of such particles can adversely affect the quality of the delivered gases. Therefore, tests to indicate their absence are important.

K.81 New systems should be purged until the particulate filter is completely clear of visible particles when viewed in a good light.

K.82 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. Again, the system should be purged to remove particles.

K.83 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 should be made.

K.84 When testing all medical gases (except surgical air and oxygen/ nitrous oxide 50:50 mix) with a membrane filter, a flow rate of not less than 150 L/min should be used for a period of 30s.

K.85 The filter should be free from visible particles when viewed in good light.

K.86 When testing surgical air terminal units, a flow of not less than 350 L/min for 30s should be used.

K.87 When testing oxygen/nitrous oxide 50:50 mix terminal units, a flow of not less than 275 L/min for 30s should be used. Care is needed to ensure that the manifold regulators do not freeze during particle testing. This flow rate is based on peak inspiratory levels and unlikely to be continuous.

K.88 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 L/min or more may not be possible without compromising the hospital system, a lower flow rate should be used at the discretion of the QC (MGPS) but the time would be increased to maintain the volume of gases tested.

K.89 Particle sampling should also be carried out on medical/ surgical/ dental air plant and oxygen generators.

Oil

K.90 This test should be carried out at the plant test point of all newly installed medical/ surgical/ dental compressed air plant and for all medical/ surgical/ dental compressed air plant on a quarterly basis.

K.91 When break-ins to a tested (and compliant) medical/ surgical air system have been completed, repetition of this test will not normally be required, unless plant test history dictates otherwise.

K.92 Work that may involve the contamination of compressor plant with oil will require a follow-up oil test by the Quality Controller (MGPS).

K.93 Oil may be present as liquid, aerosol or vapour, and an appropriate test device should be utilised to ascertain the levels present.

K.94 The total oil content should be in accordance with Table K.3.

K.95 For new installations, it is advisable to carry out an oil 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.

K.96 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).

K.97 Care should be taken in siting the test point to ensure a representative sample.

Water vapour

K.98 The most distant terminal units on each branch of an oxygen, medical/ surgical air, nitrous oxide or oxygen/nitrous oxide 50:50 mix pipeline systems should be tested for water vapour. In addition, a representative percentage of terminal units should be tested.

K.99 Water vapour content may be measured using the appropriate electronic test device.

K.100 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.

K.101 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/L limit; this is the result of desorption of minute quantities of moisture into the gas stream.

K.102 This is particularly noticeable where the test flow is low and should not cause undue concern. The QC (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.

K.103 New developments in future hose materials may lead to hoses with reduced water vapour permeability characteristics.

K.104 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.

K.105 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 should 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 ppm v/v.

K.106 Failure to achieve the minimum dew point standard will not be acceptable, in the event that the plant does not reach the required dewpoint the system requires to be modified/ replaced.

Carbon monoxide

K.107 The most distant terminal units on each branch of an oxygen, medical/ surgical air, nitrous oxide or oxygen/nitrous oxide 50:50 mix pipeline systems should be tested for carbon monoxide. In addition, a representative percentage of terminal units should be tested.

K.108 The concentration of carbon monoxide should not exceed 5 ppm v/v.

K.109 When break-ins to a tested (and compliant) medical/ surgical air system have been completed, repetition of this test will not normally be required. However, this may be tested at the discretion of the QC (MGPS) for example, if the quarterly compressor test programme has been delayed.

Carbon dioxide

K.110 The most distant terminal units on each branch of an oxygen, medical/ surgical air, nitrous oxide or nitrous oxide: oxygen 50:50 pipeline systems should be tested for carbon monoxide. In addition, a representative percentage of terminal units should be tested.

K.111 The concentration of carbon dioxide should not exceed 500 ppm v/v in medical/ surgical/ dental air or 300 ppm v/v in oxygen, nitrous oxide or nitrous oxide/oxygen 50:50 pipeline systems

K.112 When break-ins to a tested (and compliant) medical/ surgical/ dental air system have been completed, repetition of this test will not normally be required. However, this may be tested at the discretion of the QC (MGPS) for example, if the quarterly compressor test programme has been delayed.

Note 78: Increasing or fluctuating carbon dioxide readings in air or PSA-generated oxygen can be an early indication of dryer failure or poor compressor maintenance. Carbon dioxide is no longer used as an inert shield gas during pipeline brazing.

Sulphur dioxide

K.113 The most distant terminal units on each branch of a medical/ surgical/ dental air should be tested for sulphur dioxide. In addition, a representative percentage of terminal units should be tested.

K.114 The concentration should not exceed 1 ppm v/v.

K.115 When break-ins to a tested (and compliant) medical/ surgical air system have been completed, repetition of this test will not normally be required. However, this may be tested at the discretion of the QC (MGPS) for example, if the quarterly compressor test programme has been delayed.

Oxides of nitrogen (NO and NO_2)

K.116 The most distant terminal units in medical/ surgical/ dental air pipeline systems supplied from a compressor plant should be tested for oxides of nitrogen. In addition, a representative percentage of terminal units should be tested.

K.117 The concentration should not exceed 2 ppm v/v.

K.118 When break-ins to a tested (and compliant) medical/surgical air system have been completed, repetition of this test will not normally be required. However, this may be tested at the discretion of the QC (MGPS) for example, if the quarterly compressor test programme has been delayed.

Nitrogen

K.119 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.

Pipeline odour

K.120 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 50:50 mix and carbon dioxide, which should not be inhaled. The odour threshold of particulate matter is approximately 0.3 mg/m^3.

K.121 In certain circumstances, 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 50:50 mix systems.

K.122 In addition to all new terminal units, a representative sample of terminal units on existing parts of the systems should be checked.

K.123 Some low-pressure connecting assemblies may give off an odour although levels are well below those considered harmful. If an odour is detected where flexible hoses are not involved, the QC (MGPS) should perform additional oil and polytest analysis.

Line pressure

K.124 It may be necessary to repeat some of the systems performance tests such as line pressure. The QC (MGPS) should verify, through testing, that the static pressure of the system is maintained at the correct level. This is particularly important for medical/ surgical air systems to ensure that the appropriate pressures are achieved for the specific gas product.

Vacuum systems

K.125 The presence of suction should be demonstrated. Ideally static and dynamic pressure should be quantified using a pressure gauge. Static pressure should be greater than or equal to 400mmHg (-0.533 bar) and dynamic pressure should be greater than or equal to 300mmHg. (-0.4 bar).

AGS disposal systems

K.126 British Standard (BS) EN ISO 7396-2 specifies the tests to be carried out on Anaesthetic gas scavenging (AGS) disposal systems. The tests specified are designed to ensure adequate performance and that the safety provisions of receiving systems will be met.

K.127 The responsibility for the tests should be clearly identified at the contract stage for new installations, in the same way as for the MGPS. In general, the contractor should carry out the tests, which should be witnessed by the AP (MGPS).

K.128 Where these systems are installed the QC (MGPS) is not required to test or witness these systems routinely but the evidence of compliance of these systems should be presented to the QC (MGPS) to ensure they have the confidence in the system.

K.129 AGS testing is not normally carried out by the QC (MGPS); however, the QC (MGPS) may undertake testing at individual points if there are any reservations about the performance of the system.

K.130 These will be recorded as per all QC testing and presented as part of the main report.

Reporting medical gas testing results

K.131 All test results must be recorded on medical gas report documents. The reports should:

- record the location for example, hospital and department of the QC test
- date and time of the QC test
- the QC(s) (MGPS) in attendance
- the AP (MGPS) in attendance
- tests and acceptance criteria for each medical gas
- batch numbers and expiry dates of consumables should be recorded as appropriate for example, calibration gases

K.132 Results should be recorded individually as numerical values for each terminal unit/ test point (except for particles/ polytest which should be recorded as a ‘Pass’ or ‘Fail’ as appropriate).

K.133 Any damage to terminal units should be recorded.

K.134 Action taken in response to non-compliant results should be recorded.

K.135 Section 4 of the permit-to-work/ relevant form contained within Appendix A of this SHTM should be signed and dated.

Requirements before a medical gas pipeline system is taken into use

K.136 Before a system is used, the appropriate persons should certify in writing that the tests and procedures have been completed, and that all systems comply with the requirements.

K.137 All reports and certification must be complied and examined for deficiencies, relevant form contained within Appendix A of this SHTM completed and a full handover to the clinical team undertaken.

Removal of warning notices

K.138 When all tests have been completed satisfactorily by the QC (MGPS), the ‘Do not use’ labels or ‘Terminal unit out of use’ plugs affixed to or inserted into the terminal units should be left in place until their removal is approved by the AP (MGPS). This should be recorded on the relevant form contained within Appendix A of this SHTM and the permit-to-work if applicable.

Table K.2 - Quality specifications for medical gases

Gas and source	Particulates	Oil	Water	CO	CO_2	NO/ NO_2	SO_2	Polytest (optional)	Odour
Oxygen from PSA plant	Free from visible particles in a 75 L sample	≤0.1 mg/m^3	≤67 vpm (≤0.05 mg/L, atmospheric dew - point of -46°C)	≤5 mg/m3 ≤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 L sample	–	≤67 vpm (≤0.05 mg/L, atmospheric dew - point of -46°C)	–	–	–	–	No discoloration	Safety Not performed
Nitrous oxide/ oxygen mixture	Free from visible particles in a 75 L sample	–	≤67 vpm (≤0.05 mg/L, atmospheric dew- point of -46°C)	–	–	–	–	No discoloration	Safety Not performed
Medical and surgical air	Free from visible particles in a 75 L sample (for medical air) and 175 L sample (for surgical air)	≤0.1 mg/m^3	≤67 vpm (≤0.05 mg/L, 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

Gas and source	Particulates	Oil	Water	CO	CO_2	NO/ NO_2	SO_2	Polytest (optional)	Odour
Dental compressed air	Free from visible particles in a 75 L sample	≤0.1 mg/m^3	≤1020 vpm (≤0.78 mg/L, 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 L sample	–	≤67 vpm (≤0.05 mg/L, atmospheric dew-point of -46°C)	–	–	–	–	No discoloration	None
Oxygen from bulk liquid or cylinders	Free from visible particles in a 75 L sample	–	≤67 vpm (≤0.05 mg/L, atmospheric dew-point of -46°C)	–	–	–	–	No discoloration	None
Helium/ oxygen mixture O_2, <30%	Free from visible particles in a 75 L sample	–	≤67 vpm (≤0.05 mg/L, atmospheric dew-point of -46°C)	–	–	–	–	No discoloration	None

Notes applicable to Table K.2:

a. The quality of the gases delivered at the terminal units should also comply with the specifications given in the current edition of the Ph. Eur (see Table K.3). 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 should be carried out when the source of supply is from cylinders and cryogenic systems, due to rare instances of oil contamination arising from the pipeline have occurred.

c. Synthetic air will be tested for identity as shown in Table K.3. 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.

Table K.3 - Ph. Eur. quality specifications for medical gases

Gas and source	Oil	Water	CO	CO_2	NO/ NO_2	SO_2	Odour/ taste
Oxygen from bulk liquid or cylinders	–	≤67 vpm (≤0.05 mg/L, 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/L, 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/L, 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/L, 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/L, 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/L, atmospheric dew-point of -46°C)	–	–	–	–	None

Gas and source	Oil	Water	CO	CO_2	NO/ NO_2	SO_2	Odour/ taste
Helium/ oxygen mixture O_2, <30%	–	≤67 vpm (≤0.05 mg/L, atmospheric dew-point of -46°C)	≤5 mg/m^3 ≤5 ppm v/v	≤300 ppm v/v	≤2 ppm v/v	–	None

Table K.4 - Gas concentrations for identification purposes

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%	–	–	–

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
Synthetic air	95–105% of nominal value of 21.0–22.5%	–	–	–
Vacuum	–	–	–	Suction present
Nitrogen shield gas	0%	0% (IR)	–	–

Notes applicable to Table K.4: The tolerance of the measuring instrument should be allowed in addition. For oxygen concentrator plant (PSA) supplied system, the minimum concentration should be 94% oxygen. A vacuum gauge may be used to obtain a quantitative reading of vacuum level and verify terminal unit performance.

Table K.5 - Carbon dioxide tests and acceptance criteria

Test type	Limits
Identification	≥99.5%
Inferred Identification	O_2 -0.2%
Particulates (30 secs)	None visible in 75 litres
Carbon Monoxide	≤5ppm *V/V*
Oxides of nitrogen (NO & NO_2)	≤2ppm *V/V*
Sulphur Dioxide	≤2ppm *V/V*

Test type	Limits
Hydrogen Sulphide	≤1ppm *V/V*
Water	≤67ppm *V/V* (equivalent ADP ≤-46°C)
Poly-test (optional)	No discolouration

Abbreviations

A&E: Accident and Emergency

AAGBI: Association of Anaesthetists of Great Britain & Ireland

AE: Authorising Engineer

AGS: Anaesthetic gas scavenging

AGSS: Anaesthetic gas scavenging system

ALARP: As Low as Reasonably Practicable

AP (MGPS): Authorised Person (Medical Gas Pipeline Systems)

AVSU: Area Valve Service Unit

BCGA: British Compressed Gas Association

BDA: British Dental Association

BIM: Building Information Modelling

BP: British Pharmacopeia

BS: British Standard

BS EN ISO: British European International Standard

CCU: Coronary Care Unit

CIG: Capital Investment Group

CMT: Corrugated Metal Tubing

CO: Carbon monoxide

CO_2: Carbon dioxide

CO_2e: Carbon dioxide emissions

COSHH: Control of Substances Hazardous to Health

CP: Code of Practice

CPAP: Continuous Positive Airway Pressure

CPD: Continuing Professional Development

CSO: Contract Supervising Officer

dBA: Decibel (A-Weighted)

dc: Direct current

DCO: Designated Clinical Officer

DL: Director Letter

DOP: Dispersed Oil Particulate

DU: Delivery Unit

EBME: Electronic and Biomedical Equipment

EIGA: European Industrial Gases Association

ELV: Extra-low Voltage

EMC: Electromagnetic Compatibility

EN: European Standard

ERM: Emergency Reserve Manifold

EU: European Union

FELV: Functional Extra Low Voltage

FFL: Finished Floor Level

FM: Facilities Management

GMP: Good Manufacturing Practice

GPhC: General Pharmaceutical Council

GWP: Global Warming Potential

HAZOP: Hazard and Operability (analysis)

HBN: Health Building Note

HDU: High Dependency Unit

He/O2: Helium/Oxygen mix

HSE: Health and Safety Executive

HSG: Health and Safety Guidance

HSIB: Healthcare Safety Investigations Branch

HTM: Health Technical Memorandum

HV: High voltage

IACSD: Intercollegiate Advisory Committee for Sedation in Dentistry

IDP: Informed design process

IEC: International Electrotechnical Commission

IPC: Infection Prevention and Control

IPCT: Infection Prevention and Control Team

IS: Inhalation Sedation

ISO: International Standard

ITU: Intensive Therapy Unit

kPa: kilo Pascal

KSAR: Key Stage Assurance Review

KSB: Knowledge, skills and behaviours

kW: kilowatt

kWh: kilowatt per hour

LDRP: Labour, Delivery, Recovery and Post-partum

LEV: Local Exhaust Ventilation

LOX: Liquid oxygen

LV: Low voltage

LVA: Line valve assembly

mA: Milliamp

MA: Medical air

MA4: Medical air (4bar)

MCC: Motor control centre

MCP: Manifolded cylinder pack

MCS: Master control sheet

mg/m3: Milligrams per cubic metre

MCD: Medical carbon dioxide

MGPS: Medical gas pipeline system

MHRA: Medicines & Healthcare products Regulatory Agency

MIA: Manufacturing and Importation Licence

MMC: Modern methods of construction

mmHg: Millimetres of Mercury

MSc: Master of Science

MV: Medical vacuum

N: Newton

N_2: Nitrogen

N_2O: Nitrous Oxide

N_2O/O_2: Nitrous oxide/oxygen 50/50% mix

NDT: Non-destructive Testing

NES: NHS Education for Scotland

NIST: Non-interchangeable screw thread

NOS: National Occupational Standard

NPD: Non-profit Distributing

NPF: National Performance Framework

NPSA: National Patient Safety Alert

NSS: National Services Scotland

O2: Oxygen

°C: Degrees Centigrade

OEL: Occupational Exposure Limit

OES: Occupational Exposure Standards

OFN: Oxygen-free Nitrogen

P&ID: Piping and Instrumentation Diagrams

PFI: Private Finance Initiative

Ph. Eur.: European Pharmacopoeia

PMTD: Particulate Matter Test Device

PPM: Planned Preventative Maintenance

ppm: Parts per million

PPP: Public Private Partnership

PSA: Pressure swing absorber

PTFE: Polytetrafluoroethylene

PVC: Polyvinyl chloride

Q: Diversified flow

QC: Quality Controller

QMS: Quality Management System

RACI: Responsible, Accountable, Consulted, Informed (matrix)

RAG: Red, Amber, Green

RIBA: Royal Institute of British Architects

ROCA: Royal College of Anaesthetists

RPSGB: Royal Pharmaceutical Society of Great Britain

RPS: Royal Pharmaceutical Society

RRM: Risk Reduction Measure

RSC: Royal Society of Chemistry

SA: Surgical air

SA7: Surgical air (7 bar)

SAAD: The Society for the Advancement of Anaesthesia in Dentistry

SBC: Strategic Business Case

SCBU: Special Care Baby Unit

SCTA: Safety Critical Tast Analysis

SDCEP: Scottish Dental Clinical Effectiveness Programme

SELV: Safety Extra Low Voltage

SEPA: Scottish Environment Protection Agency

SHPN: Scottish Health Planning Note

SHTM: Scottish Health Technical Memoranda

SO_2: Sulphur dioxide

SOP: Standard Operating Procedure

SRO: Senior Responsible Officer

SRR: Safety, Reliability and Risk

SSD: Sterile Services Department

STP: Standard temperature and pressure

STPA: Systems Theoretic Process Analysis

TC: Thermal conductivity

TCO: Timed changeover

TIVA: Total Intravenous Anaesthesia

TRA: Task Risk Analysis

TWA: Time-weighted averages

UCV: Ultra-clean ventilation

UPS: Uninterruptible Power Supply

V: volt

v/v: % volume per volume

VIE: Vacuum Insulated Evaporator

VIPR: Valve with an integral pressure regulator

VPM: Volume per million

WI: Work Instructions

WRA: Well-Reasoned Argument

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